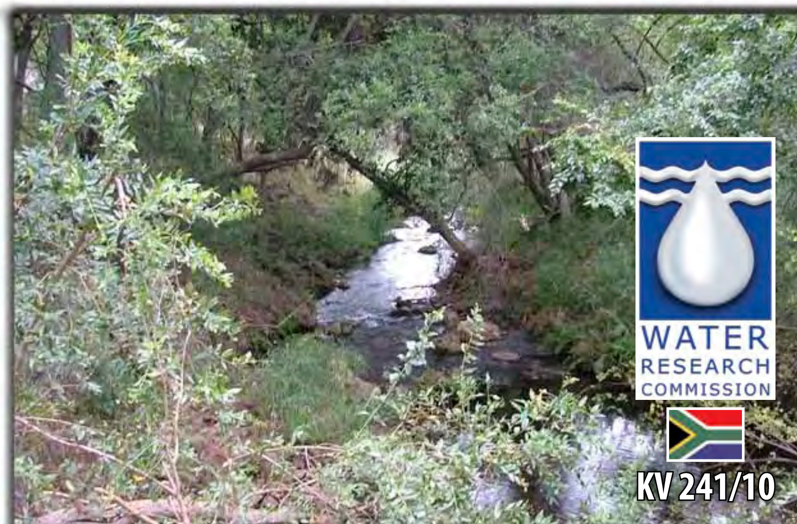
The Karst System of the Cradle of Humankind World Heritage Site

The South African Karst Working Group

GAUTENG PROVINCIAL GOVERNMENT

IUCN
The World Conservation Union

Cradle of Humankind ©
World Heritage Site



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THE KARST SYSTEM

OF THE

CRADLE OF HUMANKIND

WORLD HERITAGE SITE

A COLLECTION OF 13 ISSUE PAPERS

BY

THE SOUTH AFRICAN KARST WORKING GROUP

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The publication of this report emanates from a consultancy entitled *The Karst System of the Cradle of Humankind World Heritage Site* (WRC Consultancy K8/624).

FOREWORD

The following document is intended to be a summary of the current circumstances surrounding the Cradle of Humankind World Heritage Site (COH WHS) and the underlying karst system.

The COH WHS is located in the Gauteng and North West Provinces of South Africa, and is listed as a world heritage site with the United Nations Educational Scientific and Cultural Organization (UNESCO) as the Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai and environs. The site is renowned for its unparalleled collection of prehistoric hominid and animal fossils, as well as a multitude of prehistoric tools. In addition to its palaeontological and archaeological significance, the COH WHS also lies on top of a vast karst system which is vital to the region's water supply and forms part of a unique ecosystem housing a variety of organisms. In more recent years, it has become apparent that the karst system of the COH WHS is becoming increasingly threatened by a multitude of factors such as mining, agriculture, tourism, and increased urbanisation of the area. In line with its mission for a just world that values and conserves nature, the IUCN – South Africa Office is acting as the secretariat to assist in this project. This publication is the product of the Karst Working Group (KWG) which functions under the auspices of the IUCN - SA Office. The KWG consists of experts in cave and karst management which are affiliated to national, provincial and local government agencies, public and public funded institutions, academics from a number of prominent South African universities, and members from non-governmental organisations, particularly cave and bat organisations. It is hoped that this publication will act as a platform for future research and projects that will lead to the protection of the COH WHS and the underlying karst system, which hold great cultural, economic and environmental value. The publication was co-funded by the Water Research Commission (WRC) and the Cradle of Humankind World Heritage Site Management Authority (COH WHS MA). The WRC funded all the water related papers.

The papers presented in this booklet were completed over a period of two years from 2005 to 2006. The socio-political landscape has changed since then particularly in terms of changing legislation and the government department mandated to manage the Cradle of Humankind World Heritage Site. The decision to publish this information in 2010 is based on the reality that most of the technical information and environmental issues are still relevant. This publication provides, therefore, not only public record of Karst issues but adds to the growing body of knowledge on Karst systems and the management thereof in South Africa, and more specifically, the Cradle of Humankind World Heritage Site (COH WHS). The following explanation of the existing legislation and Departmental responsibilities has been added to avoid reader confusion.

The Cradle of Humankind World Heritage Site is constituted in terms of the World Heritage Convention Act (WHC), Act 49 of 1999. Because of its status as a World Heritage Site it is managed according to the prescriptions of the National Environmental Management: Protected Areas Act, Act 57 of 2003 and the Regulations for the Proper Administration of Special Nature Reserves, National Parks and World Heritage Sites. Both these Acts make provision for the establishment of an Authority whose responsibility it will be to manage the site.

The WHC Act makes provision for an Authority that is responsible for the management of the site. This function has been delegated by the National Minister for Environment (previously the Department of Environmental Affairs and Tourism) to the MEC of the Gauteng Department of Economic Development (DED), earlier the Department of Finance and Economic Development. The Cradle of Humankind World Heritage Site Management Authority (MA) is established specifically to manage the COH WHS. The site is managed according to sustainable environmental practices and is ably assisted in this regard by the Gauteng Department of Agriculture and Rural Development (GDARD), formally the Department of Agriculture, Conservation, Environment and Land Affairs (DACEL) and the Department of Agriculture, Conservation and Environment (GDACE).

Some National Government departments were restructured in 2009; the table below shows the changes. New departments were created, others merged and some were split. The Departments of Water and Environment are now two separate departments, reporting to a single Minister.

	Current Departments	**Previously / was part of**
New	Agriculture, Forestry and Fisheries	Agriculture Water Affairs and Forestry
	Arts and Culture	
New	Basic Education	Education
	Communications	
	Cooperative Governance and Traditional Affairs	Provincial and Local Government
	Correctional Services	
New	Defence and Military Veterans	Defence
New	Economic Development	Finance
New	Energy	Minerals and Energy
New	Environmental Affairs	Environmental Affairs and Tourism
	Health	
New	Higher Education and Training	Education
	Home Affairs	
New	Human Settlements	Housing
New	International Relations and Cooperation	Foreign Affairs
	Justice and Constitutional Development	
	Labour	
New	Mineral Resources	Minerals and Energy
New	Police	Safety and Security
	Public Enterprises	
	Public Service and Administration	
	Public Works	
New	Rural Development and Land Reform	Land Affairs
	Science and Technology	
	Social Development	
	Sport and Recreation	
New	Tourism	Environmental Affairs and Tourism
	Trade and Industry	
	Transport	
New	Water Affairs	Water Affairs and Forestry
New	Women, Children and People with Disabilities	

ACKNOWLEDGEMENTS

The production of this publication has its origins in the formation of the IUCN (South African) – Karst Working Group (KWG). The importance and sensitivity of karst environments has been recognised for some time now and to this end, an International IUCN (Karst Working Group) was established some time ago to facilitate awareness and prudent management of such environments. Karst environments form part of the South African geological record and the majority of these are associated with the Transvaal Supergroup rocks. Also associated with these rocks are cave deposits containing world renowned palaeontolgical/palaeo-anthropological deposits including the Cradle of Humankind World Heritage Site (COH WHS).

With the aforementioned in mind, various concerned individuals from various backgrounds considered it appropriate to establish a local (South African) group with similar objectives of the IUCN International Karst Working Group. A "brainstorming session" was held at the IUCN offices in Pretoria on the 11th February 2004 at which the following individuals were present : Saliem Fakir, Michael Raimondo and Melissa Fourie (all from the SA IUCN Office), Sue Taylor and Melinda Swift (from DACEL the Management Authority for the COH WHS) Lientjie Cohen (Mpumalanga Parks Board), Mike Buchanan (Cave Research Organisation of SA, Chairman and speleologist), Murray Macgregor (SAC&ES- Earth and Natural Scientist and Precambrian Palaeontologist), Neil Norquoy (Wild Cave Adventures), Garfield Krige (African Environmental Development and Water Technologist) and Nigel Fernsby (Bat Specialist). Resultant from the aforementioned meeting the South African IUCN - Karst Working Group (hereafter referred to as the KWG) developed. The IUCN then under the management of Saliem Fakir kindly facilitated the logistics of establishing the KWG and thanks are due to all those mentioned above involved in this process.

The KWG shortly after its formation facilitated several workshops and a process by which a broader spectrum of Interested and Affected Parties (I&APs) were approached to participate in the organisation. It was soon established that it was imperative to establish the status quo of karst in South Africa and to establish appropriate management principles and practices for such environments. It was decided that the departure point to this end should include the compilation of a document encompassing the most relevant aspects of karst in South Africa and with the importance of the COH WHS in mind; this was chosen as the "type site" for this purpose. This publication is the outcome of that process.

Numerous other acknowledgements are due in respect of this publication. The production of this publication required funding and the inputs of various authors. The funding was obtained from the Water Research Commission (WRC) and the Management Authority of the COH WHS with the logistical support of the IUCN. Thanks are due to preceding and especially to Kevin Pietersen of the WRC (now in private practice), Saliem Fakir and Melissa Fourie for logistical support. Peter Mills largely represented the interests of the COH WHS Management Authority. Thanks are also due to authors whose inputs in many instances exceeded the allocation of resources to enable the finalisation of such comprehensive documentation.

Following the resignation of Saliem Fakir and Melissa Fourie from the IUCN, the responsibility for this publication within the IUCN fell largely on Jenny Tholin who was voluntary assisted by Murray Macgregor and together with some input from Christine Bradley, was responsible for the finalisation of the First Draft in mid-2006. This was preceded by a workshop facilitated by the IUCN (Jenny Tholin and Murray Macgregor) in January 2006 at Sterkfontein Caves, the objective of which was to discuss/review and obtain input from members of the KWG on the "initial draft" papers which had been distributed in the later part of 2005 to this end. Thanks go to all who attended and had input in this regard.

Shortly after the finalisation of the First Draft in early July 2006 Jenny regrettably left the employ of the IUCN and the production of this publication entered an uncertain phase during which final publication was appearing not to be guaranteed. Only the persistent inputs from Dr. Shafick Adams of the WRC and Murray Macgregor took it to an initial review/edit by Dr. Francois Durand and finally to the final edit by Martha Pretorius.

COVER PHOTOS CREDIT: Murray Macgregor

- Bottom left – Drimolen fossil site – ninety two hominid specimens have been discovered here including *Paranthropus robustus* & early *Homo*.
- Middle right – Swartkrans fossil site – this site contains evidence of the first known use of fire by hominids.
- Bottom right – stream emanating from a dolomitic spring within the COH WHS (Gladysvale site).
- Top left- typical dolomitic terrain within the COH WHS after a controlled veldt management burn.
- Middle left - bone breccia from the Gladysvale fossil site. Homonid teeth & numerous faunal and plant fossils up to 3 million years old have been found at this site.
- Top right – chert / bone breccia & "flow stone" from the Gladysvale fossil site.

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ABBREVIATIONS

AMD	Acid mine drainage
AQA	Air Quality Act
CARA	Conservation of Agricultural Resources Act
CCI	Cameron Cross Incorporated
CEC	Cation exchange capacity
CERAC	Cave Exploration Rescue and Adventure Club
CGS	Council for Geosciences
COD	Chemical oxygen demand
COH	Cradle of Humankind
COH WHS	Cradle of Humankind World Heritage Site
CPSS	Cape Peninsular Speleological Society
CROSA	Cave Research Organisation of South Africa
Cu	Copper
CWG	Cradle Water Group
DEAT	Department of Environmental Affairs and Tourism
DFA	Development Facilitation Act
DME	Department of Minerals and Energy
DNHPD	Department of Nation Health and Population Development
DOC	Dissolved organic carbon
DWAF	Department of Water Affairs and Forestry
ECA	Environment Conservation Act
EIP	Environmental Implementation Plans
EMP	Environmental Management Plans
ENE	East North East
Fe	Iron
GDACE	Gauteng Department of Agriculture, Conservation and Environment
GFP	Good Farming Practice
GMOA	Genetically Modified Organisms Act
GNORBIG	Gauteng and Northern Regions Bat Interest Group
Ha	Hectare
IAP	Interested and Affected Parties
IAH	Intensive Animal Husbandry
IDP	Integrated Development Plan
IEM	Integrated Environmental Management
IUCN	International Union for the Conservation of Nature and Natural Resources
K	Potassium
KWG	Karst Working Group

kg	Kilogram
LAC	Limits of Acceptable Change
ℓ	Litre
m	Metre
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
mg/ℓ	Milligrams per litre
Mn	Manganese
Mo	Molybdenum
MoU	Memorandum of Understanding
MPRDA	Mineral and Petroleum Resources Development Act
N	Nitrogen
NEMA	National Environmental Management Agency/Act
NEMBA	National Environmental Management: Biodiversity Act
NEMPAA	National Environmental Management: Protected Areas Act
NFI	Northern Flagship Institute
NHRA	National Heritage Resources Act 25 of 1999
NSS	National Speleological Society
NWA	National Water Act
P	Phosphorus
PCB	Polycarbonbiphenol
PDI	Previously disadvantaged individual
ROS	Recreational Opportunity Spectrum
SAHRA	South African Heritage Resources Agency
SAR	Sodium adsorption ratio
SASA	South African Speleological Association
SDP	Spatial Development Framework
SEC	Speleological Exploration Club
TDS	Total dissolved solids
UJ	University of Johannesburg
WHCA	World Heritage Convention Act
WL	Working level
WNW	West North West
WWTP	Waste water treatment plant
Zn	Zinc

GLOSSARY

Many readers of this document will probably be surprised at the terms included in this list. There is however so much ambiguity and confusion about certain terms, many of which are well ensconced in the lay reference framework, that it is necessary to define these terms as the scientific realm sees them. For instance: fungi are not plants as most people think and bacteria are not germs. There is but a subtle chemical difference between limestone and dolomite while there is a major difference between hibernation and torpor in bats. Some definitions will undoubtedly stir up some controversy, since many readers believe themselves to be authorities on geology, caves, biology, etc. and the definitions may conflict with their paradigms. Certainly for every term listed there may be more complex, and more detailed definitions. These are however the simplest definitions available in scientific literature which will hopefully cater for a wide and diverse readership.

Abiotic: non-living, non-organic. Specifically the non-living, non-organic component of the ecology e.g. rocks, minerals, salts, water, sand, silt, mud, air, ambient temperature, and gases. It excludes living organisms and organic material.

Acid mine drainage: effluent containing sulphuric acid created by oxidation of pyrites in the rock combined with water during mining operations.

Allochthonous food sources: food that reaches an aquatic community from elsewhere in the form of organic detritus.

Amphipods: ubiquitous peracarid crustaceans which occur from the sea floor to mountain tops where they inhabit marine, freshwater, brackish and even damp soil. Contains almost 7 000 described species which include burrowing, free-swimming, parasitic and planktonic forms.

Animal: a multicellular organism without cell walls that feeds on other organisms, usually by ingesting them whole or in parts.

Anoxemia: an abnormal reduction in the oxygen content of the blood.

Anthropogenic influences: man-made influences, includes pollution, habitat destruction, poisoning, eutrophication, etc.

Aquifer: a water-bearing geological unit or set of units that yields a significant amount of water to wells or springs of a high enough quality to be economically usable. Although consolidated geological units such as dolomite may act as an aquifer, aquifers also exist in unconsolidated geological units such as sand, gravel and fractured sandstone and granite.

Associates: organisations with a stake in conservation. With regard to caves, key associates include groups, recreationalists (especially cavers), conservationists, concessionaires and scientists.

Autolithotrophic bacteria: bacteria that get their nutrients from rocks and minerals and their derivatives. These bacteria can exist independent of photosynthesis and can occur kilometers below the surface of the earth.

Basin: hydrogeographic unit receiving precipitation and discharging runoff in one point.

Bioaccumulation: the net accumulation of a chemical by an organism.

Biodiversity: the number and variety of organisms found within a specified geographic region.

Biofilm: organic layer consisting of a complex aggregation of microorganisms, primarily bacteria and fungi, that surrounds the sand grains on the floor of the body of water, often marked by the excretion of a protective and adhesive matrix.

Bioindicator: an organism that gives information about the physical and chemical environment in which it lives.

Biomagnification: the tendency for some pollutants such as metals and DDT to accumulate within food webs, notably towards the predator and scavenger poles of the food web.

Biome: is a homogeneous ecological formation that exists in a geographical region, such as bushveld or grassland. A biome is a major regional group of distinctive plant and animal communities well adapted to a specific region's physical environment.

Biotic: organisms and non-living organic material, such as leaf litter and dung.

Breccia: see Cave-fill.

Calcite: calcium carbonate ($CaCO3$), the main constituent of limestone.

Carrying capacity: the level of human interaction a system can endure before its resources are exhausted or irreversible damage is caused.

Catchment area: in relation to a watercourse or watercourses or part of a watercourse, means the area from which any rainfall will drain into the watercourse or watercourses or part of a watercourse, through surface flow to a common point or common points.

Cave Advisory Committee: refers to a committee comprised of appropriate provincial administrators and departments and the scientific and recreational caving community, in conjunction with the Provincial Directorate of Nature Conservation. This committee will be the only recognised body regarding the Management of Caves in the Gauteng Province.

Cave life: any life form which normally occurs in, uses, visits, or inhabits any cave or subterranean water system.

Cave material: all or part of any archaeological, palaeontological, biological, or historical items, breccia and sediments including, but not limited to any human remains, indigenous artefacts or camp sites, (Refer to any legislation covering the protection of Indigenous/Cultural sites).

Cave: any naturally occurring void, cavity, recess, or system of interconnecting passages beneath the surface of the earth or within a cliff of ledge including natural subsurface water and drainage systems which are large enough to permit a person to enter but not including any mine, tunnel, aqueduct, or other excavation. The word cave includes or is synonymous with cavern, sinkhole, natural pit, grotto, and rock shelter. Alternatively a cave can be defined as a solution cavity with an entrance to the surface. Some speleologists specify that a cave must contain a deep zone to distinguish it from overhangs, rock shelters, hollows, sinkholes, etc.

Cave-fill: a conglomeration of sand, mud and silt that is washed in from outside, the breccia from roof collapses and speleothems that form from the mobilisation and deposition of calcite from the surrounding limestone and dolomite. These may occur in unconsolidated deposits in young caves, dolines and sinkholes but may become consolidated over time as a conglomerate known as cave breccia.

Cavern: large cave, large room within cave system or large solution cavity with multiple entrances.

Chert: a black, brown or grey rock, consisting of very fine-grained silica, that occurs as horizons of nodules and discontinuous bands, generally less than 200mm thick, within many limestone's. It is very hard and almost insoluble in water, so commonly it projects from cave walls where it forms passage or shaft ledges and waterfall lips.

Clutter foragers: bats that hunt amongst tree tops.

Commercial cave: any cave or any part of a cave that is utilised by the owner for the purposes of exhibition to the general public as a profit or non-profit enterprise.

Concessionaires: people who have been granted a lease, easement, licence or permit to trade, occupy or run a business in selected caves administered by the COH WHS.

Constant frequency calls: calls emitted by certain bats are long and have constant frequency or a static range of frequencies and are suitable to Doppler-shift analysis which enables the bat to determine the speed and direction of its target.

Coprovore: dung eater.

Cryptozoic: animals living under stones or in crevices or amongst vegetation, dead leaves and other detrital matter on the bottoms of streams.

Cyanobacteria: bacteria that can photosynthesise also known as blue green algae.

Dedolimitization: Destruction of dolomite to form calcite and periclase, usually by contact metamorphism at low pressure.

Deep zone of cave: the part of the cave where it is completely dark and has a constant temperature.

Detritivore: an organism which feed on any organic material in the water including the carcasses of their dead, leaf litter washed into the karst system from outside.

Discharge: in its simplest concept, discharge means outflow and is used as a measure of the rate at which a volume of water passes a given point. Therefore, the use of this term is not restricted as to course or location, and it can be used to describe the flow of water from a pipe or a drainage basin. With reference to groundwater, the process by which groundwater leaves the Zone of Saturation via evaporation, evapotranspiration, or by flow to the surface through springs and seeps.

Doline: a closed topographic depression caused by dissolution of surface bedrock or collapse of underlying rock in karst areas. Often used as a synonym for sinkhole.

Dolomite: a mineral consisting of the double carbonate of magnesium and calcium, $CaMg(CO_3)_2$ or a rock made chiefly of dolomite mineral. When the magnesium carbonate ($MgCO_3$) content of limestone increases, it turns into dolomite. Pure dolomite $CaCO_3.MgCO_3$ is a rock or mineral, which contains 45.46% magnesium carbonate.

Dykes: a tabular body of intrusive igneous rock that cuts across the layering or structural fabric of the host rock. It may be a composite or multiple intrusions. Dykes may be fine, medium or coarse grained, depending on their composition and the combination of their size and length of their cooling period. They vary in width from a few centimeters to many meters, but they may be traced for several kilometers. A group of dykes is called a dyke swarm.

Ecosystem: a naturally occurring assemblage of plants, animals, fungi, Monera and Protista, living together in a certain environment, functioning as a loose unit which is characterised by the flow of energy and matter between its constituent elements. The organisms are usually well balanced in an ecosystem through various types of interaction including, predation, parasitism, mutualism, competition, etc.

Ecotone: a buffer or transitional area between two ecological communities such as the Bushveld and Grassland biomes or habitats such as the phreatic zone or caves which exist between the surface water and groundwater. An ecotone is characterised by a mix of elements from both neighbouring ecological communities.

Edaphic factor: any property of the soil, physical or chemical that influences plants growing on that soil (Greek edaphos = ground)

Endemic: organisms that occur only in a particular region, and nowhere else. Usually used to describe a limited distribution range of an organism within a country or province.

Epeiric: of a sea: connected with the ocean but situated on a continent or continental shelf.

Epeirogenic: the formation and alteration of continents by the movement of the earth's crust.

Epigean organism: organism that is surface dwelling e.g. in rivers.

Epikarst: a relatively thick (the thickness may vary significantly, but 15 to 30 meters thick is a good generalization) portion of bedrock that extends from the base of the soil zone and is characterised by extreme fracturing and enhanced solution.

Eutrophic: water with an excess of minerals and organic nutrients that promote a proliferation of plant life, especially algae and certain bacteria, which reduces the dissolved oxygen content and often causes the extinction of other organisms.

Evapotranspiration: the total loss of water in vapour form from all sources - open water, from the plant surface (interception), through plants (transpiration) and from the soil surface: it involves the transition of water from the liquid phase to the vapour phase, and during this process energy (termed latent heat) is absorbed.

Faecal coliforms: bacteria associated with faeces and faecal pollution.

Fault: a fracture or zone of fractures along which there has been displacement of the sides relative to one another, parallel to the fracture.

Frequency modulated calls: short repetitive calls emitted by certain bats. These calls encompass many frequencies that start at a relatively high frequency and drops down to a lower one. This type of call provides detailed information about the distance to potential targets and is useful in a cluttered environment.

Fungi: a multicellular organism with cell walls containing chitin, lacks chlorophyll and which feeds on the remains of other organisms which they dissolve. Usually saprophytic but sometimes pathogenic.

Gate: any structure or device located so as to limit or prohibit access or entry to any cave or part of such cave.

Geohydrology: the study of the hydrologic or flow characteristics of subsurface waters. The term ''geohydrology'' is often used interchangeably with hydrogeology as the study of the interrelationships of the affects of geologic materials and processes with water.

Geological formation: the fundamental lithostratigraphic unit, which may consist of consolidated or unconsolidated material. This definition could arguably include formations such as the Kalahari sands and the Quaternary sands of the dune fields in the Western Cape.

Gleaners: bats that skim over surfaces to capture insects.

Grike: a vertical fissure in limestone, such as a joint enlarged by solution.

Groundwater level: the water level in a borehole/well penetrating the zone of saturation.

Groundwater quality: a term used to describe the chemical, physical, and biological characteristics of groundwater, usually in respect to its suitability for a particular purpose.

Hibernacula: a structure or place used by bats to hibernate.

Hibernation: the inactive stage, usually during winter, when an organism's metabolism and body temperature are at its lowest in order to conserve energy.

Histoplasmosis: a severe disease affecting the eyes or the lungs with symptoms resembling flu, caused by the fungus Histoplasma capsulatum which often occurs in caves, especially on bat faeces.

Hypogean organism: organism that lives in a subterranean, e.g. groundwater habitat.

Indigenous: occurring naturally but not exclusively in a delimited area.

Insectivorous: insect eater.

Interspecific relationships: relationships or interaction between different species, e.g. predator and prey, host and parasite, herbivore and plant. Here it refers to the relationship between subterranean organisms within the karst system and troglophiles and other species outside the caves.

Interstitial spaces: spaces between pebbles and grains of sand.

Karren: natural furrows on the surface of carbonate rocks ranging in depth from a few millimeters to more than a meter formed as a result of natural solution of bedrock by rain or from sub-soil moisture interaction with the bedrock.

Karst: named a limestone plateau in the Dinaric Alps, which are located between Croatia and Bosnia, Herzegovina. Karst systems are dominated by carbonate-rich rock. It is characterised by its relief caused by the dissolution of the underlying rock by the groundwater flow. Caves, sinkholes, aquifers, disappearing rivers and springs are all typical of a karst landscape. Distinctive surface and subsurface landform due to the solubility of certain rock types in natural water. Karst usually forms in relatively pure hard carbonate rock such as limestone and dolomite although it can occur in other rock types such as gypsum and marble. Karst areas usually include distinctive soils, microclimates, flora and fauna and patterns of hydrology.

Karstification: the processes of solution and infiltration by water, mainly chemical but also mechanical, whereby the surface features and subterranean drainage network of a karst terrain are developed to form a karst topography, including such surface features such as dolines, karren, swallow-holes and such subsurface features as caves and shafts.

Karst ecology: the interaction of the organisms and the interaction between those organisms and their physical and chemical surroundings within and outside the karst system. The biotic aspect includes the complex interaction between troglophiles, troglobites, stygobites and the organisms in the vicinity of the cave on which they depend. The abiotic aspect includes the rocks and minerals, which have a profound effect on the chemical and physical properties of the karst but also the temperature, water, solubles, air and other gasses in the karst system

Lampenflora: plants such as algae, mosses and ferns which occur in caves or dark recesses in the vicinity of lighting fixtures due to the heat, light and available levels of nutrients and moisture.

Limestone: consists mainly of calcium carbonate ($CaCO_3$) with variable amounts of magnesia, ferrioxide, alumina and silica. Calcium carbonate minerals include calcite and aragonite.

Lithostratigraphy: the science of classifying or organising rock strata according to the properties of the constituent material and stratigraphic position in relation to other units.

Mass movement: the movement of a portion of the land surface down a slope (e.g. slumps, shallow landslides and debris flows).

Middle zone of the cave: that area with complete darkness but with variable temperature - it is often occupied by several species some of which may commute to the surface.

Monera: prokaryotic organisms such as bacteria and blue-green "algae". These single cell organisms have neither cell nucleus nor double membrane organelles such as mitochondria or chloroplasts. Most bacteria are decomposers but some are pathogenic. Blue-green algae or cyanobacteria photosynthesise but a high concentration in a water body may be toxic to animals that drink the water.

Monitoring: the act of measuring change in the state, number or presence of the characteristic(s) of something.

Necrosis: is the name given to the unprogrammed death of living tissue which can be caused by injury, infection, cancer, infarction, inflammation, poisoning, etc.

Obligate stygobite: an organism, which is dependent on ground water and subsurface habitats. Most have undergone troglomorphy.

Organotrophic: a metabolism that is based on the ingestion or absorption of organic material, either by feeding on organisms or organic remains or products of other organisms. Majorities of organisms are organotrophic and directly or indirectly linked to the process of photosynthesis.

Owner: a person who owns title to land in a karst area and on which a cave may be located, including a person who owns title to a leasehold estate for such land and specifically including, but not limited to the Province and any of its agencies, departments, boards, bureaus, commissions, authorities and other administrative subdivisions of the Province who have title to Provincial and Tribal Trust Land.

Parenteral: parts of the body outside the digestive system, e.g. skin, lungs, blood, skeleton, mucous linings, kidneys.

Pathogen: an agent that causes a disease, especially a living microorganism such as bacteria, fungi or protozoa.

Pelindaba rock: a predominantly local term for dolomitic rock with thin layers of chert, often used in rockeries.

Perched water table: localised, unconfined groundwater separated from the underlying main body of groundwater by an unsaturated zone i.e. the local water table is not in hydraulic continuity with the regional groundwater system.

Photosynthesis: the method of producing sugar-rich molecules by means of water, carbon dioxide and sunlight. $6H_2O + 6CO_2 + \text{light} \rightarrow C_6H_{12}O_6$ (glucose) $+ 6O_2$

Phreatic surface: the upper limit of the saturated zone i.e. the water table.

Phreatic zone: groundwater in the zone beneath the water table.

Plant: an autotrophic multicellular photosynthesizing organism with cell walls that contain cellulose.

Protista: single-celled free-living or colonial organisms with nucleus and double membrane organelles such as mitochondria and chloroplasts, e.g. Protozoa such as Amoeba, certain types of algae e.g. golden-brown algae, yellow-green algae and diatoms. Some are decomposers, others photosynthesise and yet others may be pathogenic.

Provincial land: all land the title to which is owned by the Provincial Government and administered by the relevant authority.

Pseudokarst: karst-like landforms not derived from the dissolution of rock. These may occur in other rock types.

Recharge: the processes involved in the absorption and addition of water to the zone of saturation. **Synonym: Replenishment.**

Register of Significant Caves: refers to the register that contains relevant information regarding Significant Caves as defined below.

Reserve (National Water Act, 1998): the quantity and quality of water required to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108, 1997), for people who are now or who will, in the reasonably near future, be relying on, taking water from, or being supplied from the relevant water resource, and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

Resource partitioning: phenomenon where scarce resources in an ecosystem are shared by species with similar requirements by using the resources at different times, in different ways or in different places.

Riparian zone: strips or patches of vegetation that border streams. These are very important ecological resources for animals.

Roost: term used to describe the domicile of bats. It may include caves, cliff overhangs, crevices, trees and leaves.

Satellite imagery: a digital image captured by a sensor mounted on an earth orbiting satellite.

Significant caves: those caves, which by virtue of their nature or position may be particularly sensitive or under threat.

Sinkhole: 1. a hole that forms on the surface after the collapse of the roof of an underground solution cavity. 2. a topographic depression or basin, generally draining underground, including but not restricted to a doline, blind valley or sink.

Solution cavities: cavities formed in carbonate rocks by shallow circulating groundwater carrying dissolved carbon dioxide.

Speleogen: an erosional feature of a cave boundary and includes, but is not limited to anastomoses, scallops, rills, flutes, sponge work, chert boxes, petromorphs and rock pendants in solution caves. It refers to relief features on the walls, ceiling and floor of any cave and which are parts of the surrounding bedrock.

Speleothem: (Greek for "cave deposit") or natural mineral formation or deposit in a cave. This includes, but is not limited to stalagmites, stalactites, helicities, anthodites, flowstone, curtains, oolites (cave pearls), cave coral, columns, cave flowers, rimstone, needles, or formations of clay or mud. Speleothem are commonly composed of, but not limited to calcite, gypsum, halite, epsomite, aragonite, celestite, and other similar minerals. These structures form when calcite (sometimes gypsum) is dissolved and deposited by evaporation in air-filled caves. The formations grow molecule by molecule over tens of thousands of years.

Stromatolite: a laminated calcareous mounded structure built up of layers of cyanobacteria and trapped sedimentary material. In geology it refers to a fossilised structure of this kind from the early Precambrian.

Stygobite (or sometimes called stygobiont): animals that are confined to groundwater and not necessarily the caves where they were originally observed by researchers. Most stygobites have undergone troglomorphy due to convergent evolution to troglodytes because of the similar conditions that exist in subterranean habitats, whether aquatic or in caves above water.

Stygoxen: aquatic species that live in epigean environments.

Syenite: a coarse-grained igneous rock, allied to granite, composed mainly of alkali feldspar, with hornblende, other ferromagnesian minerals, and accessory oxides**.**

Syncline: a fold in rocks (or the landscape) in which the strata dip inwards from both sides towards the axis. **.**

Synergistic: when the total effect or impact is more than the sum of the individual actions.

Talus: a heap of fallen loose rock fragments forming a slope at the base of a steeper rock face.

Torch and Takkie: a term used to describe ill equipped and often environmentally insensitive cave adventurers**.**

Torpor: the inactive state of animals e.g. bats during daytime or snakes after feeding.

Transmissivity: Also known as the coefficient of transmissivity. The rate of movement of water at the prevailing kinematic viscosity through an aquifer of unit width under a unit of hydraulic gradient. Transmissivity, T, is a function of the liquid and the aquifer, as is hydraulic conductivity, K, but also incorporates the saturated thickness along with the properties of the contained liquid.

Tribal Trust Land: all land held in trust by the Provincial Government for the benefit of an indigenous society/people, and administered by the relevant authority.

Troglobites/Troglodites: animals that are obligatory cave dwellers, for part or whole of their life cycle. Troglobites are characterised by the degree of troglomorphy they have undergone in response to the dark, damp subterranean environments where they have to survive.

Troglomorphy: morphological adaptations to life in caves - it usually includes the loss of pigmentation and sight as well as the attenuation of antennae and limbs, typical of obligatory cave dwelling organisms.

Troglophiles: animals that live in caves temporarily or opportunistically, usually only for shelter such as bats and humans. Troglophiles usually get their food and water outside the cave and have to leave it at regular intervals.

Trogloxenes: species, which utilise caves, but must leave the caves to complete their life cycle.

Twilight zone: the area in a cave where light (but not direct sunlight) penetrates into a cave.

Uvala: a large surface depression (up to several kilometers in diameter) in karst areas, formed by the coalescence of adjoining dolines.

Vadose zone: the zone between the land surface and the water table. Air and other gasses typically occur in the interstitial spaces.

Visitors: people who come to experience a cave. They include independent visitors and clients of concessionaires both from South Africa and overseas.

Vulnerability: the sensitivity of groundwater quality to an imposed contaminant load, which is determined by the intrinsic characteristics of the aquifer (e.g. dolomite).

Water balance: a measure of the amount of water entering and leaving a system, also referred to as Hydrologic Budget.

Water Management Area: an area established as a management unit in the national water resource strategy within which a catchment management agency will conduct the protection, use, development, conservation, management and control of water resources.

Water resource: includes a watercourse, surface water, estuary, or aquifer.

Wild cave: any cave of portion of cave that is not a commercial cave or part of such a cave.

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ISSUE PAPER 1 BACKGROUND AND INTRODUCTION TO THE PUBLICATION AND ISSUE PAPERS

I.M. Macgregor

ABSTRACT

The contents of this paper serve as an introduction to this publication and the background to its origin which is linked to the formation of the IUCN – South Africa Karst Working Group (KWG) in 2004. The nature and importance of karst environments are considered only in brief as more detailed discussion on this topic is referred to by way of appropriate references and also covered to a large extent in the papers comprising the publication.

IUCN – South Africa Office hosts the Karst Working Group (KWG), a national group of experts in the field of karst management and consisting of a broad spectrum of organisations and individuals including the following: representatives from national, provincial and local government; public research institutes; academics from a number of prominent South African universities; members from NGOs including caving organisations and bat interest groups; specialists and consultants in various aspects of the karst environment and land owners.

At the first workshop of the KWG held in May 2004 various objectives were identified one of which was "to use the Cradle of Humankind World Heritage Site (COH WHS) as a pilot project, but subject thereto that it is designed and implemented as a process model for karst management throughout the country". At the same workshop it was agreed that the design of an effective monitoring and management system was required, including an overview and synthesis of all available data and research. The production of this publication is the first step in achieving this objective.

The publication includes 13 papers on various topics pertinent to the karst environment of the COH WHS including impacts associated with mining, agricultural operations and urban development, as well as legal, geological, hydrological, ecological and educational perspectives.

The final paper represents a synthesis report on the publication and contains some recommendations in respect of the future of the KWG and the management of the caves and karst system of the COH WHS.

1.1 Introduction

This publication comprises of 13 Issue Papers on various topics pertaining to the Cradle of Humankind World Heritage Site (COH WHS) and the associated karst environment. The fossil deposits occurring within the COH WHS are of enormous national and international scientific value and the management of these sites is directly linked to the management of the karst system in which they occur.

Initially two publications were to be produced, one concentrating mainly on the hydrological system (i.e. water resources and water-based ecosystems of the COH WHS) and the second on the karst ecology, land and cave usage and environmental factors impacting on the karst of the COH WHS. Aspects pertaining to policy and legal issues of relevance were also to be included. However, considering that many of the issues that would be covered in the two publications were closely linked and taking into account the importance of cross linkages in the management of the karst system of the COH WHS, it was decided to combine all the papers into a single document. It was also decided that due to the range of topics covered in the publication, each paper would be produced in a format that would allow to it to read as a "stand alone" paper. This has many advantages but has inevitably led to some duplication of information. The final section of this publication is devoted to a synthesis of the Issue Papers, recommendations and conclusions resulting from inputs from various sources including the authors and other interested and affected parties.

Due to the technical nature of the publication, the following section provides a brief description on the nature and importance of karst and associated environments.

1.2 The Nature And Importance Of Karst And Associated Environments

The topic of karst was very appropriately addressed in a publication produced by the IUCN World Commission on Protected Areas (WCPA) – Working Group on Cave and Karst Protection entitled "Guidelines for cave and karst protection", (synthesised and edited by Watson *et al.*, 1997). The primary aim of this document was to increase awareness of cave and karst protection issues within IUCN WCPA and other associated management and conservation agencies with emphasis on national parks and other protected areas. The document was compiled with inputs from experts worldwide and includes the following important aspects of karst, amongst others: the context of karst protection; karst environments and cave systems; the importance of caves and karst; threats to caves and karst; some options in protection of karst; management at the regional and site level; international cooperation and liaison and references for further reading.

A brief description of the nature of karst follows but the reader is urged to refer to the Guidelines for Cave and Karst Protection (Watson *et al.*, 1997) for additional background to karst. Some important aspects concerning karst and a summary of the guidelines stemming from this document are summarised in Boxes 1.1 and 1.2.

1.2.1 The Nature Of Karst

Karst scenery according to the Penguin Dictionary of Geology (Whitten and Brooks, 1974) refers to "a landscape which shows a pattern of denudation in limestone and dolomitic rocks similar to that of the Karst region of Yugoslavia. This type of topography is not produced by normal surface runoff but by percolating groundwaters and underground streams [*sic*]. The process may be initiated by the uplift of a limestone surface upon which normal drainage has commenced, or by down cutting of a stream, through other sediments into a limestone, or through an unconformity".

The term karst therefore denotes a distinctive style of terrain which is characterised by individual landform types and landscapes that in large are the product of rock material having been dissolved by natural waters to a greater degree than is the norm in most landscapes. Watson *et al.* (1997) note that the word refers to any area which has been shaped by solution processes and more broadly, it is an integrated, yet dynamic system of landforms, energy, water, gases, soil, bedrock and life in which perturbation of any one of these will impact upon the rest of the system.

All rocks are soluble to a degree but as can be expected the most fully developed karst is to be found in environments where the more soluble rocks such as dolomite, limestone and evaporite rocks such as gypsum are found. It is estimated that such rocks represent over 30 percent of the earth's surface but they vary in their susceptibility to the karstification process. It should however, be noted that given sufficient time and environmental stability, true karst phenomena can also develop in what may generally be considered to be relatively insoluble rocks such as quartzites and quartz sandstone among others, while sculpturing by solution may also occur in granitic and similar related rocks. Caves and other features typically associated with karst may also result from other processes and give rise to what is referred to as pseudokarst comprising land systems which contain karst-like features such as caves and surface collapses which are not formed by solution. Examples here include lava tubes (tunnels) associated with volcanic landscapes and caves resulting from melting of ice in and under glaciers to mention but a few. Directions of underground drainage in karst areas are typically dictated by geological structures and surface topography can portray a quite misleading picture of drainage. In well-developed karst there may be no consistent surface drainage patterns. Dry valleys are common on the surface and underground waters often breach drainage divides sometimes flowing from one valley to another and often flowing uphill under pressure in confined solution channels. Subterranean flow is often rapid, opportunities for natural cleansing of polluted or sediment-laden groundwater is largely lacking and pathogenic organisms can often survive the travel time. Caves which are often decorated by speleothems (stalactites and stalagmites) and flow stone are for most people the best known elements of karst. They provide sites of beauty, mystery, excitement and challenge, are sources of spiritual, religious, educational and heritage significance and are important resources for recreation and tourism. Caves also have considerable scientific value in both current terms and with respect to palaeontological/palaeo-anthropological significance. Indeed, the majority of the famous fossiliferous deposits within the COH WHS are associated with caves and associated karst landforms.

1.2.2 The Importance of Karst and Caves

Karst landscapes represent an important facet of the earth's geo-diversity and are of major management significance. Readers are referred to Watson *et al*. (1997) and Buchanan and Maguire (2002) amongst other references referred to in this publication.

In addition to the importance of retaining examples of karst landforms and landscapes as part of a strategy to safeguard global geodiversity, a number of cultural, scientific and economic values may be present in karst areas. For example, some of the economic values of karst environments include agriculture, water management, forestry, limestone mining and tourism.

Agricultural production on which the world's population is dependent is reliant on the upper few centimetres of the earth's surface in the form of suitable topsoil. Millions of people live in karst areas worldwide and some karsts offer rich and highly productive soils utilised for both general and specialised agriculture. However, some karst soils are often particularly vulnerable due to degradation by a variety of karst-specific processes that add to the usual pressures on soil. Caves are known to be utilised for some specialised forms of agriculture and industry including mushroom growing, fish breeding and cheese production for instance. Limestone obtained from karst areas is also utilised as a source of agricultural lime.

It is estimated that approximately a quarter of the world's population obtain their water from karst, either from discreet springs or from karst groundwater. Thus in some karsts, settlement patterns have been strongly influenced by sources of water. Major engineering works have for instance been undertaken in the karsts of Slovenia and China and irrigation, hydro-electric power and fisheries are other recorded major uses to which karst waters are put. Water supply may be particularly difficult to obtain in karst areas upstream of springs whether for human or agricultural use and pollutants can be transported rapidly through subterranean networks.

Karst limestone is an important resource used in many areas of agriculture and industry, e.g. in the manufacturing of fertilisers or cement, or as a flux in steel making. It is also utilised in other industrial processes to reduce pollution by removing the sulphur dioxide from waste gas vented into the atmosphere.

Tourism constitutes a major economic activity in some karsts including the use of both developed and undeveloped caves and surface scenery thereby generating local employment. Examples in South Africa include the Sterkfontein Caves and Wonder Cave in the COH WHS and the Cango Caves in the Western Cape. It is estimated that approximately 20 million people globally visit caves annually.

Other uses of caves worldwide include their usage as sanatoria for respiratory and other ailments especially where hot springs are present such as Banff in Canada.

In addition to economic values of karst there are numerous scientific values associated with karst environments. The fossil deposits of the COH WHS have already been cited previously. Such fossiliferous material is often specifically well preserved in a karst environment. In terms of earth sciences, karsts offer geologists clear exposures of geological structures, minerals and lithological units and offer palaeontologists/anthropologists access to important fossil sites. Karst environments also assist geomorphologists to obtain insight into landform evolution and climate change over broad areas from the morphology of particular caves and the study of cave sediments. Karst environments often host highly specialised and endangered fauna and flora species and communities both at the surface and underground which is of importance to biologists. Some karsts have served as refuge areas for species that have persisted underground through environmental changes which have eliminated their surface dwelling relatives. Probably the most common creature associated with caves are bats, however a variety of often endemic invertebrate and vertebrate animals inhabit karst, some of which may have only small populations or are highly adapted to the underground environment. In many instances subsurface environmental conditions can be very constant and cave species may have little tolerance to subsurface environmental change.

In respect of societal values, some karsts are important for religious, spiritual, recreational, educational and aesthetic reasons. Some societies attach considerable importance to certain caves and other limestone landforms such as in the case of the Mayas who use caves as temples as do many Hindus and Buddhists. Around the world caves continue to be used as burial sites and places of worship continue to be erected amidst karst, for example in the karst towers of Southern China.

Some of the world’s most scenic environments owe much of their appeal to karstic phenomena including many mountain areas that attract climbers, hikers, photographers, nature lovers and artists. Caving is a significant recreational activity in some parts of the world while every year millions of people visit developed tourist caves as previously mentioned.

Caves and karst areas often provide splendid sites for educational purposes. Various economic, scientific and spiritual values are demonstrated in a limited area and there are very few environments where the ecological chains of cause and effect and environmental determinants on human society are better demonstrated and clearly evident.

Heritage value of considerable significance is attached to the built environment in some karst areas ranging from prehistoric constructions in caves to some cave resorts in Europe and distinctive cave-associated tourist hotels in Australia and the USA.

Box 1.1:

Summary of important issues pertaining to karst environments as documented in the publication "Guidelines for Cave and Karst Protection" – prepared by the IUCN WCPA Working Group on Cave and Karst Protection.

1. In addition to the importance of retaining examples of karst landforms and landscapes as part of a strategy to safeguard global geodiversity, a number of economic, cultural and scientific values may be present in karst areas. Hence, there may be a diversity of demands that are in conflict with one another.
2. Their mysterious character and beauty has often caused attention to be focused specifically on caves and so diverted interest from the wider karst environment. Protection and management of this wider karst environment is important, not only in its own right but also because it underpins the adequate protection of a cave or any other single element in a karst landscape.
3. It is fundamentally important to recognise that the proper protection of caves and karst is not just a matter of preserving interesting, beautiful or scientifically interesting natural features. In most cases, protection has far-reaching environmental implications which in turn generate significant economic impacts. In particular, proper management of karst is an essential element of water resources management.
4. Caves and karst are amongst the most vulnerable of ecosystems, and are often subject to degradation as a result of phenomena or events which occur at a considerable distance. Their effective protection and management therefore requires consideration and action at both area and local levels.
5. Protection of karst features has all too often focused upon caves, and not given adequate consideration to the need for protection and proper management of the total karst area as a land unit.
6. The establishment of protected areas is not, in itself, enough to ensure karst protection. The management of karst demands specific interdisciplinary expertise and this is in the early stages of development in most countries. Management agencies should recognise the importance of this expertise and take advantage of inter-agency or international cooperation in order to enhance their own capacity.
7. Karst management must be holistic in its approach and should aim to maintain the quality and quantity of water and air movement through the subterranean environment as well as the surface.
8. In general, karst systems development over geological timescales which must inevitably include significantly different environments from that of today. Some karst systems may be so changed due to prevailing conditions that they have no capacity to regenerate. Other systems may have some capacity to regenerate but this may entail timescales greater than that of individual human generations. Caves and their contents (speleothems sediments and bones) may have been formed or emplaced under different climate regimes and may remain unaltered for millennia. These may require specific management attention because of their fragility.
9. The karst catchment boundary is not a single line that can be represented on a map, but a zone which has a dynamic outer boundary dependent on local details of surface geology and weather conditions.
10. Defining the contributing catchment of a cave may be difficult and even, in some cases, impossible. The elucidation of the drainage network of Mammoth Cave, Kentucky USA, was the result of over twenty years' investigation and hundreds of dye tracing experiments.
11. The maintenance of water quality in karst can be viewed as a common good which is becoming increasingly important in those areas where rural populations are increasing rapidly and the settlement of karst is well established.

Box 1.2

IUCN Guidelines for cave and karst protection (1997). Prepared by the WCPA Working Group on Cave and Karst Protection

Summary of Guidelines

1. Effective planning for karst regions demands a full appreciation of all their economic, scientific and human values, within the local cultural and political context.
2. 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.
3. 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.
4. Destructive actions in karst, such as quarrying or dam construction, should be located so as to minimise conflict with other resource or intrinsic values.
5. 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.
6. 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.
7. While recognising the non-renewable nature of many karst features, particularly within caves, good management demands that damaged features be restored as far as practicable.
8. 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.
9. Governments should ensure that a representative selection of karst sites is declared as protected areas (especially as category I to IV of the IUCN Categories and Management Objectives of Protected Areas 1996) under legislation which provides secure tenure and active management.
10. 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 system of their country.
11. Where possible, a protected area should include the total catchment area of the karst.
12. 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 quality and quantity of water inputs to the karst system.
13. 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.
14. Management agencies should seek to develop their expertise and capacity for karst management.
15. 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 atmospheric elements.
16. 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.
17. Managers should recognise that in karst, surface actions may be sooner or later translated into impacts directly underground or further downstream.

Box 1.2 (Continued)

18. 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.

19. 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.

20. 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 water tracing experiments and cave mapping. It should be recognised 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.

21. 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.

22. 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.

23. A stable natural vegetation cover should be maintained as this is pivotal to the prevention of erosion and maintenance of critical soil properties.

24. Establishment and maintenance of karst protected areas can contribute to the protection of both the quality 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.

25. 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.

26. 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.

27. Imposing fire regimes on karst should, as far as is practicable, mimic those occurring naturally.

28. 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.

29. International, regional and national organisations concerned with aspects of karst protection and management should recognise the importance of international cooperation and do what they can to disseminate and share expertise.

30. The documentation of cave and karst protection/management policies should be encouraged and such policies made widely available to other management authorities.

31. 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.

1.2.3 Threats to Caves and Karst

Caves and karsts are known to be particularly vulnerable, probably more vulnerable than other land resources. The integrity of any karst system is dependent on a sensitive interrelationship between land, water, air, vegetation and soils. It should be noted that in terms of the hydrological system, groundwater catchment boundaries may not coincide with surface water catchment boundaries. Thus the fragility of the interrelationships of the biotic and non-biotic elements of karst can easily compromise the integrity of the system by the slightest impact on one or more of the elements. Threats to karst environments include both direct and indirect impacts and particular cognisance needs to be made of accumulative impacts.

Some of the generic threats to karsts and caves include, but are not limited to the following: human utilisation of caves, land-use practices (i.e. forestry, land clearance, agricultural activities, waste disposal), major land and soil disturbance, pollution, mining and quarrying, disturbance to hydrological systems (surface and sub-surface) to mention but a few. Further examples and details of threats to karsts are documented in the papers that follow and also in Watson *et al.* (1997) and in the KWG Circular dated 11 June 2004.

1.2.4 Protection of Karst

One of the main purposes of this publication is to establish the *status quo* of the COH WHS karst system and to obtain baseline information to facilitate appropriate management of the site. Due to the nature, complexity and fragility of karst systems, the underlying management principle must be towards not only "total catchment management" but to a high degree, monitoring and management of peripheral areas in the "zone of influence" surrounding karst systems.

Ultimately an Integrated Environmental Management Plan (IEMP) with appropriate monitoring and audit protocols and procedures is required to ensure the integrity of karst environments. This will however, be linked to and depend on the establishment and maintenance of a reliable database and the management objectives of the site. The papers that follow highlight some of the issues to be addressed in the establishment of such a database and the reader is further referred to Watson *et al*. (1997) and Buchanan and Maguire (2002) for more in-depth perspectives on the management and protection of karst landscapes and caves.

1.3 South African Karst Rocks and the COH WHS

South Africa's karst environment constitutes a significant proportion of world karst. The majority of karst in South Africa is associated with the Transvaal Supergroup dolomites which are considered to be the oldest known occurrence of extensive shelf carbonates in the world.

A stretching of the crust of the Kaapvaal Craton commenced about 2 650 million years ago forming a trough into which rocks of the Wolkberg Group accumulated. As this trough became deeper, the whole of the Kaapvaal Craton began to subside below sea level, and sediments of the Transvaal Supergroup began to accumulate (McCarthy and Rubidge, 2005). The epeiric sea into which these sediments were deposited was more extensive than the current outcrop of these strata which is presented in **Figure** 1.1. Apart from being the oldest extensive shelf carbonate rocks known, the dolomites also contain well preserved stromatolites in which microfossils in excess of 2 300 million years old have been identified (Macgregor *et al*., 1974; Macgregor, 1979). The geological, palaeontological and evolutionary importance of these and the part they played in the development of an oxygenetic atmosphere is regrettably overshadowed by the more well known hominid and other much younger fossil remains in this karst system.

The famous Cango Caves in the Western Cape occur in yet another karst system in South Africa which are of more limited extent and younger than the Transvaal Supergroup rocks.

More detailed geological information in respect of the karst geology of the COH WHS is presented in the papers that follow (see for instance Issue Paper 6 – Holland *et al*.

1.4 Background to the South African Karst Working Group

For some time, various groups, organisations, individuals and members of Government Departments (including Environmental and Conservation agencies) have expressed concern at the preservation of karst environments in South Africa. However, there was no coordinated effort or approach to address these concerns and the formation of an umbrella body in mitigation of this was indicated and desirable.

An exploratory meeting was held between Mr Saliem Fakir (the then Country Programme Coordinator of the IUCN South Africa Office) and Mr Mike Buchanan of the Cave Research Organisation of South Africa (CROSA) in Pretoria on 9 July 2003.

This led to the foundation meeting of the South African Karst Working Group at the IUCN offices on 5 February 2004, which was attended by Saliem Fakir (IUCN), Melissa Fourie (IUCN), Melinda Swift (GDACE), Lientjie Cohen (Mpumalanga Parks Board), Garfield Krige (Consultant and land owner in the COH WHS), Nigel Fernsby (GNORBIG), Neil Norquay (Wild Cave Adventures), Mike Buchanan (CROSA) and Murray Macgregor (SA Conservational and Environmental Services - Earth and Natural Scientist/Consultant).

With the existence of the IUCN (WCPA) Working Group on Cave and Karst Protection, it was a logical step that the local KWG should fall under the umbrella of the local office of IUCN. Saliem Fakir assumed the position of the Acting/Interim Chairmanship of the KWG and IUCN supplied the secretarial and administrative support to launch the organisation. A provisional Steering Committee was established as well as four Sub-committees including the following: Biodiversity Sub-committee, Geology and Palaeontology Sub-committee, Hydrology and Geohydrology Sub-committee and the Land and Cave Use and Education Sub-committee.

The KWG constitutes a national group of experts in the field of karst management.

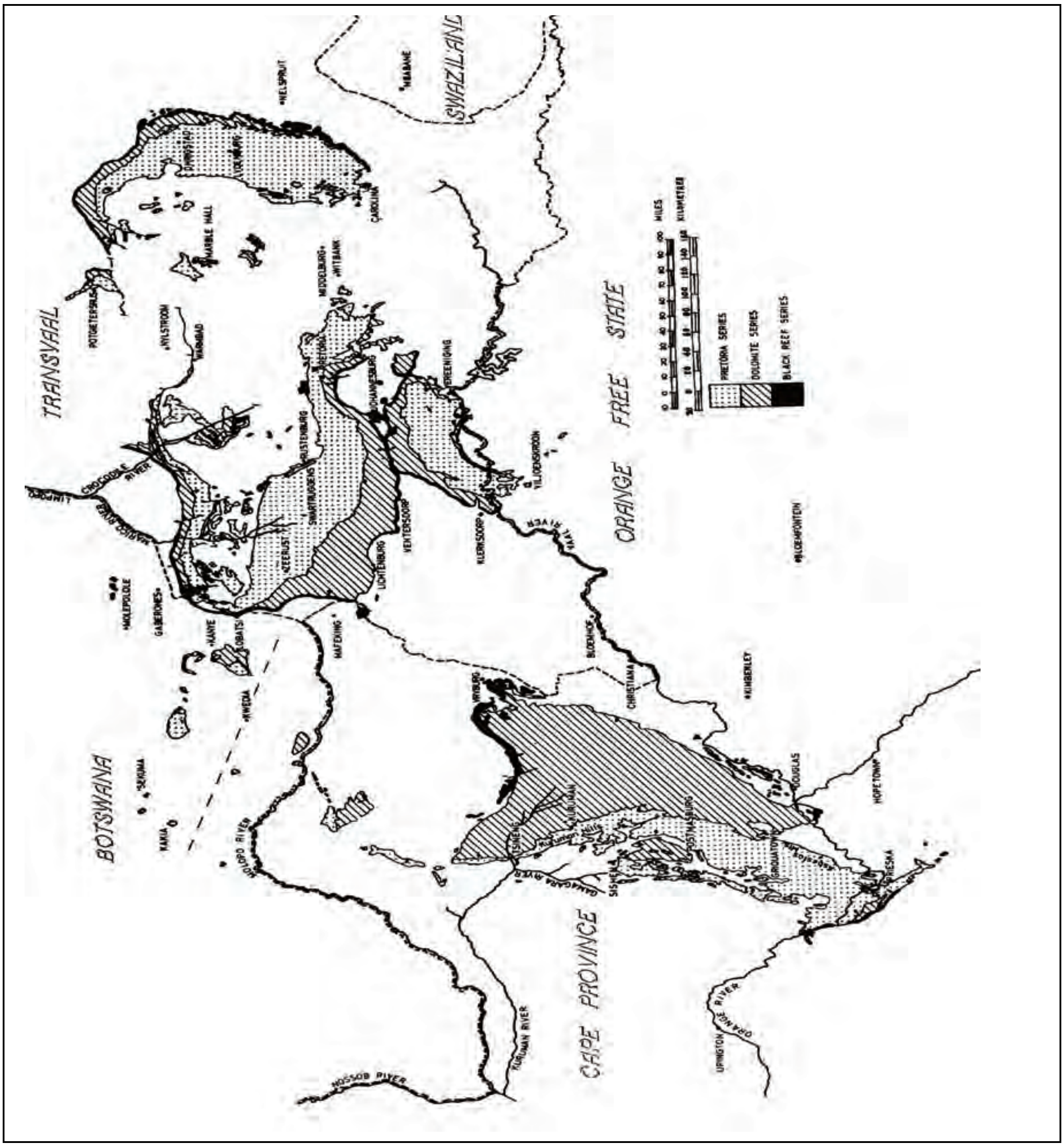

Figure 1.1: Distribution of the Transvaal Supergroup Dolomites (modified after Truswell, 1970).

The overall objective of the KWG is to find creative solutions for the complex problems and challenges facing the karst environment in South Africa. The following objectives were identified as being of relevance:

- To serve as a platform for scientists and managers to share experiences and knowledge on the role and functions of karst systems in maintaining vital ecosystem functions and services;
- To serve as a vehicle to develop decision-support material and information for scientists, managers and operators;
- To establish a network of experts and partnerships with relevant institutions;
- To establish a database of information on karst;
- To promote intergovernmental and scientific cooperation;
- To enlist with the IUCN's Global Programme on Protected Areas to gain international support and recognition;
- To develop, as a pilot project, baseline studies and a monitoring and management tool for karst management in the Cradle of Humankind World Heritage Site (COH WHS) in Gauteng, South Africa. The monitoring and management tool would focus on water (groundwater in particular), land use, stability and karst features. The working group would initially focus on this site for demonstration purposes and drawing lessons that will be of national value.

Since the establishment of the KWG several workshops have been held - the first of which was on 4 May 2004. Several further Circulars were also released by the KWG during 2004.

1.5 The Background To This Publication

With reference to the objective of developing, as a pilot project, baseline studies and a monitoring and management tool for karst management in the Cradle of Humankind World Heritage Site (COH WHS) in Gauteng South Africa, the KWG in 2005 was to focus on compiling a "Synthesis Publication" on research on karst and caves in the COH WHS. At a workshop held in May 2004 it was agreed that the design of an effective monitoring and management system was required and an overview and synthesis of all available data and research was necessary. Although a range of studies have been done, no study has taken a holistic, multidisciplinary approach to the management of the entire karst system.

The purpose of the synthesis reports was to consolidate existing information, identify major threats and responses, identify research gaps and make monitoring and management recommendations, which would feed into the COH WHS reporting to the World Heritage Authority.

The publication comprises and includes a synthesis of papers as presented in the Table of Contents.

REFERENCES

BUCHANAN M and MAGUIRE J (2002) The Management of Karst Landscapes and Caves, Cradle of Humankind WHS Cultural Heritage Resources Management. Project Report prepared by the Mahube Consortium.

Karst Working Group Circular, 11 June 2004.

MACGREGOR IM (1979) Precambrian Life-forms from the Campbellrand and Asbesheuwels Subgroups, South Africa. MSc Dissertation, University of the Witwatersrand, Johannesburg, South Africa.

MACGREGOR IM, TRUSWELL JF and ERIKSSON KA (1974) Filamentous Algae from the 2300 m.y. old Transvaal Dolomite, Nature, 247:538-540.

MCCARTHY T and RUBIDGE B (2005) The Story of Earth and Life – A Southern African Perspective on a 4.6 Billion Year Journey, Struik Publishers, Cape Town, South Africa.

TRUSWELL JF (1970) An Introduction to the Historical Geology of South Africa, Purnell and Sons (SA) Pty. Ltd, Cape Town, South Africa.

WATSON J, HAMILTON-SMITH E, GILLIESON D and KIERNAN K (1997) Guidelines for Cave and Karst Protection, WCPA Working Group on Cave and Karst Protection, IUCN (World Conservation Union).

WHITTEN DGA and BROOKS JRV (1974) A Dictionary of Geology, Penguin Books, Middlesex, England.

ISSUE PAPER 2 THE SOCIAL, ENVIRONMENTAL AND FINANCIAL SIGNIFICANCE OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

C. Bradley and J. Tholin

ABSTRACT

The Cradle of Humankind was declared as a World Heritage Site for the conservation of the unique fossil and archaeological heritage of this region. The social, environmental and financial reasons for the need for the declaration of this area are discussed. The present and future impacts of the declaration of the COH WHS are described. Key threats to the conservation of this area are identified.

2.1 Introduction

In 1998, a year after signing the World Heritage Convention, the Government of the Republic of South Africa submitted three sites to the UNESCO World Heritage Committee as potential World Heritage Sites. These three sites consisted of Robben Island near Cape Town, Isimangaliso (formerly known as St. Lucia) in KwaZulu-Natal and the Fossil Hominid sites of Sterkfontein, Swartkrans, Kromdraai and the surrounding area, which is now known as the Cradle of Humankind (Interpretation Network Master Plan, 2001). Covering 47 000 hectares, the Cradle of Humankind encompasses a multitude of caves which are home to one of the largest collections of hominid fossils ever to be excavated. The discoveries made at the Cradle of Humankind have shed light on our human origins, as well as the daily lives of our ancestors from millions of years ago. The unique cultural value of the area was acknowledged when the site was declared a World Heritage Site in December of 1999. Since its inception as a World Heritage Site, the Cradle of Humankind has become a premier destination for people visiting South Africa and currently receives 40 000 visitors a year (Alexander, 2006).

This paper intends to summarise the social, environmental and financial significance of the Cradle of Humankind World Heritage Site (COH WHS). As a component of a larger synthesis paper dealing with the management of the karst and cave environment in the COH WHS, this paper outlines the various motivations for creating an effective management plan. Threatened by a variety of factors, which are described in further detail in subsequent papers, the COH WHS and its corresponding karst and cave system are crucial to the regional environment, as well as the health and economic stability of many of its inhabitants.

The protection and preservation of the karst and cave system within the COH WHS provides a vast range of benefits. The social motivations include respecting a designated World Heritage Site, which encompasses the safeguarding of one of the best-preserved fossil records of our human heritage. Also, the protection of the natural resources of the COH WHS, allows them to be utilised and enjoyed by both present and future generations. Environmentally, a karst system is extremely beneficial, as it provides a clean water supply for the region, as well as providing habitats for a multitude of species, and maintaining the karst cave structure. Karst formations have also been viewed as valuable sources of carbon sequestration, which if preserved, can lessen the global impact of global warming. Karst and cave systems also comprise of a wealth of information for scientists such as geologists, biologists and educators.

Finally, there are many financial incentives to work towards the preservation of the COH WHS and the surrounding karst and cave system. The COH WHS and adjacent areas are an important source of tourism-generated revenue for the region and the South African economy as a whole. Furthermore, a healthy and uncontaminated karst system is beneficial for local agriculture and potential future urbanisation through the provision of a clean source of water. It must also be mentioned that it is economically prudent to prevent further degradation of the karst system, as the potential clean up of major contamination of the groundwater may be extremely expensive.

2.2 Social Motivations for Preserving the COH WHS

The social and cultural significance of the COH WHS cannot be emphasised enough. Many of the caves in the region have exceptional universal value because they hold a record for the faunal population in the area as well as hominid fossils ranging as far back as 3.5 million years (Davie, 2004). Although many other caves in southern and eastern Africa have yielded hominid fossils, the COH WHS is unusual in that it has yielded over 500 hominid fossils, 9000 stone tools, and thousands of fossilised animals and pieces of fossilised wood (Davie, 2004). Since 1947, fossils have been excavated from the various caves, including the famous 2.6 million year old Mrs. Ples and the 3.3 million year old “Little Foot” (Davie, 2004). The Sterkfontein Cave is the world’s richest region in terms of Australopithecus fossils, and is to date, the longest sustained excavation carried out at an ancient hominid site anywhere in the world. It is expected that excavation projects in the area will continue for at least another 100 years, allowing for the potential for more important discoveries (Davie, 2005). Upon granting the site World Heritage status, the World Heritage Committee stated that the fossil sites at the COH WHS, "throw light on the earliest ancestors of humankind,” and that, “they constitute a vast reserve of scientific information, the potential of which is enormous" (Alexander, 2006). By not properly protecting the environment at the COH WHS, the wealth of scientific and educational information found there may be lost forever, which would be a great loss to humanity worldwide. Also, by signing and ratifying the World Heritage Convention, and then designating the Cradle of Humankind as a World Heritage Site, the South African government has essentially made a declaration and promise to the people of the world that it will enable the protection and preservation of this site and the surrounding environment. There is therefore a degree of social responsibility that South Africa holds to the rest of humanity to protect and preserve places such as the COH WHS for present and future generations.

2.3 Environmental Motivations for Preserving the COH WHS

Throughout the world, karst and cave environments are important to the surrounding ecosystem, and those that lie under the COH WHS are no exception. The karst and cave systems of the COH WHS are home to a multitude of species, which depend on the specialised environment to survive. Among these species are cave-dwelling bats such as *Nycteris thebaica, Myotis tricolor, Miniopterus schreibersii natalensis, Rhinolophus blasii, Rhinolophus simulator* and *Rhinolophus clivosus (*Durand, 2007). These are bat species that are indigenous to the region and depend on the caves for shelter. The specialised environments of the caves also provide home to other animals and plants, which can only survive under certain conditions, such as humidity, CO_2, and light levels that exist in the caves. The COH WHS is also home at certain times of the year to a bat, once listed as a Red Data species, *Miniopterus schreibersii natalensis,* also known as the Natal clinging bat, making the area of great importance in the preservation of this species (Durand, 2007). Within the COH WHS, there are certain factors present which, according to IUCN, may contribute to the extinction of certain bat species (IUCN, 1994). These include recorded or predicted population decline, small populations and restricted distribution. By housing scarce species, as well as containing many depending on its unique ecosystem, the COH WHS has strong environmental significance to the region and to the world.

The protection of the karst and cave system in the COH WHS is also important because they have developed slowly over thousands of years, and in many of the caves, even a slight alteration of the environment could have drastic consequences to the flora and fauna which depend on the cave environment for survival. Many of the caves have almost no interaction with the outside environment and an event changing the conditions inside may be as simple as a single drop of water. Due to the low energy content in certain caves, an alteration to the environment may take hundreds of years to repair. These unique ecosystems are extremely delicate and fragile, and this needs to be taken into account when considering how to best manage them. There is a need for respect for this unique environment and a realisation that poor management of this resource may result in irreparable alterations to the environment for years to come (Durand, 2007).

The karst and cave system underlying the COH WHS is also a valuable aquifer for the region and if not managed properly, could result in the contamination of groundwater and the destruction of the karst and cave system itself. For example, water which has been contaminated through mining activities may enter the system. This contaminated water may be toxic to humans, animals and plants living in the area, especially if they depend on the aquifer as their main source of water. Furthermore, acid mine drainage (AMD) may occur when water fills the region's abandoned shafts and is thereby exposed to the various metals and acids that were left behind when mining activities were terminated. This contaminated water may be highly acidic and therefore have the ability to dissolve the dolomite, creating sinkholes and destroying the karst formations (Durand, 2007).

Contamination of the water can also create problems for those who depend on the karst aquifer as their main water resource. According to The Nature Conservancy (2006), worldwide karst systems provide a perfect conduit for freshwater and it is estimated that over one quarter of the world's population receives their water supply from karst systems. This region is no different, and it is estimated that the water held within the karst system is more than the total of available surface and dam water in the Gauteng, Northwest and Limpopo Provinces (Durand, 2007).

According to a study commissioned by the Gauteng Provincial Government regarding the socio-economic conditions of the COH WHS, an estimated 14 600 people live in the COH WHS, with roughly an equivalent number of people in the environs, totaling approximately 30 000 people who depend on this karst system for their daily water supply. The environmental significance of the karst and the preservation of this environment are therefore extremely crucial to the region in and around the COH WHS. The preservation of the COH WHS, as well as the conservation of its natural resources, is also of social importance especially in the light of issues relating to environmental justice. Section 24 of the Bill of Rights states that everyone has a right "to an environment that is not harmful to their health or well-being" and "to have the environment protected, for the benefit of present and future generations" (Cross, 2006). With thousands of people depending on the groundwater found in the karst and caves under the COH WHS as their principal water source, contaminating the aquifer may compromise these aspects of the Bill of Rights.

Finally, it is important to note that karst systems make a valuable contribution towards carbon sequestration, which aids in the reduction of greenhouse gases affecting the climate of the earth. In the event that the karst is destroyed, the carbon dioxide will be released into the atmosphere and further add to the effects of global warming (Daoxian, 2006).

2.4 Financial Motivations for Preserving the COH WHS

One of the most significant financial benefits that can be derived from the COH WHS is the revenue created by tourism to the site. Tourism in general is extremely important to the South African economy and the industry has grown rapidly, increasing from 1 million foreign visitors in 1990 to 7 million foreign visitors in 2005 (Rivett-Carnac, 2006). Tourism currently contributes about 7.4 percent of GDP to the South African economy, and it is estimated that by 2010, it will provide, directly and indirectly, over 1.2 million jobs within the country (Rivett-Carnac, 2006). At present, tourism surpasses gold as the leading foreign exchange earner, with a value of almost 5.3 billion Rand (Rivett-Carnac, 2006). It is also important to note that ecological tourism, such as caving, comprises the largest segment of the growing South African tourism industry. The COH WHS itself is a significant tourist destination within the country, and with the recent opening of the 163 million Rand Interpretation Center Complex at the Sterkfontein Cave in December 2005, it is estimated that over 65 million Rand in revenue will be generated by the Interpretation Center site alone during its first year in operation (Masha, 2004). These changes will make the COH WHS a more desirable tourist destination, and it is also expected that the annual visitation to the COH WHS will soon exceed 50 000 visitors per year (Masha, 2004). It is important to note that according to a study prepared by the Gauteng Provincial Government, most households in the area and surrounding the COH WHS have an income of around R1000-2000 per month. Thus the financial significance of the COH WHS to this region is extremely important, as it provides a source of outside revenue into the area.

The commercial and adventure caving businesses within the COH WHS are also a source of income for many living in the region. Although there are potential problems that can be brought about by this industry if it is not managed properly, it has the potential to bring in much needed revenue to the residents of the COH WHS. The potential threats that these industries pose to the COH WHS are further outlined in *Legal Aspects of Karst and Cave Use in the Cradle of Humankind World Heritage Site* and *The Use of Caves and Karst in the Cradle of Humankind World Heritage Site* (both in this publication).

In addition to being a major tourist destination and a large source of tourism revenue, the COH WHS lies on top of vast systems of karst and caves, which house a large supply of the region's freshwater. As mentioned in the previous section, the preservation of this water resource is crucial not only to the existence of the karst and cave structures, but also as source of freshwater for the people living in the region. The financial implications of maintaining the area's environment and in turn preserving the water supply to the region cannot be emphasised enough. If not protected properly, the freshwater resources of the region could become contaminated, and the financial implications of either cleaning the water supply, or finding a freshwater source outside of the region, are immense. It is also important to keep in mind that the future expansion and urbanisation of the region depend on this abundant supply of freshwater. The potential impacts on these water resources are further elaborated in the papers on *Hydrology of the Cradle of Humankind World Heritage Site*, *The Impact of Urban Development on the Water Resources and Water-based Ecosystems of the Cradle of Humankind*, and *The Impact of Mining on the Water Resources and Water-based Ecosystems of the Cradle of Humankind World Heritage Site.*

2.5 Conclusion

South Africa is fortunate to reap the benefits of the COH WHS which lies within the country's borders. The country has been honoured to house the fossils and remains of some of the region's oldest ancestors, and there are still extensive excavation projects underway, which may shed even more light on these people's primitive roots. Not only is the COH WHS a lucrative tourist destination with vast potential for expansion, but it is also a distinct ecosystem, which houses a unique flora and fauna. The underlying karst and caves provide an abundant supply of freshwater, which may allow for the urbanisation and expansion of the region. Despite the site's importance, there are many factors which threaten to contaminate or destroy the COH WHS and the underlying karst and cave system. The following papers in this synthesis paper outline these threats in more detail, as well as offering constructive recommendations and solution on how to reduce or halt these negative impacts.

REFERENCES

ALEXANDER M (2006) World Heritage in South Africa. International Marketing Council of South Africa. http://www.southafrica.info/ess_info/sa_glance/history/worldheritagesites.htm#cra

CROSS J (this report) Policy and legislative overview: Management of karst and caves in the Cradle of Humankind World Heritage Site, In: The Karst System of the Cradle of Humankind World Heritage Site, Issue Paper 3, WRC Consultancy Project No. K8/624, pp. 20-75.

DAOXIAN Y (2006) The Carbon Cycle in Karst, Ministry of Land Resource Karst Dynamics Laboratory. http://www.karst.edu.cn

DAVIE L (2005) Showcasing Humankind's Cradle. The International Marketing Council of South Africa. http://www.southafrica.info/plan_trip/holiday/culture_heritage/cradle-centre.htm

DURAND JF (this report) Threats to karst ecology of the Cradle of Humankind World Heritage Site, In: The Karst System of the Cradle of Humankind World Heritage Site, Issue Paper 5, WRC Consultancy Project No. K8/624, pp. 90-112.

ELLIS R and GROVE A (this report) Legal aspects of karst and cave use in the Cradle of Humankind World Heritage Site In: The Karst System of the Cradle of Humankind World Heritage Site, Issue Paper 12, WRC Consultancy Project No. K8/624, pp. 258 -229.

GROENEWALD J (this report) The impacts of agriculture on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site, In: The Karst System of the Cradle of Humankind World Heritage Site, Issue Paper 11, WRC Consultancy Project No. K8/624, pp. 217-257.

HOLLAND M, WITTHÜSER KT and JAMISON AA (this report) Hydrology of the Cradle of Humankind World Heritage Site: Geology, surface- and groundwater, In: The Karst System of the Cradle of Humankind World Heritage Site, Issue Paper 5, WRC Consultancy Project No. K8/624, pp. 113-127.

THE HERITAGE AGENCY (2001) Interpretation Network Master Plan.

IUCN (1994) IUCN Red List Categories, IUCN Species Survival Commission, IUCN, Gland, Switzerland, pp. 21.

MASHA L (2004) Cradle means birth of "hundreds of jobs", Mogale City News. http://www.mogalecity.gov.za/news2004/july/jul2_cradle_jobs.stm

RIVETT-CARNAC K (2006) Tourism investment opportunities: South Africa, Presented to the Department of Tourism and Industry, Lugano, Switzerland.

SIAPAC (no date) Specialist Study on the Socio-Economic Context of the COH WHS, Black and Veatch Africa.

THE NATURE CONSERVANCY (2006) Subterranean Conservation, The Nature Conservancy. http://www.nature.org/initiatives/programs/caves/

ISSUE PAPER 3

POLICY AND LEGISLATIVE OVERVIEW: MANAGEMENT OF KARST AND CAVE IN THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

J. Cross

ABSTRACT

Cameron Cross Incorporated was requested by the IUCN, South Africa Office, to undertake a policy and legislative review in order to identify applicable law and relevant legal instruments dealing with the management and protection of karst and cave in the Cradle of Humankind World Heritage Site (COH WHS).

In accordance with the terms of reference, this paper refers to the relevant applicable international conventions, as well as national, provincial and local laws which are relevant to the protection and management of karst and caves within the COH WHS. The paper identifies the environmental legal framework applicable to karst and cave within the COH WHS.

This paper follows on various other papers produced by the Karst Working Group (KWG) in relation to karst and cave within the COH WHS. Details of the findings of these papers are not repeated in this paper but brief reference to the main issues affecting karst and cave are referred to as these issues serve to inform the environmental legal framework more fully described in the legal paper. The main issues recorded in the various papers produced by the KWG generally concern negative impacts and risks to the surface and subsurface of karst and caves as a result of various activities or practices including urbanisation, mining, agriculture, commercialisation of caves, collection of stones and tourism.

A review of international agreements/conventions indicates that the World Heritage Convention and the Biodiversity Convention are prominent international mechanisms by which impacts to the environment, heritage resources, biodiversity and ecosystems associated with karst and cave in particular, could be managed and protected. The definitions of cultural and natural heritage in the World Heritage Convention bears direct relevance to karst and cave. The legal standing of these conventions in South African domestic law has been reinforced by the promulgation of national legislation giving effect thereto.

Review of national legislation concerned with environmental management legislation, biodiversity legislation, protected areas legislation, water legislation, air quality legislation, land use legislation, heritage resources legislation, mining legislation, agricultural legislation and genetically modified organisms legislation indicates that all the statutes considered bears relevance to the management and protection of aspects to karst and

cave. There is no national statute that regulates use and protection of karst and cave in particular. However, various statutory mechanisms could be identified in these statutes that could assist in the management and protection of karst and caves.

In this regard the mechanism of permitting, licensing and other authorisations were identified to undertake certain listed activities, water uses, activities impacting on air quality, mining activities, activities in threatened ecosystems, activities with regard to alien and invader species, bio-prospecting, genetic modification of organisms, activities in relation to national heritage resources and the like as an important measure to protect specific impacts to karst and cave. The issuing of government directives to seize activities having impacts on the environment or to undertake activities to remediate environmental impacts were also identified as a mechanism whereby specific impacts to karst and cave could be managed. From a constitutional and common law perspective the mechanism of instituting legal action based on damages or an interdict as a measure that could be utilised to protect karst and cave, were identified. In addition, criminal prosecution as well as the institution of civil-type damage claims in accordance with the relevant provisions in the National Environmental Management Act can also be identified as legal mechanisms available to the State to ensure that statutory regulations and duties which affect karst and cave are complied with.

Provincial legislation was reviewed and it was concluded that there are no environmental statutes on a provincial level which directly concern the protection of karst and cave. The conservation legislation applicable in the Gauteng Province contains certain provisions on the management and protection of caves. However, these provisions, as well as the criminal sanctions imposed for non-compliance are generally inadequate and ineffective in deterring persons from acting in contravention to the statutory requirements. No similar provisions could be found in relation to karst specifically. Reference is briefly made to the legislation in the Limpopo Province which regulates use of caves more comprehensively and imposes significant fines for non-compliance with the statutory provisions concerning the protection of caves.

No by-laws were found which are directly concerned with the management and protection of karst and caves. The Mogale City Local Municipality by-laws provide limited assistance with only the City of Tshwane Metropolitan Municipality Public Amenities by-laws providing for the protection of caves.

The review of guideline documents, white papers and other departmental documentation confirmed the findings of other authors of the KWG who concluded that whereas certain guidelines apply specifically to karst (referred to as dolomite) there are no guidelines specifically concerned with caves.

The literature and legislative review undertaken indicates that certain difficulties may be identified with regard to the current legal state pertaining to the management and protection of karst and caves. These are:

- There is no single dedicated body of legislation concerned with the management and protection of karst and cave in a holistic and integrated manner. There are various international, national and provincial legislative provisions which cumulatively comprise the legal framework for the protection of karst and cave referred to in this legal paper. Of the legislative provisions reviewed, very few directly concern management and protection of karst and cave. In addition, most of these provisions concern caves in particular and are to be found in the provincial and local legislation. There are also no international conventions, national statutes or regulations dedicated exclusively to the management and protection of karst and cave.
- The legal provisions reviewed are derived from statutes concerned with various aspects of environmental regulation and protection, land use regulation and protection, agricultural management and protection and heritage resource management and protection. The diversity of legislation by necessary implication results in fragmentation and a proliferation of management structures and management tools, such as management plans and frameworks required in terms of the suite of environmental management statutes being developed in accordance with the National Environmental Management Act. There appears to be an emphasis on integration but a general lack of coordination of these various statutory planning mechanisms. As such, there appears to be a need for a coordinated approach to the planning of management measures and protection in respect of karst and cave within the COH WHS.
- The broad ambit of certain bodies of legislation, notably the National Environmental Management: Biodiversity Act, as well as the National Environmental Management: Protected Areas Act and in particular the regulations promulgated in terms thereof, has resulted in significant overlap of measures to manage biodiversity vis-à-vis protected areas. Furthermore, the extent of regulations promulgated in terms of the Protected Areas Act, insofar as they relate to the management of world heritage sites in particular, appear to have overtaken those management mechanisms that are available in the World Heritage Convention Act as far as the COH WHS is concerned.
- Notwithstanding the fact that various statutory provisions concern, albeit in an indirect fashion, the management and protection of karst and caves, the enforcement of the various provisions under discussion poses a significant problem. It is trite that state departments and various statutory bodies concerned with the management and protection of the environment, land use, planning and heritage resource protection are experiencing difficulties with the capacity to enforce legislation. It is also significant to note that in those instances where statutory provisions directly concern management and

protection of caves, these provisions are to be enforced at provincial and local government levels where the greatest capacity problems are experienced.

- There are no guidelines which are specifically concerned with the management and protection of karst and cave. The development of these guidelines are essential to facilitate decision making with regard to the management and protection of karst and cave as well as enforcement for non-compliance with operational rules, regulations and other statutory provisions.

Having regard to the problem statement referred to above, it is recommended that the following response actions be considered:

- Firstly, by way of a regulatory response, it is initially concluded and recommended that action should be taken to formalise Blue IQ Projects appointment as the Authority in terms of the World Heritage Convention Act in respect of the COH WHS. It appears that such appointment/declaration has been formalised by a notice published in the Government Gazette.
- It was furthermore concluded that in the author's opinion, legal certainty would be derived from gazetting the designation as required in terms of the World Heritage Convention Act.
- However, notwithstanding the above, it appears from the notice published in the Government Gazette that the wording of the notice does not clearly identify which provincial MEC has been declared as the Authority, although it is assumed that based on previous notices published in the Government Gazette the reference to a MEC refers to the MEC of Agriculture, Conservation and Environment.
- It should also be noted that although the declaration of the Authority has now been formalised, the powers and duties of the Authority have been limited to the duties referred to in Section 13(2). The Act clearly states that Section 13(1) concerns the powers of an Authority whilst Section 13(2) concerns the duties. The notice curiously refers to both the powers and duties in Section 13(2). Unfortunately, by limiting the powers and duties to Section 13(2) it appears that none of the powers in Section 13(1) have been given to the Authority. This is unfortunate as it strictly fails to provide the Authority with the powers in Section 13(1) to perform the duties in Section 13(2) and does not contribute to legal certainty. Furthermore, important powers referred to in Section 13(1) (m) such as inter alia the powers to initiate, assist, comment on or facilitate any application under the Development Facilitation Act, 1995, or other applicable development, planning or management law relating to or affecting a World Heritage Site, which constitutes an important management mechanism, appears to have been lost to the Authority together with other important management powers in Section 13(1).
- In addition, the formal establishment of an Authority for the COH WHS in terms of the World Heritage Convention Act will ensure that the Authority draws upon the extensive management powers provided for in the regulations to the National Environmental Management: Protected Areas Act. These regulations

are to be implemented by a management authority, legally defined as the organ of state or other institution or person in which the authority to manage the protected area is vested.

- Secondly, the Authority should commence with the coordination of all the management measures undertaken by Blue IQ Projects and SAHRA and the various planning authorities and incorporate it into the integrated management plans to be developed in terms of the World Heritage Convention Act.
- Thirdly, the Authority should assess its role within the context of the environmental legal framework referred to in this legal paper. The Authority should play a coordinating and facilitating role in order to ensure that the legislation mandated to other government departments, provincial departments, local government departments or statutory bodies is effectively enforced within the COH WHS to ensure the management and protection of karst and cave.
- The statutory mandate to undertake such a coordinating and facilitating role is founded in the powers and duties referred to in the World Heritage Convention Act and in particular those sections which require inputs from the Authority into various Development Facilitation Act procedures, as well as other planning measures within national, provincial and local government spheres. However, as more fully discussed in this legal paper, it appears from the relevant Government Notice that these powers may not have been given to the designated Authority. In addition, the regulations promulgated in terms of the National Environmental Management: Protected Areas Act state in regulation 19(2) that no commercial activity or activity contemplated in Section 50 of the Act, which requires an environmental impact assessment to be undertaken in terms of the Act or any other law may be implemented before a management authority has approved, with or without conditions, the environmental impact assessment before it is submitted to the relevant authority for approval. An Authority could therefore manage impacts to karst and cave associated with mining, undertaking of all the listed activities referred to in this legal paper, heritage impact assessments, impacts required in terms of biodiversity management and protection as well as genetic modification.
- Fourthly, it is recommend that the Authority, proceed to establish a monitoring system to identify applications for all types of authorisations requiring an environmental assessment before a decision is taken, within the COH WHS. As such, other state departments or statutory bodies must inform the Authority of applications submitted for development, water use licensing, prospecting and mining operations, atmospheric emission licences, undertaking of listed activities and change in land use within the COH WHS. A Memorandum of Understanding (MoU) could serve as legal vehicle whereby inter-governmental duties to communicate regarding applications for authorisation within the COH WHS could be formalised. In addition, communication by land owners or communities within the COH WHS to the Authority, of the undertaking of activities should be promoted.

- In the fifth instance, an Authority should proceed to implement the regulations in terms of the National Environmental Management: Protected Areas Act. The relevant Authority must ensure that authorised officials (legally defined to mean an employee of a management authority, or any other person, acting as such on the written authorisation of a management authority and includes an environmental management inspector appointed in terms of Section 31B of NEMA), operating within the COH WHS, receive training to apply the regulations with regard to the protection of karst and cave in particular.
- In the sixth instance, once the regulatory systems of indirect intervention and direct management and enforcement are established, consideration could be given to undertaking of a feasibility study to determine whether the development of dedicated sub-ordinate legislation (i.e. regulations) are required in order to manage and protect karst and cave.
- Furthermore, by way of a management response, it is recommended that the KWG produce, as soon as possible, a Guideline Document in respect of the management and protection of karst and cave in order to inform the Integrated Management Plan to be developed by the Authority. The Guideline Document can also serve as a useful guide to develop operational rules in terms of the World Heritage Site Administration Regulations promulgated in terms of the National Environmental Management: Protected Areas Act.
- Finally, this legal paper serves as a legal baseline from where further action should be identified and recommended. It is recommended that further detailed legal assessment (research) be undertaken with regard to the development of an Integrated Environmental Management Plan in order to ensure coordination with the legislation referred to in this paper, specialist legal advice on the Authority's power of enforcement and legal training of authorised officials (being Authority employees) as well as environmental management inspectors appointed in terms of the National Environmental Management Act. Training should in particular refer to the environmental legal framework for the management and protection of karst and cave referred to in this paper.

Having regard to the legal framework identified in this legal paper as well as the abovementioned problem statements and response/actions required for the management and protection of karst and cave in the COH WHS, the following conclusions are made:

- The legislation referred to in this paper is primarily concerned with the regulation of aspects having an indirect bearing on the management and protection of karst. There is no legislation directly concerned with the management of karst although reference is made to aspects associated with karst in the World Heritage Convention, the World Heritage Convention Act, National Heritage Resources Act and other legislation concerned with the protection of environmental media such as water, air and soils. Therefore, karst situated within the COH WHS, presently derives indirect benefit by virtue of the status of the area as a world heritage site, national heritage site or protected area. It was therefore concluded that there is no immediate need for additional statutory measures dedicated to the management and protection of karst within the COH WHS in view of the fact that existing available statutory management measures appear to be adequate.

- With regard to caves situated in the COH WHS, existing statutory management and protection measures appear to be adequate. It is also noted that whereas limited direct references in legislation were identified with regard to karst, direct references to caves are to be found in national, provincial and local legislation. Unfortunately, with regard to provincial legislation applicable to the COH WHS it was concluded that such legislation is out of date and ineffective. The statutory provisions in the Limpopo Province legislation were found to be progressive especially as far as the criminal sanctions are concerned. With regard to by-laws, those relevant to the COH WHS in particular are disappointing insofar as management and protection of caves are concerned. Notwithstanding the aforementioned, it was concluded therefore that there is no immediate need for additional statutory measures dedicated to the management and protection of caves within the COH WHS in view of the fact that existing available statutory management measures appear to be adequate.
- Having regard to the conclusions on karst and cave referred to above, it is recommended that resources be allocated to focus on the development of guidelines on karst and caves to be incorporated into planning (i.e. Integrated Management Plans), operational rules (i.e. applicable within the COH WHS in terms of the Administration Regulations under the NEMPAA), statutory enforcement mechanisms and resources (i.e. Authority Officials and Environmental Management Inspectors) and training (i.e. community, property owners, economic sectors and enforcement), before specific legislation is developed to manage karst and caves in the COH WHS.
- Based on the recommendations above, the justification for the development of dedicated legislation becomes more compelling in respect of karst and caves that may not be situated within the confines of world heritage sites, natural heritage sites, provincial heritage sites or other protected areas in general. However, under these circumstances, it is recommended that the feasibility be assessed of developing additional legislation or to utilise the existing mechanisms identified in the national legislation referred to in this paper, to manage and protect such karst and cave.
- In addition to the conclusions reached on the statutory mechanisms whereby karst and cave may be managed and protected, it is also concluded and recommended that guidelines for the management of karst and cave should be developed as the first point of departure. As previously stated, the guidelines will serve to assist decision making, empowerment (education) and enforcement of measures to protect karst and cave in the COH WHS. Once developed for the COH WHS, these guidelines may serve as the basis for the development of national guidelines to be followed by legislative development. The KWG has a leading role to play in the development of such guidelines.

- It is also recommended that legal training of authorised officials employed by a management authority as well as environmental management inspectors be provided with technical and legal training regarding the legal framework for the management and protection of karst and cave. Emphasis should be placed on rights and obligations associated with the various statutory mechanisms and remedies in the event of non-compliance.

3.1 Introduction and Purpose

Cameron Cross Incorporated (CCI) was requested by the IUCN (World Conservation Union) South Africa Office to undertake a policy and legislative review in order to identify applicable law and relevant legal instruments dealing with the management and protection of karst and cave in the Cradle of Humankind World Heritage Site (COH WHS). This legal paper records the findings, conclusions and recommendations with regard to the current environmental legal framework by which karst and cave could be managed and protected within the COH WHS.

This paper follows on various other papers produced by the Karst Working Group (KWG) in relation to karst and cave within the COH WHS. These papers consider issues relating to:

- Legal aspects of karst and cave use in the COH WHS[1];
- Use of caves and karst in the COH WHS[2];
- The state of karst ecology research in the COH WHS[3];
- The impact of mining on the water resources and water-based ecosystems of the COH WHS[4];
- The impact of urban development on the water resources and water-based ecosystems of the COH WHS[5];
- Hydrology of the COH WHS[6];
- Threats to the karst ecology of the COH WHS[7].

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1 Ellis, R and Grove (2007), A: Legal aspects of karst and cave use in the Cradle of Humankind World Heritage Site, (Issue Paper 12, this publication).

2 Kenyon, P and Ellis, R: (2007) The Use of Caves and Karst in the Cradle of Humankind World Heritage Site, (Issue Paper 7, this publication).

3 Durand, JF and Peinke, D: (2007) The State of karst ecology research in the Cradle of Humankind World Heritage Site (Issue Paper 4, this publication)

4 Krige, G and van Biljon, M: (2007) The impact of mining on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site, (Issue Paper 9, this publication).

5 Krige, G: The Impact of Urban Development on the water resources and water-based ecosystems of the Cradle of Humankind, Synthesis Publications: Synthesis I – Water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site, Revision 2 dated 5 September 2005.

6 Holland, M, Witthüser, KT and Jamison, AA: (2007) Hydrology of the Cradle of Humankind World Heritage Site, Geology, surface- and groundwater (Issue Paper 6, this publication).

7 Durand, JF: (2007) Threats to the Karst Ecology of the Cradle of Humankind World Heritage Site (Issue Paper 5, this

Details of the findings of these papers are not repeated in this paper but brief reference is made to the main issues affecting karst and cave by way of introduction as these issues serve to inform the environmental legal framework more fully described in the paragraphs that follow herein below. The term "karst" is not legally defined and therefore, for purposes of this paper, karst means a type of landscape dominated by carbonate-rich rock, characterised by its relief caused by the dissolution of the underlying rock by the flow of groundwater. Caves, sinkholes, aquifers, disappearing rivers and springs are all typical features of a karst landscape[8]. Caves are legally defined in South African legislation and for purposes of this legal paper caves mean a natural geologically formed void or cavity beneath the surface of the earth[9].

The main issues recorded in the various papers produced by the KWG generally concern negative impacts to the surface and subsurface of karst and caves as a result of various activities or practices presently being undertaken in the COH WHS. These are:

- Quarrying and mining activities which include limestone, dolomite mining, and gold mining, as well as the impacts associated with such activities being, acid mine drainage as well as associated toxic chemicals and heavy metals;
- Farming practices, including traditional livestock and agricultural farming, trout farming, horse breeding, irrigation of land, pesticides and use of fertilisers;
- The process of urbanisation and establishment of informal settlements resulting in habitat loss, introduction of alien species and the creation of habitat for competitive species. Urbanisation also results in the proliferation of associated infrastructure such as gravel and tar roads, commercial and industrial ventures and ventures for relaxation such as hiking trails, nature reserves, commercial caving, etc. In addition, urbanisation subjects the land to subdivision into smaller, more dense units which in turn increases risks of environmental pollution and waste generation associated with urbanisation;
- Polluted water entering the karst and cave system influencing karst and cave ecology;
- Commercial caving, tourism and palaeontological excavations;
- Use of caves as dump sites;
- Harvesting of "Pelindaba Rock"[10].

The intention of this paper is therefore to, in accordance with the terms of reference, refer to the relevant applicable international agreements or

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publication).

8 Durand, JF and Peinke, D: (2007) The state of karst ecology research in the Cradle of Humankind World Heritage Site – (See Issue Paper 4 and Glossary of this publication.

9 Nature Conservation Ordinance 12 of 1983 (Gauteng), Section 1, see definition of caves.

10 Ellis, R and Grove, A: (2007) Legal aspects of karst and cave use in the Cradle of Humankind World Heritage Site, (Issue Paper 12, this publication). The list of issues were summarised and taken from this chapter.

Conventions as well as national, provincial and local law which may be relevant to the protection and management of karst and cave within the COH WHS. The paper also identifies the environmental legal framework applicable to karst and cave within the COH WHS.

It should be emphasised that whereas certain statutory provisions in the legislation under review specifically deal with the management and protection of caves and cave formations, no similar provisions were identified in relation to karst. However, various statutory provisions in the legislation under review concern environmental as well as heritage resource management and protection and all these provisions find application to the management and protection of karst as well as cave. Furthermore, it should be noted that the karst and caves under discussion is situated within the COH WHS, which, by necessary implication, result in world heritage legislation being relevant. Although several of these statutory provisions concern general rules for the management of world heritage sites, several of these management rules indirectly result in the protection of karst and cave. The paper however does not refer to all these management provisions and the reader is referred to the relevant legislation in this regard.

Following the review of legislation, common law mechanisms are briefly considered in order to protect karst and cave. This is followed by a "policy" review in accordance with the terms of reference. A problem statement is formulated, responses or actions required identified and conclusions and recommendations made.

3.2 Literature Review – Environmental Legal Framework for Karst and Cave

3.2.1 International Perspective

3.2.1.1 STATUS OF INTERNATIONAL LAW IN SOUTH AFRICAN LAW[11]

The application and status of international law has been formalised in South African law by Chapter 14 of the Constitution, and in particular Sections 231, 232 and 233. These sections in the Constitution confirm the common law position that customary international law is recognised as law in the Republic unless it is inconsistent with the Constitution or an Act of Parliament. It also confirms that all international agreements that were binding on the Republic prior to the enactment of the Constitution continue to be in force.

Flowing from the relevant sections in the Constitution, Chapter 6 of the National Environmental Management Act 107 of 1998 provides for International Obligations and Agreements. Chapter 6 refers to "*…international environmental instruments* …" which are defined in Section 1(1) (xviii) as "*…any international agreement, declaration, resolution, convention, or protocol which relates to the management of the environment*".

11 Dugard, J: International Law (Second Edition), 2000 Cape Town, Juta and Company Ltd.

Chapter 6 differentiates between international environmental instruments to which South Africa is not bound and those to which it is bound. Within this context, Section 25(3) of the NEMA empowers the Minister of Environmental Affairs and Tourism, to pass domestic legislation or regulations to give effect to any international instrument to which South Africa is a party. In addition, the importance of international legal obligations in the protection of the environment and by implication karst and cave is recognised as an environmental management principle in Section 2 of the NEMA. Section 2(4) (n) states that: "*global and international responsibilities relating to the environment must be discharged in the national interest*." The national environmental management principles in the NEMA, as well as their importance and relevance to the protection and management of karst and cave within the COH WHS are more fully discussed hereunder.

For purposes of this legal paper, only international environmental conventions are considered to which South Africa is a party and which bears relevance to the protection and management of karst and cave within the COH WHS.

3.2.1.2 INTERNATIONAL ENVIRONMENTAL CONVENTIONS

South Africa is party to over 50 international conventions which are directly or indirectly relevant to the environment[12]. Signature, ratification and accession of conventions by the government of the Republic of South Africa are significant events in relation to the coming into being and the coming into force of an international convention. Although signature of a convention does not in itself impose a legal obligation in terms of such convention, legal obligations may arise after ratification or accession of an agreement[13].

Two conventions which are of particular importance to the management and protection of karst and cave which South Africa either ratified or acceded to include the Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (World Heritage Convention) and the Convention on Biodiversity, 1992.

Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (World Heritage Convention)

The World Heritage Convention represents an international agreement which, on an international and national level, appears to have direct relevance to the management and protection of karst and cave within the COH WHS. Reference is made in the definitions to monuments which include cave dwellings and combinations of features. Furthermore, "sites" are defined as works of man or combined works of nature and man, in areas including archaeological sites[14]. South Africa acceded to the Convention during 1999 and enacted the World

12 Glazewski, J: Environmental law in South Africa (Second Edition), 2005, p. 39.

13 Ibid. p. 40.

14 World Heritage Convention, Article 1.

Heritage Convention Act 49 of 1999 as a national response to its international commitments.

The World Heritage Convention applies to "cultural heritage" and "natural heritage" which is of "outstanding universal value"[15]. Cultural heritage *inter alia* includes monuments (architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, art or science) and sites (works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view).

In terms of the Convention, natural heritage includes natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view. National heritage also includes geological and physiographical formations and precisely delineated areas, which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation.

Having regard to the definition of cultural heritage and natural heritage referred to in the Convention, it appears that both karst and cave within the COH WHS derives benefit from the management measures and protection afforded by this Convention. In terms of this Convention, each State Party recognises that the duty of ensuring the identification, protection, conservation, presentation and transmission to future generations of the cultural and natural heritage situated on its territory, belongs primarily to that State[16].

Each party must ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory by adopting and undertaking various measures and planning programmes. These measures include the adoption of a general policy, setting up of government services to protect and conserve the heritage, develop scientific and technical studies through research and to establish infrastructure for training. Parties to this Convention undertake not to damage the cultural and natural heritage situated in the territory of other states which are party to this Convention[17].

Convention on Biodiversity (1992)

The Convention came into force in 1993 and South Africa ratified it in November 1995. The overall objective of the Convention is the conservation of biological diversity, the sustainable use of its components and the fair and

15 Ibid., Articles 1 and 2.

16 World Heritage Convention, Article 4.

17 Ibid., Article 5.

equitable sharing of the benefits arising out of the utilisation of genetic resources[18].

Article 6 provides for general measures for conservation and sustainable use and requires contracting parties to develop national strategies, plans and programs for the conservation and sustainable use of biological diversity and to integrate these as far as possible into relevant sectoral programs. Secondly, specific articles provide for in-situ conservation and ex-situ conservation respectively[19]. Thirdly a series of articles sets out a regulatory regime ensuring access to genetic resources by importing countries while providing for various returns to exporting countries[20].

The Convention contains various provisions which are relevant to the protection and management of ecosystems and species which may be associated with karst and cave within the COH WHS. South Africa's involvement with the Convention has resulted in the South African government promulgating the National Environmental Management: Biodiversity Act 10 of 2004.

Other conventions concern the management and protection of specific environmental impacts which may be associated with karst and cave within the COH WHS. Based on the issues raised in the various Issue Papers of the KWG, these conventions are:

International Plant Protection Convention 1951 (IPPC) 21

This Convention aims to secure "common and effective action to prevent the introduction and spread of pests and diseases of plants and plant products and to promote measures for their control"[22]. As such, it appears that although South Africa signed the Convention in 1951 and ratified it in 1956, it is of indirect relevance to karst and cave.

Convention on International Trade in Endangered Species or Wild Fauna and Flora (CITES), 1973

Trade in wild animals and plants within the COH WHS have been raised as an ongoing issue in the papers prepared by the KWG. CITES' aim is to control trade in live animals and plants and wildlife products such as hides, fur skins, ivory, timber and other derivatives. Although not directly related to the protection and management of karst and cave, it may nevertheless find indirect application in that the ecology and biodiversity of karst and cave environs may be disturbed or permanently damaged by the removal of plant or animal species with a view to trade therein.

18 Convention on Biodiversity, Article 1.

19 Ibid., Articles 8 and 9.

20 Ibid., Articles 10 – 19.

21 International Plant Protection Convention, 1951 (Rome, 6 December 1951).

22 International Plant Protection Convention, Article 1.

South Africa ratified the Convention in July 1975 but has not enacted specific legislation to give effect to CITES, relying on enforcement through the respective provincial nature conservation ordinances and the National Environmental Management: Biodiversity Act 10 of 2004[23]. In view of the above, it must be said that its application as a tool to protect karst and cave per se is only relevant insofar as international trade may be undertaken in respect of endangered species of fauna and flora which may occur on karst landscapes or in caves.

International Undertaking on Plant Genetic Resources 1983 (FAO Undertaking) and Agreed Interpretation of the International Undertaking, 1989 (Agreed Interpretation)[24]

The FAO undertaking currently represents the central international agreement governing plant resources. This is a non-binding document with the objective of preserving plant genetic resources and to make them as widely available as possible for plant breeding. It is furthermore stated that it is premised on the "principle that Plant Genetic Resources are a heritage of mankind and consequently should be available without restriction", thus having interesting implications for the international law notion of sovereignty over natural resources. The undertaking is complemented by an institutional component namely the Commission on Plant Genetic Resources (CPGR).

Having regard to the above, the International Undertaking on Plant Genetic Resources as well as its Agreed Interpretation could render indirect assistance to the protection of plant resources situated on karst and within caves to be found within the COH WHS.

Convention on Persistent Organic Pollutants, 2001 (Stockholm)

Based on the concerns raised in the KWG papers on the release of chemicals associated with mining, industrial processes and mineral beneficiation, mine and industrial waste disposal practices and the use of pesticides within the COH WHS, the resultant contamination of the soil, surface water and groundwater and the effects on karst and cave, it should be noted that the Convention on Persistent Organic Pollutants has as its aim to counter toxic effects of certain hazardous chemicals known as Persistent Organic Pollutants (POPs). South Africa ratified the Convention in September 2002[25].

Although the value of the Convention may lie in its contribution to the control of the release of POPs by agricultural, mining or industrial concerns in and around the COH WHS, its application as a mechanism to manage and protect karst and cave per se is of lesser significance.

23 Glazewski, p. 50.

24 Glazewski., p. 52.

25 Ibid,, p. 46.

International Treaty on Plant Genetic Resources for Food and Agriculture, 2001

The Plant Genetic Resources Treaty was adopted in November 2001. The objectives of the Treaty are the conservation and sustainable use of Plant Genetic Resources for Food and Agriculture and the fair and equitable sharing of benefits derived from its use, in harmony with the Convention on Biological Diversity for Sustainable Agriculture and Food Security[26]. As such, its value to the protection of Plant Genetic Resources associated with karst and cave appears to be limited although it finds broader application within the context of agricultural practices undertaken within the confines of the COH WHS, as described in the papers presented by the KWG.

INTERNATIONAL ENVIRONMENTAL CONVENTIONS: PRELIMINARY CONCLUSIONS

Having regard to the international conventions referred to above, it is evident that the World Heritage Convention and the Convention on Biodiversity are prominent international mechanisms by which impacts to the environment, heritage resources, biodiversity and ecosystems associated with karst and cave in particular, could be managed and protected. The definitions of cultural and natural heritage in the World Heritage Convention bear direct relevance to karst and cave. The legal standing of these conventions in South African domestic law has been reinforced by the promulgation of national legislation giving effect thereto.

The rights and duties associated with these conventions should be considered in the compilation of management structures for karst and cave within the COH WHS.

3.2.2 National Perspective

3.2.2.1 CONSTITUTIONAL CONSIDERATIONS

Constitution Act 108 of 1996

Section 24 of the Bill of Rights states that everyone has the right to an environment that is not harmful to their health or wellbeing and to have the environment protected for the benefit of present and future generations through reasonable legislative and other measures. Government must ensure that reasonable legislative and other measures prevent pollution and ecological degradation, promote conservation and secure ecologically sustainable development and use of natural resources while promoting justifiable economic and social development.

The incorporation of environmental rights into the Bill of Rights elevates these rights to the level of fundamental rights, guaranteed and protected by the state. Although the term "environment" is not defined in Section 24 of the Constitution, it is to be expected that the wide ambit which the definition enjoys in

26 Ibid., p. 52.

national legislation[27] should also serve as an indication of the ambit of its application for purposes of Section 24 of the Constitution. This is furthermore substantiated by the reference in Section 24 to an environment that is not harmful to health and well being, both being terms of wide application. As such, it appears that Section 24 of the Bill of Rights in the Constitution is directly, albeit generally, applicable to the management and protection of karst and cave in the COH WHS.

Section 24 of the Bill of Rights should be read with Section 8 which states that the Bill of Rights applies to all law and binds the legislature, the executive, the judiciary and all other organs of state as well as a natural person or a juristic person. Section 8 also states that when applying a provision of the Bill of Rights to a natural or juristic person, a court, in order to give effect to a right in the Bill, must apply, or if necessary, develop the common law to the extent that legislation does not give effect to that right.

Section 36 is generally referred to as the limitation clause and provides that any of the rights mentioned in the Bill of Rights may be limited by law of general application only to the extent that the limitation is reasonable and justifiable in an open and democratic society based on human dignity, equality and freedom, taking into account all relevant factors including those specifically referred to in the Constitution. This provision is important from a public management perspective insofar as limitations may, for example, be placed on property ownership which is also a fundamental right in the Bill of Rights, with a view to the protection of karst and cave in the COH WHS. In this regard, the limitations implied in the execution of various statutory provisions in the World Heritage Convention Act as well as the National Heritage Resources Act become relevant.

Meaningful application of Section 24 of the Bill of Rights is inextricably linked to certain other fundamental rights in the Constitution. These are the rights to freedom of movement and residence in Section 22, freedom of trade, occupation and profession in Section 23, property rights referred to in Section 25, access to housing in Section 26, access to information in Section 32 and the right to just administrative action referred to in Section 33 of the Constitution. Environmental management and protection often result in the limitation of one or more of these rights in favour of the public interest of prevention and protection of the environment. The constitutional threshold for such limitation is to be found in the limitations clause contained in Section 36 of the Constitution referred to above.

27 According to the NEMA *"environment" means: "the surroundings within which humans exist and that are made up of: (i) the land, water and atmosphere of the earth;*

(ii) micro-organisms, plant and animal life;

(iii) any part or combination of (i) and (ii), the interrelationships among and between them; and

(iv) the physical, chemical, aesthetic and cultural properties and conditions of the foregoing that influence human health and wellbeing").

According to the ECA "environment" means: "*the aggregate of surrounding objects, conditions and influences that influence the life and habits of man or any other organism or collection of organisms*".

CONSTITUTIONAL CONSIDERATIONS: PRELIMINARY CONCLUSIONS

Environmental and other impacts to karst and cave as a result of the activities identified by the KWG may result in an infringement of the right to an environment which is not detrimental to well being. The enforcement of the rights in Section 24 usually involves the institution of legal action in a court of law, including the Constitutional Court. As such, its value as a tool to enforce effective management and protection of karst and cave is limited in view of the legal uncertainty associated with legal action, lack of legal precedent with regard to the interpretation of Section 24 and the costs involved to ensure that the right is enforced vis-à-vis the state or other persons.

However, its value as a fundamental legal principle, in terms whereof government administration and decision-making concerned with the management and protection of the environment associated with karst and cave should be guided, is of major importance.

As such, it serves to manage and protect karst and cave by virtue of the guidance it may afford officials at the Department of Environmental Affairs and Tourism (DEAT), Department of Water Affairs and Forestry (DWAF), Department of Minerals and Energy (DME), Blue IQ Projects and GDACE in the taking of decisions affecting the environment of karst and cave. Furthermore, it should similarly serve to guide and inform the conduct of statutory Management Authorities such as the Authority to be designated in the World Heritage Convention Act, the South African Heritage Resources Agency and other provincial heritage resources agencies established in terms of the National Heritage Resources Act, in order to protect the environment associated with karst and cave within the COH WHS.

3.2.2.2 ENVIRONMENTAL MANAGEMENT LEGISLATION – STATUTORY MECHANISMS TO MANAGE AND PROTECT KARST AND CAVE

National Environmental Management Act 107 of 1998 ("NEMA")

National Environmental Management Principles and Administrative Decision Making

A statutory mechanism whereby karst and cave could be managed and protected is to be found in Section 2 of the NEMA. Section 2 contains the national environmental management principles and states that these principles apply throughout the country to the actions of all organs of state that may significantly affect the environment. The principles serve as guidelines by reference to which any organ of state must exercise any function when taking any decision in terms of NEMA or other statutory provisions concerning the protection of the environment.

The preventative principle is, for example, reflected in the principle that the disturbance of ecosystems and loss of biological diversity are to be avoided, minimised and remedied, the directive that disturbance of a landscape and the nation's cultural heritage is avoided, and when it cannot altogether be avoided, minimised and remedied, and in the precept that the negative impacts on the environment and on people's environmental rights must be anticipated and prevented, and where they cannot be altogether prevented, minimised and remedied.

ENVIRONMENTAL MANAGEMENT LEGISLATION – STATUTORY MECHANISMS TO MANAGE AND PROTECT KARST AND CAVES: PRELIMINARY CONCLUSIONS

Due recognition and proper application of the national environmental management principles by DEAT, Blue IQ Projects, GDACE, DWAF an Authority in terms of the World Heritage Convention Act, SAHRA in terms of the National Heritage Resources Act and other statutory bodies, as well as the relevant Local Authority will ensure that decisions which affect karst and cave within the COH WHS are taken in a participative, informed and risk averse manner in order to ensure its proper management and protection in accordance with the principle of sustainable development.

3.2.2.3 ENVIRONMENTAL AUTHORISATIONS AND ENVIRONMENTAL IMPACT ASSESSMENTS

The statutory mechanism of issuing environmental licences, permits or other authorisations, which follow after the undertaking of an environmental assessment process, is a valuable tool to ensure that activities undertaken within the area of the COH WHS do not have an unacceptable negative impact on karst and cave situated within the COH WHS. At present, the Environment Conservation Act 73 of 1989 is the statute governing the authorisation of certain listed activities based on the results of an environmental impact assessment process. Major legal reform is imminent. The NEMA was amended to provide for a system of environmental authorisations and environmental impact assessment. For this purpose, new listed activities and authorisation processes on which the licensing mechanism is based were recently published.

However, at the time of writing of this legal paper, Section 50(1) and 50(2) of NEMA retains those sections of the Environment Conservation Act dealing with the declaration of listed activities and all notices and regulations made pursuant to those sections which are concerned with the process of undertaking an environmental impact assessment. The current statutory regime in the Environment Conservation Act and its effectiveness as a tool to manage and protect karst and cave within the COH WHS is therefore more fully discussed herein below.

As was stated above, the NEMA also provides for the authorisation of certain listed activities. In this regard the National Environmental Management Amendment Act 8 of 2004, which came into effect on the 7th of January 2005, amended the NEMA so as to include amongst other statutory provisions, the legal mechanism for environmental authorisations in relation to the new "listed" activities.

Section 24 headed "Environmental Authorizations", sets out the provisions which are to give effect to the general objectives of Integrated Environmental Management (IEM), laid down in Chapter 5. In terms of Section 24(1), the potential impact on the environment of listed activities must be considered, investigated, assessed and reported on to the competent authority charged by the Act with the granting of the relevant environmental authorisation. This section will take effect once the new listed activities which have recently been promulgated are commenced with by way of a notice to be published in the Government Gazette.

It should also be noted that the underlying rationale for environmental management and protection based on the undertaking of listed activities has considerably been broadened in Section 24(2) of the NEMA. This section now provides that the Minister as well as every MEC, with the concurrence of the Minister may identify:

- Activities which may not commence without environmental authorisation from the competent authority;
- Geographical areas based on environmental attributes in which specified activities may not commence without environmental authorisation from the competent authority;
- Geographical areas based on environmental attributes in which specified activities may be excluded from authorisation by the competent authority;
- Individual or generic existing activities which may have a detrimental effect on the environment and in respect of which an application for an environmental authorisation must be made to the competent authority.

It should be evident that the legal platform established by Section 24 and in particular Sections 24(2) (a), (b), and (d) referred to above, creates an opportunity to more effectively manage the nature of activities to be undertaken within the COH WHS. The identification of geographical areas based on environmental attributes in which specified activities may not commence will effectively enable the Minister or MEC to designate areas for example, such as the COH WHS, in which activities having an impact on karst and cave cannot be commenced with, without prior impact assessment and approval.

Although the protection of a World Heritage Site, National Heritage Sites or karst and caves within these sites has not been identified as new listed activities per se, the new listed activities under NEMA could also serve to better manage impacts to karst and cave.

For example, the new listed activities now provide for the construction of facilities or infrastructure for storage of coal and ore of certain specified tonnages[28]. These activities are usually associated with mining and industrial activities and generally result in the pollution of ground and surface water resources. Reference has been made in the various papers prepared by the KWG to the existence, in and around the COH WHS, of quarrying and mining activities. Storage of these raw materials may have impacts on ground and surface water which in turn detrimentally affect karst and cave. The establishment of storage

28 GNR 386 in Government Gazette Nr 28753 of 21 April 2006: ("List of Activities and competent authorities identified in terms of Sections 24 and 24(D) of the National Environmental Management Act, 1998"). See the Schedule to the regulations, in particular Items 1(b) and 1(c).

facilities for these raw materials will therefore be regulated in future and their environmental impacts will be assessed.

The new listed activities provide for the construction of facilities or infrastructure for resorts, lodges, hotels or other tourism or hospitality facilities in protected areas contemplated in the National Environmental Management: Protected Areas Act, 57 of 2003[29]. As will be indicated herein below, world heritage sites have been identified as protected areas in terms of this Act. It is to be anticipated that this listed activity will greatly contribute to more effective management and protection of the environment within the COH WHS and in particular karst and caves, as a proliferation of these types of developments are to be expected by virtue of the status of the COH WHS.

The construction of facilities or infrastructure for slaughtering of animals and the concentration of animals for the purpose of commercial production in certain densities as well as the construction of facilities or infrastructure for aquaculture production with a certain product throughput per year are also listed activities which require environmental assessment before they are authorised[30]. These listed activities will serve to address concerns raised in the various papers of the KWG pertaining to agriculture, breeding of animals and trout farming in and around the COH WHS and to better manage associated impacts to karst and caves in the COH WHS.

Having regard to the issues raised regarding urbanisation (change in land use), and the associated environmental impacts of pollution and waste management, the new listed activities require environmental assessment for the construction of facilities or infrastructure for bulk transportation of sewage and water, including storm water in pipelines of a certain specification as well as the transmission and distribution of electricity[31].

The new listed activities provide for environmental assessments to be undertaken in relation to construction of facilities and infrastructure for recycling, re-use, handling, temporary storage or treatment of general waste as well as the temporary storage of hazardous wastes[32]. Both these types of wastes are associated with urban development, farming, industry and mining activities in and around the COH WHS as referred to in the various papers produced by the KWG. As such, the legal requirement to obtain an authorisation to undertake the activity may contribute to the improved management and protection of karst and cave which is affected by waste disposal practices and particularly its impacts to groundwater.

The new listed activities provide for the above ground storage of dangerous goods, including petrol, diesel, liquid petroleum, gas or paraffin, in containers with a combined capacity of more than 30 cubic meters but less than 1000 cubic meters at any one location or site[33]. Obtaining of an authorisation prior to the

29 Item 1(d).

30 Items 1(g), 1(h) and 1(i), see also item 1(j).

31 Items 1(k), 1(l).

32 Items 1(o), 1(p).

33 Item 7.

installation of these facilities will ensure better prospects of avoiding impacts to ground and surface water, which poses a significant threat to karst and cave.

The listed activities also require authorisations to be obtained in respect of reconnaissance, prospecting, mining or retention operations as provided for in the Mineral and Petroleum Resources Development Act 28 of 2002 as well as any renewals thereof[34]. The commencement of this provision should assist in the management of the environmental impacts associated with mining operations in and around the COH WHS and possibly an improvement of groundwater pollution which has a significant impact on karst and caves.

Other listed activities requiring environmental authorisation and assessment relate to land use and biodiversity. These activities include the transformation or removal of indigenous vegetation of three hectares or more or of any size where the transformation or removal would occur within a critically endangered or an endangered ecosystem listed in terms of Section 52 of the National Environmental Management: Biodiversity Act 10 of 2004[35]. The listed activities also include the construction of roads under certain specified circumstances[36], transformation of undeveloped vacant or derelict land to establish infill development for residential, mixed, retail, commercial, industrial or institutional use under certain specified circumstances and subdivision of portions of land nine hectares or larger into portions of five hectares or less[37]. Concerns rose with regard to the threats and risks of urbanisation on karst and cave could therefore be identified, managed and monitored through this system of environmental assessment.

The new listed activities provides for the transformation of an area zoned for use as public open space or for a conservation purpose to another use[38], and the release of genetically modified organisms into the environment in instances where assessment is required by the Genetically Modified Organisms Act 15 of 1997 or the National Environmental Management: Biodiversity Act 10 of 2004[39].

Finally, it should be mentioned that the new listed activities also provide for environmental authorisation to be obtained in respect of the decommissioning of existing facilities or infrastructure under certain circumstances[40]. This is a positive development within the context of mine closure and the termination of industrial operations at an industry. Latent or historical environmental impacts associated with the operation phase of these facilities are now subjected to environmental assessment.

34 Item 8 and Item 9.

35 Item 12.

36 Item 15.

37 Item 16(a) and Item 16(b).

38 Item 18 and Item 20.

39 Item 21.

40 Item 23.

ENVIRONMENTAL AUTHORISATIONS AND ENVIRONMENTAL IMPACT ASSESSMENTS: PRELIMINARY CONCLUSIONS

Having regard to the above it is submitted that subject to the effective enforcement and the commencement of the listed activities within the framework set by Section 24 read with Sections 24A to 24G of the NEMA will serve as a useful tool whereby environmental impacts to fauna, flora, soil and water resources associated with activities in and around the COH WHS and which poses a risk of impacts to karst and cave could be managed and protected.

3.2.2.4 DUTY OF CARE AND DIRECTIVES

Another statutory mechanism, which could arguably serve as a useful management tool in order to manage and protect karst and cave in the COH WHS is the statutory duty of care provided for in Section 28 of the NEMA. This section provides for a general statutory duty of care to take reasonable measures to protect the environment under certain circumstances.

Section 28(1) states that, every person who causes, has caused or may cause significant pollution or degradation of the environment must take reasonable measures to prevent such pollution or degradation from occurring, continuing or recurring. Where such pollution or degradation of the environment is authorised by law or cannot reasonably be avoided or such stopped, the person must take reasonable measures to minimise and rectify pollution or degradation of the environment.

The persons on whom Subsection 28(1) specifically imposes an obligation to take reasonable measures include an owner of land or premises, a person in control of land or premises or a person who has a right to use the land or premises on which or in which any activity or process is or was performed or undertaken; or any other situation exists, which causes, has caused or is likely to cause significant pollution or degradation of the environment. Although the status of a person (i.e. owner, controller or user) is indicative of who should attract the duty, causality nevertheless remains a prerequisite in order to attract the obligation (i.e. duty) to take reasonable measures.

The measures required to prevent pollution or degradation from occurring, continuing or recurring may include a variety of activities ranging from environmental impact assessment to particularly onerous measures such as to cease, modify or control an activity or process causing pollution, the containment or prevention of pollutants or the causant of degradation, the elimination of a pollution or degradation source or the remediation of the effects of pollution or degradation.

Section 28(4) states that the Director-General of Environmental Affairs or a Provincial Head of Department may (after consultation with any other organ of state concerned and after having given adequate opportunity to affected persons to inform him or her of their relevant interests), direct any person who fails to take such "reasonable measures", to investigate, evaluate and assess the impact of specific activities and report thereon, or to commence taking specific reasonable measures before a given date.

DUTY OF CARE AND DIRECTIVES: PRELIMINARY CONCLUSION

Failure to comply, or inadequate compliance with the directives given to take reasonable measures to prevent pollution or degradation occurring, continuing or recurring, may result in the Director-General or Provincial Head of Department taking reasonable measures to remedy the situation in terms of NEMA (Section 28(7)) and claiming the costs from various persons stipulated in the Act.

Having regard to the ambit of Section 28, it follows that this section could potentially serve as a useful statutory mechanism whereby impacts to karst and cave within the COH WHS could be prevented and where possible remedied. It should also be noted that the statutory mandate to issue directives rests with the Director-General of the DEAT as well as the Head of Department on a provincial level, for example GDACE.

Unfortunately however, the potential benefits of the wide ambit of the duty of care, together with its open ended wording such as “reasonable measures” and “significant pollution or degradation” appear to be a disincentive in the application of Section 28, as it exposes the enforcing authority to potential legal technical argument of statutory interpretation based on the ever present element of subjectivity and personal predilections.

Furthermore, whereas environmental assessment in conjunction with a system of environmental licensing and permitting ensures that issues are considered and identified in a pre-emptive manner, Section 28 of NEMA concerns remedying the effects of pollution or degradation by virtue of rehabilitation which pre-supposes a re-active approach to environmental degradation. As a minimum however, it can be argued that it in principle empowers Blue IQ Projects to, for example, act against property owners on whose property karst and cave is situated, operators of caves for commercial gain and mining companies which may have a right to operate mines on properties in and around the COH WHS to take reasonable measures to protect the environment and in particular the environment within the COH WHS.

Having regard to the abovementioned provisions in the NEMA, it is concluded that this Act offers a useful statutory mechanism through the system of environmental impact assessment and environmental authorisations, in order to protect karst and cave in the COH WHS by regulating various activities in and around the COH WHS which may have a detrimental impact on the environment of karst and cave. Other statutory mechanisms in the NEMA which must be considered by the relevant authority (i.e. DEAT, Blue IQ Projects, GDACE, DWAF, DME, and Authorities in terms of the WHCA, SAHRA and Local Authorities) are the national environmental management principles with regard to any authorisation of any new listed activity. Finally, GDACE and DEAT may consider the application of Section 28 of the NEMA in order to direct that impacts to karst and cave within the COH WHS be remedied and rehabilitated or where it cannot be remedied or rehabilitated, mitigated to acceptable levels.

3.2.2.5 ENVIRONMENT CONSERVATION LEGISLATION

Environment Conservation Act 73 of 1989 (ECA)

Environmental Authorisation of Identified Activities

The ECA contains two statutory mechanisms whereby karst and cave can be managed and protected. The first concerns the authorization of listed activities, discussed in this section and the second the issuing of government directives.

Activities which may have a detrimental effect on the environment will in future no longer be regulated by the ECA but will be regulated by Section 24 of the National Environmental Management Act. However, Sections 21, 22 and 26 of the ECA and notices and regulations promulgated in terms of these sections presently remain in force until they are repealed and the new listed activities are commenced with.

Section 22 of the ECA states that no person may undertake an "identified activity" or cause such an activity to be undertaken, without written authorisation issued by the Minister, by a competent authority, local authority of officer empowered to do so. A list of identified activities was published in terms of Sections 21 and 26 of the ECA. These were subsequently amended by various government notices.

Listed activities which are relevant to the management and control of various activities referred to in the various papers prepared by the KWG and which impact on karst and cave within the COH WHS can be identified in the regulations to the ECA. The listed activities are *inter alia* the construction, erection or upgrading of manufacturing, storage, handling, treatment or processing facilities for any substance regarded as hazardous or dangerous and controlled by national legislation[41]. Undertaking of this activity is typically related to the construction of filling stations comprising underground storage of fuels and plant and equipment infrastructure on industrial and mining sites in and around the COH WHS as well as plant and infrastructure associated with mining and industrial concerns.

The listed activities also refer to the construction, erection or upgrading of roads, railways and associated structures[42]. The papers produced by the KWG *inter alia* point out that there is a proliferation of roads within the COH WHS. There is similarly a proliferation of tarred roads associated with continued pressures of urbanisation and change in land use. Other relevant listed activities include the construction, erection or upgrading of canals and channels, including structures causing disturbances to the flow of water in a river bed, and water transfer schemes between water catchments and impoundments[43]. In addition, the construction of dams, levees and weirs affecting the flow of a river as well as

41 GNR 1182 in Government Gazette 18261 of 5 September 1997 as amended: Regulations under Section 21 of the Environment Conservation Act 73 of 1989 – Identification of activities which may have a substantial detrimental effect on the environment. See Schedule 1, Item 1(c)(i) and (ii).

42 Item 1(d).

43 Item 1(i).

schemes for the abstraction or utilisation of ground or surface water for bulk supply purposes require authorisation and impact assessment[44]. This last mentioned aspect addresses a serious concern raised in the papers by the KWG in that groundwater levels drop and rise as a result of increased pressure on the use associated with urbanisation, farming, industry and mining in and around the COH WHS.

The change of land use from agricultural or zoned undetermined use or an equivalent zoning, to any other land use, use for grazing to any other form of agricultural use and use for nature conservation or zoned open space to any other land use are activities associated with urbanisation[45].

From a biodiversity perspective, activities such as concentration of livestock, aquatic organisms, poultry and game in confined structures for the purpose of commercial production, including aquaculture[46], the intensive husbandry of, or importation of, any plant or animal that has been declared a weed or an invasive alien species[47] and the genetic modification of any organism with the purpose of fundamentally changing the inherent characteristics of that organism[48] require an authorisation in terms of Section 22 of the ECA and should be preceded by an environmental impact assessment.

In view of the issues raised in the papers prepared by the KWG concerning the effects of waste disposal practices associated with mining and industry on groundwater resources, negatively impacting on karst and cave, this listed activity referred to in item 8 of the listed activities should be emphasised. This activity holds that the disposal of waste as defined in Section 20 of the Act, excluding domestic waste, but including the establishment, expansion, upgrading or closure of facilities for all waste, ashes and building rubble should be authorised in terms of Section 22 following the undertaking of an environmental impact assessment process, unless otherwise exempted.

However, its application has been limited by virtue of the fact that many of the waste disposal sites and facilities may have been established prior to the activity being promulgated. The amendment in 2002 to also extend its ambit to expansion, upgrading or closure of facilities for all waste, contributed to the management of environmental impacts associated with existing waste disposal sites and facilities.

Directives in the ECA

Section 31A of the ECA provides that where, in the opinion of the Minister, competent authority, local authority or government institution concerned, any person performs any activity or fails to perform any activity as a result of which the environment is or may be seriously damaged, endangered or detrimentally

44 Item 1(l).

45 Items 2(c), 2(d) and (e).

46 Item 3.

47 Item 4.

48 Item 6.

affected, the person may be directed in writing to cease such activity or take such steps as the Minister, competent authority, local authority or government institution, as the case may be, may deem fit, within a period specified in the directive, with a view to eliminating, reducing or preventing the damage, danger or detrimental effect.

Failure to comply with a directive in terms of Section 31A constitutes an offence and in addition, action may be taken by government to remedy the effects of the degradation and recover the cost thereof from the person concerned.

ENVIRONMENT CONSERVATION LEGISLATION: PRELIMINARY CONCLUSIONS

The success of the implementation of the listed activities in conjunction with the environmental impact assessment process has been met with mixed results. A limiting factor to the successful implementation of these listed activities is the often vague, open ended and uncertain manner in which the activities find expression in the legislation.

Furthermore, the fact that the ECA does not provide for retrospective authorisation of activities which already commenced but which were not authorised was a substantial shortcoming in the environmental authorisation framework of the ECA. Many industrial and mining concerns simply rely on the fact that impacts to the environment arose prior to the commencement of a listed activity thereby avoiding the legal obligation to apply for environmental authorisations and to undertake environmental impact assessments. This aspect is now addressed in the NEMA and should substantially improve the ability of government to control and monitor environmental impacts associated with the undertaking of listed activities within the COH WHS, in order to ensure improved management and protection of karst and cave.

With regard to issuing of directives in order to prevent environmental degradation, its effectiveness has been met with mixed results. The major reasons for its limited effectiveness firstly relates to legal technical deficiencies in the notices of directives as well as the process by which the directives are issued. Secondly the court has ruled in Evans and Others v Llandudno/Houtbay Transitional Metropolitan Substructure and Others 2001 (2) SA 342 (CPD) that no direction under Section 31A of the ECA may be issued without the persons liable to be affected thereby being given notice of the intention to issue the direction and without their being given adequate notice and an opportunity to answer or respond to the views held by the issuing authority.

3.2.2.6 BIODIVERSITY LEGISLATION

National Environmental Management: Biodiversity Act 10 of 2004 (NEMBA)

The general objectives on the NEMBA include, *inter alia*, management and conservation of biodiversity; protection of species and ecosystems, use of biological resources in a sustainable way, sharing of benefits arising from bioprospecting in a fair and equitable manner, and the establishment of the National Biodiversity Institute.

Management Measures - Planning

Chapter 3 of the NEMBA describes the manner in which planning and monitoring of South Africa's biodiversity should proceed. Three types of planning instruments are provided for. National biodiversity frameworks[49], bioregional plans[50] and biodiversity management plans[51] are to be established in terms of the Act. The NEMBA provides for the coordination and alignment of these planning instruments with those prescribed in environmental laws. As such, the three biodiversity plans must not conflict with Environmental Implementation Plans (EIP), Environmental Management Plans (EMP) any Integrated Development Plans (IDPs) and Spatial Development Frameworks (SDPs). Section 48(2) of the NEMBA states that any organ of state or municipality that must prepare EMPs and IDPs must align its plan with any national biodiversity framework and any applicable bioregional plan and demonstrate in this plan how the national biodiversity framework or bioregional plan is to be implemented.

It follows from the above that any Integrated Management Plan to be developed in terms of the WHCA for the COH WHS should also be aligned with a national biodiversity framework or plan. Of particular relevance to the COH WHS is the establishment by the Minister or the environmental MEC in a particular province of a geographic region, of a bioregion. In terms of Section 40, a plan must be published for the management of such a region. The content of such a plan is contained in Section 41 of the Act.

In addition to bioregional plans, the NEMBA provides for the establishment of biodiversity management plans. A biodiversity management plan may be approved by the Minister in respect of ecosystems listed in Section 52 or if not so listed, where it warrants special conservation attention. A biodiversity management plan may also be approved in respect of an indigenous species listed in Section 56 or not so listed but where it warrants special conservation attention. The Act states that biodiversity management plans must be aimed at the long term survival in nature of the species or ecosystem to which the plan relates and the Minister must identify a person or institution responsible for implementing it.

Management Measures - Permitting[52]

The NEMBA provides for the publishing of various lists of species and ecosystems by the Minister responsible for national environmental management as well as by the MEC responsible for the conservation of biodiversity of a province in relation to which certain activities may not be undertaken without a permit.

In terms of Section 52 of the NEMBA, the Minister or the MEC may publish a list of ecosystems, which are threatened and in need of protection. An ecosystem is

Sections 38 and 39.

50 Section 40

51 Section 43

52 See Sections 88 and 89

defined as "…a dynamic complex of animal, plant, and micro-organism communities and their non-living environment interacting as a functional unit." A karst and cave system can therefore conceivably represent an ecosystem as legally defined.

Furthermore, the Minister may, in terms of Section 53 of the NEMBA identify any process or activity in such a listed ecosystem as a threatening process. Any threatening process so identified will be regarded as a specific activity requiring an environmental authorisation and an environmental impact assessment as contemplated in Section 24(2) (b) of the NEMA referred to above. As discussed above, Section 24(2) (b) of the NEMA provides that the Minister or the MEC may identify geographical areas based on environmental attributes in which specified activities may not be commenced with, without an environmental authorisation in terms of Section 24 of the NEMA[53]. Once an ecosystem has been listed it must be taken into account by organs of state in preparing EMPs, and Environmental Implementation Plans under the NEMA and IDPs adopted in terms of the Local Government: Municipal Systems Act 32 of 2000. No notices identifying ecosystems or threatening processes in terms of the NEMBA have as yet been published.

In terms of Section 57 of the NEMBA, no person may carry out any restricted activity involving any species which has been identified by the Minister in the Government Gazette as "critically endangered species", "endangered species"[54], "vulnerable species"[55] or "protected species"[56] without a permit. The NEMBA defines "restricted activity" in relation to such identified species so as to include, but not limited to, "hunting, catching, capturing, killing, gathering, collecting, plucking, picking parts of, cutting, chopping off, uprooting, damaging, destroying, having in possession, exercising physical control over, moving or translocating". It is therefore conceivable that insofar as critically endangered species, endangered species, vulnerable species or protected species may occur on karst or within caves in the COH WHS, that no restricted activities may be undertaken without a permit.

The Minister has published a draft list of threatened and protected species in terms of Section 56(1) for public information and comment in GN 151 in GG 27306 of 18 February 2005. It is important to bear in mind that once the relevant notices have been finalised and published, Section 57 of the NEMBA may become applicable to species identified in the list and which occur on karst or in caves situated in the COH WHS. In addition, trade in such species must be regulated and restricted and obliges the Minister to monitor compliance through the national structure in the NEMBA as well as the country's international obligations referred to in the Convention on Biodiversity.

53 The potential impact on the environment of the "specific activities" must be considered, investigated, assessed and reported on to the competent authority charged by the Act with granting the relevant environmental authorisation.

54 "Endangered species" means "any indigenous species listed as an endangered species in terms of Section 56".

55 "Vulnerable species" means "any indigenous species listed as a vulnerable species in terms of Section 56".

56 "Protected species" means "any species listed as a protected species in terms of Section 56".

Section 65 of the NEMBA provides that no person may carry out a "restricted activity" involving a specimen of an alien species without a permit and such a permit will only be issued after a prescribed assessment of risks and potential impacts on biodiversity is carried out. The term "restricted activity" is legally defined to refer to the importation, possession, growing, breeding, conveying, moving or translocation, selling or trading or any other prescribed activity involving alien or invasive species. No notices in terms of the NEMBA in respect of alien species have as yet been published.

With regard to invasive species, Section 71 of the NEMBA provides that no person may carry out a restricted activity involving a specimen listed as an invasive species by the Minister or the MEC in terms of the NEMBA[57], without a permit and such a permit will only be issued after a prescribed assessment of risks and potential impacts on biodiversity is carried out. "Invasive species" is legally defined as any species whose establishment and spread outside its natural distribution range threaten ecosystems, habitats or other species and may result in economic or environmental harm or harm to human health. No notices in terms of the NEMBA in respect of invasive species have as yet been published.

Finally, the NEMBA provides for various provisions concerning bio-prospecting of indigenous biological resources. The essence of the Act in regulating bio-prospecting of indigenous biological resources is that it provides for a permitting system which holds that no person may engage in bio-prospecting involving any indigenous biological resources or export such resources for bio-prospecting or any other kind of research without a permit in terms of the Act.

Management Measures – Duty of Care

The Act provides for a duty of care relating to alien and invasive species in that a permit holder carrying out a restrictive activity must not only comply with the permit conditions, but must also "take all required steps to prevent or minimise harm to biodiversity"[58]. The Act also provides for directives along the lines of those provided for in Section 28 of the NEMA referred to above, in that a competent authority may in writing, direct any person who fails to comply with this subsection to take such steps as may be necessary to remedy any harm to biodiversity and as may be specified in the directive.

The incorporation of a statutory duty of care in relation to the management of biodiversity and in particular alien and invasive species should be welcomed as it acts as an additional statutory mechanism for the protection of biodiversity associated with karst and cave within the COH WHS.

BIODIVERSITY LEGISLATION: PRELIMINARY CONCLUSIONS

The permitting provisions of the NEMBA will serve to manage and protect biodiversity on karst and in caves situated within the COH WHS. The permitting mechanism will serve to regulate collection or gathering of indigenous biological

57 Section 70 of the Biodiversity Act.

58 See Sections 69 (1) and 73(1).

resources from caves and on karst as more fully described in the papers produced by the KWG. With regard to the enforcement of the permitting system, it should be noted that Chapter 7, Part 3 of NEMA dealing with environmental management inspectors briefly referred to above, are specifically extended to apply to the Biodiversity Act.

In addition, the general duty of care referred to above which applies to both alien and invasive species will serve to assist with the enforcement of the provisions of this Act insofar as the control of alien and invasive species in the COH WHS and surrounds are concerned.

It is concluded that once the Act is fully operational, it will serve as a powerful statutory tool to manage impacts to karst and cave in general and particularly within the COH WHS.

3.2.2.7 PROTECTED AREAS LEGISLATION

National Environmental Management: Protected Areas Act 57 of 2003 (NEMPAA)

The purpose of the NEMPAA is to provide for the protection and conservation of ecologically viable areas representative of South Africa's biological diversity and its natural landscapes by the declaration and management of protected areas. This Act must be read together with the NEMA and in particular, must be guided by the principles set out in Section 2 thereof. Similarly the NEMPAA must also in relation to any protected area, be read, interpreted and applied in conjunction with the NEMBA.

The NEMPAA provides for specific kinds of protected areas which may be declared and designated by the Minister by Notice in the Government Gazette[59]. These areas are special nature reserves, national parks, nature reserves (including wilderness areas) and protected environments, world heritage sites, marine protected areas, specially protected forest areas, forest nature reserves, forest wilderness areas declared in terms of the National Forests Act, 1998 (Act No. 84 of 1998) and mountain catchment areas declared in terms of the Mountain Catchment Areas Act, 1970 (Act No. 63 of 1970).

The Act contains various statutory provisions which concern management measures associated with land designated as world heritage sites and not karst and cave in particular. However, these measures will indirectly assist in the protection of aspects of karst and cave by virtue of it being situated with the COH WHS. Unfortunately, the scope of the NEMPAA is limited to protected areas and karst and cave outside these areas will not derive benefit from its management provisions.

Access to World Heritage Site[60] - Management Measures

59 Section 9.

60 "World Heritage Site" is defined in the NEMPAA to mean "a world heritage site in terms of the World Heritage Convention Act, 49 of 1999".

Of direct relevance to the COH WHS is Section 1 which states that Chapter 1 and Chapter 2 of the Act apply to world heritage sites, declared as such in terms of the World Heritage Convention Act and that the other provisions of the NEMPAA do not apply to world heritage sites except where expressly or by necessary implication provided otherwise.

Notwithstanding the above, Section 46 of the NEMPAA prohibits any person from entering, residing or performing any activity within a world heritage site without the written permission of a management authority. "Management Authority" is legally defined to mean in relation to a protected area, the organ of state or other institution or person in which the authority to manage a protected area is vested. For example, the Gauteng Member of the Executive Council ("MEC") has by way of a government notice been declared by the Minister of Environmental Affairs and Forestry as the Authority responsible for the Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai and Environs World Heritage Site for a period of five years, in terms of the World Heritage Convention Act[61].

The Act contains various other regulatory measures or rules that must be applied within world heritage sites. Compliance with these provisions may result in improved management and protection of karst and cave situated in the COH WHS. These statutory management mechanisms concern:

Prospecting and Mining Activities in a Protected Area

Section 48(1) provides that no person may conduct commercial prospecting or mining activities in a protected area such as a world heritage site without the written permission of the Minister of Environmental Affairs and Tourism and the Cabinet member responsible for minerals and energy affairs. In addition, the Minister may in relation to the aforementioned activities as well as in relation to mining activities conducted in areas which were declared as such after the commencement of this section, prescribe conditions under which those activities may continue in order to reduce or eliminate the impact of those activities on the environment or for the protection of the area concerned[62].

The impacts of mining activities situated in and around the COH WHS have been raised as an issue of concern. This provision enables the environmental and heritage concerns to be taken into account with regard to the decision to authorise such prospecting or mining.

Restriction of Activities in a World Heritage Site

The Act provides for certain activities to be restricted in World Heritage Sites by national regulations, provincial regulations, by-laws on a municipal level and internal rules made by a managing authority[63].

Commercial and Community Activities in a World Heritage Site

61 GN 449 in Government Gazette 28831 of 19 May 2006:"Notice in Connection with the Declaration of a Management Authority for the Fossil Hominid Sites of the Sterkfontein, Swartkrans, Kromdraai and Environs World Heritage Site (Cradle of Humankind)".

62 Section 48(3) of the NEMPAA.

63 Section 49.

Section 50 states that the management authority of a world heritage site may despite a regulation or by-law, but subject to a management plan of the site, carry out or allow a commercial activity or an activity aimed at raising revenue, to take place in that site. The management authority may also enter into written agreements with a local community inside or adjacent to the site to allow members of the community to use in a sustainable manner biological resources in the park, reserve or site and set norms and standards for any activity.

Section 50(2) states that an activity allowed in terms of Section 50 may not negatively affect the survival of any species in or significantly disrupt the integrity of the ecological systems of the world heritage site. The management authority of the world heritage site must establish systems to monitor the impact of activities allowed in terms of this section on the site and its biodiversity. Section 50(5) significantly states that no development, construction or farming may take place in a world heritage site without the prior written approval of the management authority.

Section 52 states that the management authority of a world heritage site may, in accordance with prescribed norms and standards, make rules for the proper administration of the area. A person may exercise a right that that person may have to water in a public stream in a protected area, but subject to such conditions as may be prescribed by the Minister with the concurrence of the Cabinet member responsible for water affairs.

The Act states that a person is guilty of an offence if it undertakes activities in a world heritage site in contravention of the relevant provisions in the Act referred to above. A person convicted of a contravention is liable on conviction to a fine or to imprisonment for a period not exceeding five years or to both such a fine or imprisonment[64].

Regulations on World Heritage Site Management relevant to the Management and Protection of Karst and Cave[65]

Sections 86 and 87 of the NEMPAA provides for the Minister and MEC to make regulations in terms of the Act to, inter alia, regulate specified issues, prohibit or restrict the undertaking of certain activities in world heritage sites.

The Minister has promulgated regulations in terms of Section 86 in GNR 1061 in GG 28181 of 28 October 2005. These regulations inter alia provide for the proper administration of world heritage sites. The regulations aim to regulate and control a broad range of activities within world heritage sites and amplify the statutory provisions referred to in the Act. Various activities and issues which have been identified in the various papers prepared by the KWG as having an impact on karst and cave directly, alternatively, on the environment within the COH WHS are referred to in these regulations. These regulations should therefore be regarded as an important legal mechanism whereby karst and cave in the COH WHS can be protected.

64 Section 89.

65 GNR 1061 in Government Gazette 28181 of 28 October 2005: Regulations for the proper administration of special nature reserves, national Parks and World Heritage Sites. Published under Section 86 of the NEMPA.

Part 1 of Chapter 3 of the regulations concerns "Biodiversity Management and Conservation in a Special Nature Reserve, National Park and World Heritage Site". Of particular relevance here is regulation 4 which, inter alia, states that no person shall, in a world heritage site, without the prior written consent of a management authority, licence, permit or receipt:

- Introduce any species or specimen, or part thereof to a world heritage site;
- Engage in any restricted activity as defined in regulation 45;
- Intentionally disturb any species or specimen (i.e. fauna and flora associated with karst and cave systems);
- Feed any species or specimen (i.e. such as bats and other fauna in caves);
- Remove any wood, sand, gravel, stone, sea shell, guano or other material (i.e. such as Pelindaba Rock on karst and guano of bats in caves);
- Cut, damage, remove or destroy or be in possession of any plant or any part thereof, including dry wood or firewood;
- Intentionally cause pollution, deface cultural heritage resources (i.e. damages to caves, spray painting on cave walls), harm or cause death to any individual or population of any protected species;
- Significantly alter or change the sense of place or any environmental, cultural or spiritual values (i.e. commercial use of caves); or
- Remove or be in possession of a cultural artefact (i.e. to be found on various sites of cultural significance within the COH WHS).

Part 2[66] concerns use of biological resources in a world heritage site and states that a management authority may, subject to the provisions of an approved management plan, by means of the granting of a non-transferable licence or permit or the entering into of a written agreement, on the conditions it deems necessary and against payment of the fees determined by it, grant to any person the right to the sustainable use of identified biological resources in a world heritage site. Part 3[67] concerns the management of access to a world heritage site. Broad powers are given to a management authority in order to close and manage access to a world heritage sites.

Regulation 18 concerns Operating Rules in a world heritage site and states that no person may dispose of any solid or liquid waste, including motor oil, into a water area other than in places specifically designated by the management authority therefore. No person shall, in a world heritage site, throw, roll or discharge any stone, substance or missile to endanger any person or species or specimen in the world heritage site. No person shall, without the written permission of the management authority in a world heritage site, deface, paint, write on, cut names or letters in or otherwise make marks or affix bills on trees,

66 Regulations 5, 6 and 7.

67 Regulations 8 – 18.

rocks, gates, fences, buildings, signs or other property or in any other manner spoil features, buildings or facilities (i.e. such as graffiti found on cave walls).

Of further relevance in these regulations is Chapter 3 in Part 4, which deal with commercial activities in a world heritage site. Regulation 19 states that no development in terms of Section 50(5) of the Act shall be implemented in any area other than an area specifically designated for such development in a management plan and before a management authority has indicated in writing the nature and extent of the strategic or environmental impact assessment required for the development.

Regulation 19(2) significantly states that no commercial activity or activity contemplated in Section 50 of the Act, which requires an environmental impact assessment to be undertaken in terms of NEMPAA or any other law may be implemented before a management authority has approved, with or without conditions, the environmental impact assessment before it is submitted to the relevant authority for approval. This is a statutory mechanism, which provides the management authority with significant statutory powers to manage the nature and extend of development within the COH WHS.

Furthermore, a person may not undertake activities which include the conducting of tours, the selling or hiring of goods or the offering of goods for sale or hire the conducting of research, an activity of any kind for the purpose of fund raising, personal gain or making a profit, any organised or special event, including sporting or cultural events, except pursuant to a licence, permit or agreement and subject to the payment of the appropriate fees between that person, or some other person, and the management authority.

Regulation 34 concerns research and monitoring and states that no person shall, without the written permission of a management authority, carry out scientific research in a world heritage site. Regulation 35 states that a management authority may determine activities in world heritage sites generally or in specific world heritage sites for which special use permits are required.

From the perspective of karst and cave in particular, regulation 39 concerns interference with soils and substrate and states that no person shall, except with the prior written permission of a management authority inter alia remove or disturb from a world heritage site any:

- Soil, rock, mineral or similar material (i.e. see concerns raised with regard to removal of Pelindaba Rock and mining activities within the COH WHS);
- Fossil, archaeological remains or cultural artefacts (i.e. from caves and other sites of cultural significance in the COH WHS) or any object or material that is or was used for any ritual, spiritual or other practice.

Regulation 39(2) states that no person shall construct an impoundment or weir on any river or river bed or abstract any water from any impoundment or weir on any river or in any river bed within a world heritage site, without the written permission of the management authority and without conducting an environmental impact assessment. The regulations similarly provide that no person shall abstract any water by means of a pump, pipes, gravitation or any other means, located outside the boundary of a world heritage site, from any river or river bed forming a boundary with a world heritage site without the written permission of a management authority and without conducting an environmental impact assessment.

This regulation, if enforced, may assist with the issues raised by the KWG of groundwater pollution and groundwater abstraction by the mining industry operating within and around the COH WHS.

Regulation 40 states that no person shall, in a world heritage site deposit or leave any litter, bottle, broken glass, china, pottery, plastic article, rubbish, refuse, seeds, fruit or vegetable matter or other waste material, except in an area or receptacle provided for that purpose. Littering within caves has been identified by the KWG as an ongoing concern.

No person may discharge or leave any mineral, mineral waste or other industrial waste or by-product thereof or discard or discharge any toxic chemical or substance, pharmaceutical substance, including biocides, or any other pollutant or harmful substance within a world heritage site. Regulation 41 concerns pollution of water and states that no person shall pollute any water in a river, spring, pan, well, borehole, groundwater, dam, reservoir or lake in a world heritage site.

Regulation 43 states that no person shall in a world heritage site place, throw, dump or let out any refuse, rubbish, used containers, effluent, toilet waste or any objectionable matter and carry on any agricultural or gardening activities without the prior written approval of the management authority and subject to the conditions which the management authority may lay down from time to time.

This regulation also states that no person may inter alia affix to any object not belonging to that person any name, letter, figure, symbol, mark, picture, sign or notice or otherwise damage any other object or intentionally or negligently cause any damage to any object of geological, archaeological, historical, ethnological, oceanographic, educational or other scientific interest or behave in an offensive, improper, indecent or disorderly manner.

Regulation 45 concerns restricted activities with regard to the use of biological resources in a world heritage site. The regulation states that no person shall without the prior written authorisation of a management authority, within a world heritage site undertake, support or participate in any restricted activity. Various restricted activities are identified in relation to protected, alien and invasive species. These activities generally concern hunting, capturing, killing, collecting, removing and transporting such species. From a karst and cave perspective in particular, restricted activities include, touching, removing, altering or interfering with cultural resources, preventing participation in living cultural heritage and preventing the cultural or spiritual development of people, groups or communities.

Regulation 57 states that a management authority must have due regard for and seek to integrate and harmonise its management plans with the requirements of the Act and where applicable plans in terms of other national legislation, provincial government plans and development plans, regional planning and development plans, local government planning and development plans and existing planning and development plans of any other relevant management authority. Regulation 58 states that all existing planning measures in connection with any world heritage site remain in force until a management plan for a world heritage site becomes effective in accordance with the Act.

Finally, regulation 60 concerns bioprospecting and states that no person shall undertake any manner or form of bioprospecting in a world heritage site without the prior written authorisation of a management authority and subject to such conditions and against the payment of a fee as determined by the management authority.

The regulations provide for various offences[68] including the contravention or failure to comply with any provisions of the regulations, failure to comply with a notice, rule or other document displayed within a world heritage site, failure to comply with a lawful instruction[69] given in terms of the internal rules and the obstruction or hindrance of any authorised official to execute his or her duties. The regulations state that any person who contravenes or fails to comply with the regulations is guilty of an offence and liable on conviction to imprisonment for a period not exceeding five years or to a fine or to both such fine and such imprisonment.[70]

PROTECTED AREAS LEGISLATION: PRELIMINARY CONCLUSIONS

Having regard to the above, it should be evident that the NEMPAA and the regulations published in terms thereof incorporate various statutory mechanisms whereby development in the COH WHS may be managed in order to reduce the risks of impacts to the environment and in particular karst and cave. It should be noted that a management authority is vested with broad statutory powers to manage and protect various aspects of concern, affecting karst and cave, within the COH WHS.

3.2.2.8 WATER LEGISLATION

National Water Act 36 of 1998 (NWA)

The papers produced by the KWG indicates that impacts to ground and surface water resources by the undertaking of various activities in and around the COH WHS pose a significant risk to karst and cave. The mining and industrial sectors are identified as significant users and polluters of ground and surface resources. In addition, due to the migration of groundwater, it is possible that water quality may be impacted upon by industrial and mining activities, which are not situated within the COH WHS or immediate surrounds.

The provisions in the NWA concerned with the management, protection and rehabilitation of water resources are important from a karst and cave point of view.

68 Regulation 61.

69 Regulation 62.

70 Regulation 64.

Although "water" is itself not defined in the NWA, "water resources" are defined to include an aquifer, estuary, watercourse and surface water. In terms of the NWA, "aquifer" is defined to mean a geological formation which has structures or textures that hold water or permit appreciable water movement through them[71]. The papers prepared by the KWG indicate that water stored in aquifers are increasingly being utilised to serve the needs of urbanisation, agriculture, industrial and mining. These activities all have impacts on aquifers, degrading karst and cave within the COH WHS.

There are various statutory mechanisms for the management and protection of water resources which if applied and enforced by the DWAF, should indirectly contribute to the protection of karst and cave in the COH WHS. These statutory mechanisms are:

Entitlements to use water in terms of the NWA

The NWA provides for various mechanisms whereby water may lawfully be used[72]. In this regard the Act provides for a system of water use licensing in respect of a list of specified water uses, lawful continuation of existing lawful water use, (usually being water use authorised in terms of the now repealed Water Act of 1956) and a system of general authorisations in respect of certain specified water uses, where, as long as water use falls within the parameters specified in the general authorisation, no water use licence is required. Lastly the NWA provides for Schedule I type water uses which are usually of domestic, light industrial and recreational nature and where waste or water containing waste is discharged to a municipal system controlled by a local authority. No authorisation is required to be undertaken in respect of these types of uses.

The Act identifies various specific water uses, the undertaking of which requires a water use licence issued by the DWAF[73]. Many of these water uses could presently be undertaken in and around the COH WHS. As was indicated in the various papers prepared by the KWG, it is to be anticipated that the storage of polluted water, the disposal of polluted water into water resources which includes an aquifer as well as the discharging or disposing of water found underground for the continuation of mining activities and the safety of people are the most prominent listed water uses impacting on karst and cave within the COH WHS.

It should also be mentioned that the intentional recharging of an aquifer with any waste or water containing waste by mines and industry is also a water use requiring licensing[74]. As was indicated in the papers by the KWG, flooding of mines with water polluted by chemicals, acid mine drainage and other substances are occurring and this results in polluted water coming into contact with other water in aquifers, having a direct impact on karst and cave. The NWA provides that no person may undertake a controlled activity unless authorised to do so by or

71 See Section 1 for the Definitions generally.

72 Section 4.

73 Section 21 and Section 22.

74 Section 37 (1)(d).

under the NWA[75]. Undertaking of the abovementioned water uses without a water use licence and in the absence of an existing lawful water use is a criminal offence in terms of Section 151 of the NWA.

Prevention and remedying pollution to water resources (Duty of Care and directives)

In addition to the licensing mechanism referred to above, the NWA contains provisions for the prevention and remedying of the effects of pollution, which are extended to allow wider liability for pollution of water resources control and costs of remediation. Section 19 of the NWA states that an owner of land, a person in control of land or a person who occupies or uses the land on which any activity or process is or was performed or undertaken or any other situation exists, which causes, has caused, or is likely to cause pollution of a water resource, must take all reasonable measures to prevent such pollution from occurring, continuing or recurring.

Failure to take reasonable measures will result in a Catchment Management Agency (or DWAF where an agency has not been established) issuing a directive to undertake the required reasonable measures[76]. Failure to comply with such directive will enable the relevant authority to proceed to take the measures to remedy such pollution and to claim the costs thereof from various persons identified in the Act.

WATER LEGISLATION: PRELIMINARY CONCLUSION

The various authorisation mechanisms in the NWA should assist with the management of impacts to karst and cave as a result of water pollution. However, it appears that the water use licensing process is a complex and time consuming process resulting in many industries and mining enterprises continuing to operate in terms of their existing lawful water use rights issued in terms of the Water Act of 1956 resulting in the continuation of unacceptable impacts to water resources. The statutory licensing system, read with other provisions in the Act pertaining to development of water management strategies should, once fully operational, result in improved protection and management of water resources as well as karst and cave.

Although Section 19 could serve as a useful statutory mechanism to protect water resources associated with karst and cave, its successful application by government is limited due to its wide ambit and use of vague and arguably subjective standards to be found in the concept of "reasonable measures".

75 Section 21(e).

76 Section 19(3).

3.2.2.9 AIR LEGISLATION

Atmospheric Pollution Prevention Act No. 45 of 1965 ("APPA") and the National Environmental Management: Air Quality Act 39 of 2004 ("AQA")

The APPA provides for the control of four different categories of air pollution. These are control of noxious or offensive gases, atmospheric pollution by smoke, dust control and air pollution by fumes emitted by vehicle emissions[77]. Air quality has been raised as an issue by the KWG with regards to the access to and exploitation of caves which alters the air quality in caves which impact on cave ecology. Furthermore, a cave ecosystem may be impacted upon if air polluted by noxious or offensive gasses, smoke or dust enters into the cave system. In this regard, particular reference has been made to emissions of vehicles allowed to park or idle at cave entrances. Similarly, in the case of karst, it is to be anticipated that impacts to air quality will result in degradation to karst by for example acid rain caused by the release of noxious or offensive gasses into the atmosphere.

Although the APPA does not regulate air quality in relation to karst and cave specifically, it finds application through the system of authorisation being certificates authorising emissions of noxious or offensive gases to atmosphere and the legal requirement that best practicable means be undertaken to manage air pollution in general.

It is generally accepted that the APPA has become outdated and ineffective as far as enforcement is concerned. The National Environmental Air Quality Act 39 of 2004 has been promulgated and this Act, save for certain sections, has commenced.

National Environmental Air Quality Act 39 of 2004 (AQA)

The APPA is in the process of being repealed by the new AQA. At the time of writing, provisions in the APPA pertaining to the regulation of noxious and offensive gasses by way of APPA certificates were still in force pending the commencement of the licensing requirements in the AQA. The intention of the AQA is generally to regulate air quality by way of ambient standards as opposed to point source control on which the APPA was based.

Chapter 2[78] of the AQA deals with what is regarded as "the backbone" of the new approach to air quality management, namely, the establishment of national ambient air quality emission standards at the national, provincial and local level[79]. These standards will be a key mechanism to ensure that the constitutional right to an environment that is not harmful to health and well being is progressively realised through the implementation of benchmark performance standards. Furthermore, ambient air quality standards will provide the goals and objectives

77 See Part II, Part III, Part IV and Part V of the APPA.

78 Section 7 and 8.

79 Sections 9,10 and 11.

for all Air Quality Management Plans[80] and will also provide the yardstick against which the efficiency of these plans can be measured. The Act also provides for the identification of priority pollutants and the setting of ambient standards in respect of these pollutants.

Chapter 4 of the Air Quality Act describes the various air quality management measures and regulatory tools available to government for implementing and enforcing air quality management plans and achieving acceptable ambient air quality. Provision is made for: priority areas, listed activities, controlled emitters, controlled fuels, pollution prevention plans, atmospheric impact reports, dust control, rehabilitation when mining operations cease, noise control and offensive odours[81]. The AQA provides for a licensing mechanism for the undertaking of listed activities, which essentially replaces the certificate system of the APPA[82].

AIR LEGISLATION: PRELIMINARY CONCLUSIONS

It is conceivable that the development of the various air quality measures referred to above and the use of ambient air quality standards as opposed to point source control will ensure that ambient air quality improves within the COH WHS and surrounding areas as a result of the management and monitoring framework of the AQA.

The development of Air Quality Management Plans as well as the identification of new listed activities may provide the opportunity for management measures to be developed in relation to air quality concerns associated with cave environs in particular. These measures may therefore contribute to the management and protection of karst and cave within the COH WHS.

3.2.2.10 LAND USE LEGISLATION

Development Facilitation Act 67 of 1995 (DFA)

The relevance of land use legislation to the management and protection of karst and cave within the COH WHS is to be found in the threats posed by urbanisation and development of land for agricultural and industrial purposes on or in the vicinity of karst and caves.

It is therefore important that land use legislation recognise the value and importance of karst and cave and the protection of the environment of the COH WHS in general. The World Heritage Convention Act specifies, as a power of a Management Authority, that such authority must coordinate with relevant tribunals under the DFA and other planning authorities on national, provincial and local level. In this regard, the general principles for land development are contained in the DFA[83]. The principles inter alia serve to guide the administration of any physical plan, transport plan, guide plan, structure plan, zoning scheme or any like

80 Section 15 .

81 See Sections 18 to 35.

82 See Chapter 5, Sections 36 – 49.

83 Chapter 1 (Sections 2 – 4).

plan or scheme administered by any competent authority in terms of any law and serve as guidelines by reference to which any competent authority shall exercise any discretion or take any decision in terms of the DFA or any other law dealing with land development, including any such law dealing with the subdivision, use and planning of or in respect of land.

From the perspective of protection and management of impacts to karst and cave as a result of land development, it is important to note that the DFA recognises that environmentally sustainable land development practices and processes must be encouraged. The DFA also provides for the establishment of Land Development Objectives and states that the DFA Tribunal will not approve land development, which is in conflict with such Land Development Objectives.

LAND USE LEGISLATION: PRELIMINARY CONCLUSIONS

The DFA therefore provides for various mechanisms whereby land development within the COH WHS could be managed and controlled, to be coordinated with the various provisions in the World Heritage Convention Act pertaining to integration of management plans. Conversely, it is to be anticipated that Land Development Objectives could be informed by Integrated Management Plans to be developed by the Authority in terms of the World Heritage Convention Act as well as any Site Management Plans or Land Use Agreements developed in terms of the National Heritage Resources Act in respect of management and protection of national heritage sites being those situated in the COH WHS.

3.2.2.11 HERITAGE RESOURCES LEGISLATION

World Heritage Convention Act 49 of 1999 (WHCA)

The Act provides for the incorporation of the World Heritage Convention into South African Law, the enforcement and implementation of the World Heritage Convention in South Africa, recognition and establishment of World Heritage Sites and the establishment of management structures.

The Act adopts the definitions of "cultural heritage" and "natural heritage" as set out in the World Heritage Convention and the definition of "ecosystems", "environment" and "pollution" referred to in the National Environmental Management Act 107 of 1998[84]. Various statutory mechanisms concerned with the protection of world heritage sites and therefore indirectly karst and cave in the COH WHS are to be found in this Act. These are:

Fundamental Principles and Management Decisions

Section 4 contains the fundamental principles on which the Act is based. These principles appear to reflect the national environmental management principles referred to in the National Environmental Management Act 107 of 1998, with respect to public participation, sustainable development, decision making and inter-governmental cooperation. It is important to note that the fundamental

84 Section 1.

principles referred to in the WHCA, apply throughout the Republic to the actions of all organs of state and authorities in relation to world heritage sites, subject to applicable law such as the National Environmental Management Act and National Heritage Resources Act.

The Act makes direct reference to the protection of karst and cave in Section 4(1) (p) which states that sensitive, vulnerable, highly dynamic or stressed ecosystems such as dolomitic land or ridges require specific attention in management and planning procedures, especially where they are subject to significant human resource usage and development pressure.

Furthermore, Section 4(2) refers to detailed principles pertaining to the concept of sustainable development within the context of world heritage sites. If these principles are applied directly to the management and protection of karst and cave within the COH WHS, the various principles inter alia hold that the unnatural disturbance of ecosystems and loss of biological diversity associated with karst and cave must be avoided, or, where it cannot be avoided, mitigated; pollution and degradation of the environment associated with karst and cave should be avoided, or, where it cannot be avoided, mitigated and the unnatural disturbance of karst landscapes and caves which constitute the cultural and natural heritage of the Republic should be avoided, or, where it cannot be avoided, mitigated. The reader is referred to other principles in the Act.

These principles must be considered by the Authority appointed in terms of the Act of any other organ of state or statutory body concerned with the management and protection of aspects of karst and cave environs.

The Management Authority

Protection of karst and cave as a result of its location within a World Heritage Site is primarily the responsibility of an "Authority" to be appointed in terms of the Act. The Act defines an "Authority" to mean an existing Authority, declared to be an authority under Section 8 or a new Authority established under Section 9. In terms of both Sections 8 and 9, an Authority is established by notice in the Gazette.

An Authority was appointed in terms of the WHCA to manage the COH WHS by way of a Government Notice published in May 2006[85].

This notice was preceded by two other notices. Firstly, a notice published in 2003 referred to the "Declaration of the Department of Agriculture, Conservation, Environment and Land Affairs, Gauteng Provincial Government as an Authority for the Cradle of Humankind World Heritage Site"[86]. This notice records the Minister of Environmental Affairs and Tourism's intention to declare Blue IQ Projects as the Authority to manage the COH WHS. Secondly, a follow-up notice referring to the Department of Environmental Affairs and Tourism's "Call for Comments on the

85 GN 449 in Government Gazette 28831 of 19 May 2006.

86 GN 956 in Government Gazette 25134 of 4 July 2003: Declaration of the Department of Agriculture, Conservation, Environment and Land Affairs, Gauteng Provincial Government as an Authority for the Cradle of Humankind World Heritage Site.

Application by the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs to be declared the Authority for the Cradle of Humankind World Heritage Site"[87].

The powers which an Authority may enjoy are contained in Section 13 of the Act. Section 13(1) of the Act states that the Authority is inter alia empowered to conserve, manage, promote, facilitate and monitor cultural and natural heritage and to manage it in accordance with all applicable national and provincial legislation, policies and management plans. As already mentioned when the Development Facilitation Act was considered, the Management Authority should have also coordinated with relevant tribunals under this Act or similar bodies or relevant planning authorities on a national, provincial or local level in order to ensure that development takes place in accordance with all applicable laws and procedures.

From a management and protection perspective, the Act also importantly states that the Management Authority is to initiate, assess, comment or facilitate any application under the Development Facilitation Act. Other powers also include entering into contracts with competent national, provincial or local government or a private nature conservation entity. Having regard to the powers referred to in Section 13(1), it appears that the Government Notice published in May 2006, limits the powers and duties of the Authority to the duties referred to in Section 13(2) while no mention is made to the powers in Section 13(1).

In terms of Section 13(2) of the Act, an Authority has several duties in connection with a world heritage site under its control. These duties include the development of measures for the cultural and environmental protection and sustainable development of, and related activities within a world heritage site. The authority must take effective and active measures for the protection, conservation and preservation of cultural and natural heritage and the Authority must establish and implement an Integrated Management Plan. The ambit of these duties could also conceivably include the development of measures for the protection of karst and cave in particular.

Integrated Management Plans

Section 21 states that every Authority must prepare and implement an Integrated Management Plan in order to fulfill the requirements of Articles 4 and 5 of the World Heritage Convention referred to above. According to Section 22, the Integrated Management Plan must be harmonised and integrated with the World Heritage Convention, Operational Guidelines of the Convention, plans in terms of the National Environmental Management referred to above, National Heritage Resources Act referred to hereunder and certain other legislation together with various other government planning and development plans on provincial, regional and local level.

87 GN 1258 in Government Gazette 25394 of 5 September 2003: Call for Comments on the Application by the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs to be declared the Authority for the Cradle of Humankind World Heritage Site.

It is important to note that in terms of Section 24(f), such Integrated Management Plans must contain cultural or nature conservation components required by applicable law and the directives of the Minister. In terms of Section 24(g) the Integrated Management Plan must contain provisions regarding the activities allowed within a particular area, terms and conditions for conducting activities, prohibition of activities described by the Minister, control over the frequency, size, impacts or manner of conducting activities in a particular geographical area, including, without limitation, the use of, or access to, structures. Regulation of access to and use of karst and cave within the COH WHS could therefore be included in such Integrated Management Plans although this aspect has extensively been regulated in the regulations promulgated in terms of the NEMPAA.

We have been provided with various land use agreements concluded with owners of properties within the COH WHS on which sites of cultural significance occur. The purpose of these agreements is to provide for the implementation of site management plans in terms of the National Heritage Resources Act. While these agreements represent a management mechanism in terms of national heritage resources legislation, the WHCA provides for an overarching management mechanism which could include all other aspects of concern which impact on karst and cave within the COH WHS.

Other Management Mechanisms

Finally, it should be noted that the Minister may, subject to the objectives and fundamental principles of the Act, make regulations concerning the management and control of world heritage sites such as the COH WHS and incorporate as many of, or all of, the Operational Guidelines of the Convention as may be necessary, with the necessary changes, where appropriate, for their effective implementation in the Republic of South Africa[88]. The system of regulations, various specific aspects pertaining to the management and protection of karst and cave within the COH WHS could be regulated. No regulations have been promulgated in respect of the COH WHS.

WHCA Heritage Resources Legislation: Preliminary Conclusions

It appears from a notice published in the Government Gazette during May 2006, that the Minister of Environmental Affairs and Tourism has declared the "Gauteng Member of the Executive Council responsible for the Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai and Environs World Heritage Site" as the Authority to manage and protect the COH WHS as required by Section 8 of the WHCA. Unfortunately the wording of the notice does not clearly identify which provincial MEC has been declared as the Authority, although it is anticipated and assumed that based on the notices preceding the May 2006 notice, the reference to a MEC refers to the MEC of Agriculture, Conservation and Environment.

It should also be noted that although the declaration of the Authority has now been formalised, the powers and duties of the Authority have been limited to the

88 Section 44.

duties referred to in Section 13(2). The Act clearly states that Section 13(1) concerns the powers of an Authority whilst Section 13(2) concerns the duties. The notice curiously refers to both the powers and duties in Section 13(2), which appears to be an error. Unfortunately, by limiting the powers and duties to Section 13(2) it appears that none of the powers in Section 13(1) have been given to the Authority. This is unfortunate as it strictly fails to provide the Authority with the powers in Section 13(1) to perform the duties in Section 13(2).

Furthermore, the important powers in Section 13(1) (m) to initiate, assist, comment on or facilitate any application under the Development Facilitation Act, 1995, or other applicable development, planning or management law relating to or affecting a World Heritage Site, which constitutes an important management mechanism, appears to have been lost to the Authority together with other important management powers in Section 13(1).

National Heritage Resources Act 25 of 1999 (NHRA)

The NHRA aims to inter alia promote good management of the national estate, and to enable and encourage communities to nurture and conserve their legacy so it may be bequeathed to future generations. As such, the NHRA becomes a statutory management tool having direct bearing on the management and protection of karst and cave in the COH WHS by virtue of it being part of the national estate.

The national estate means the "national estate" defined in Section 3 of the NHRA. This Section states that those heritage resources of South Africa which are of cultural significance or other special value for the present community and for future generations must be considered part of the national estate and fall within the sphere of operations of heritage resources authorities. The national estate may inter alia include:

- Places[89], buildings, structures and equipment of cultural significance[90];
- Places to which oral traditions are attached or which are associated with living heritage[91];

89 "Place" includes:
- site (any area of land, including land covered by water, and including any structures or objects thereon), area or region;
- building or other structure (any building, works, device or other facility made by people and which is fixed to land, and includes any fixtures, fittings and equipment associated therewith) which may include equipment, furniture, fittings and articles associated with or connected with such building or other structure;
- group of buildings or other structures which may include equipment, furniture, fittings and articles associated with or connected with such group of buildings or other structures;
- An open space, including a public square, street or park; and
- In relation to the management of a place, includes the immediate surroundings of a place.

90 "Cultural significance" means aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance.

91 "Living heritage" means the intangible aspects of inherited culture, and may include:
- cultural tradition;

- Historical settlements and townscapes;
- Landscapes and natural features of cultural significance;
- Geological sites of scientific or cultural importance;
- Archaeological[92] or palaeontological[93] sites;
- Graves[94] and burial grounds specified in the Act.

Section 3(3) read with Section 2 provides that cultural significance, for purposes of the NHRA, means aesthetic, architectural, historical, scientific, social, spiritual, linguistic or technological value or significance. A place or object is to be considered part of the national estate if it has cultural significance or other special value more fully described in the Act.

Designation of heritage areas, protected areas and objects and permitting

Chapter II of the NHRA provides for the protection and management of the heritage resources. The chapter differentiates between formal protections in Part 1, which is generally in respect of immovable property, and general protections in Part 2, related to movable property, although this differentiation is not absolute. Part 1 provides for the declaration of four categories of protected areas being national and provincial heritage sites, protected areas and heritage areas. The Act also protects heritage objects and archaeological and palaeontological sites.

Generally, a number of obligations (as detailed in Section 27) are triggered on such a declaration, the most important being that it is a criminal offence to "… destroy, damage, deface, excavate, alter, remove from its original position, subdivide or change the planning status of any heritage site without a permit issued by the heritage resources authority responsible for the protection of such a site". Our understanding is that several sites of cultural significance within the COH WHS have been designated as national heritage sites. As such, the protection

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- oral history;
- performance;
- ritual;
- popular memory;
- skills and techniques;
- indigenous knowledge systems; and
- the holistic approach to nature, society and social relationships.

92 "Archaeological" means:

- material remains resulting from human activity which are in a state of disuse and in or on land and which are older than 100 years, including artefacts, human and hominid remains and artificial features and structures;
- rock art (as further detailed in Section 2);
- wrecks (as further detailed in Section 2);
- features, structures and artefacts associated with military history which are older than 75 years and the sites on which they are found.

93 "Palaeontological" means any fossilised remains or fossil trace of animals or plants which lived in the geological past, other than fossil fuels or fossiliferous rock intended for industrial use, and any site which contains such fossilised remains or trance.

94 "Grave" means a place of internment and includes the contents, headstone or other marker of such place, and any other structure on or associated with such place.

afforded by the NHRA by virtue of its status as a national heritage site will also be applicable to karst and cave situated within such a site.

Other areas include protected areas, heritage areas and heritage objects. Protected areas are areas of land surrounding a national or provincial heritage site. No person may damage, disfigure, alter, subdivide or in any other way develop any part of a protected area unless, at least 60 days prior to the initiation of such changes, he or she has consulted the heritage resources authority which has designated such area in accordance with the procedure prescribed by the authority[95]. Similarly, a provincial heritage resources authority may, in addition, inter alia declare land surrounding any archaeological, palaeontological site or meteorite to be a protected area[96]. It is a criminal offence to damage, disfigure, alter, subdivide, or in any other way develop the protected area, unless the heritage resources authority has been consulted in accordance with the procedure it may prescribe[97] read with Section 51(1) (c)).

A planning authority must whenever it revises a town or regional planning scheme, or a spatial plan, or at the initiative of a provincial heritage resources authority, investigate the need for the designation of heritage areas to protect any place of environmental or cultural interest[98]. Where the provincial heritage resources authorities are of the opinion that the need exists to protect a place of environmental or cultural interest as a heritage area, it may request a planning authority to investigate its designation in accordance with its proposals. A local authority is similarly empowered to designate any area of land to be a heritage area on the basis of its environmental or cultural interest.

Section 32 concerns the management of heritage objects. Any object or collection of objects, or a type of object or list of objects, whether specific or generic, that is part of the national estate and the export of which SAHRA deems necessary to control, may be declared a heritage object. These include archaeological and palaeontological objects, meteorites and rare geological specimens, visual art objects, military objects, numismatic objects, books, records, documents, films, videos, sound recordings and others. SAHRA is obliged to keep a register of such heritage objects. A number of detailed provisions are set out in the NHRA which include rules regarding the destruction or damage to heritage objects[99], a duty to keep them in a good condition[100], permit requirements for restoration[101], export [102] and a number of other detailed requirements. It should be noted that most of these restrictions apply to declared heritage objects.

95 Section 28(3).

96 Section 28(2).

97 Section 28(3).

98 Section 31.

99 Section 32(13).

100 Section 32(15).

101 Section 32(17).

102 Section 32(19).

The Act also places restrictions on import of objects protected in terms of laws of foreign states, demolition of structures older than 60 years without a permit and the protection of archaeological and palaeontological sites and materials and meteorites. Any person who discovers archaeological or palaeontological objects or material in the course of development or agricultural activity must immediately report the find to the responsible heritage resources authority or the nearest local authority offices or a museum which must in turn immediately notify such heritage resources authority[103]. No person may, without a permit issued by the responsible heritage resources authority, destroy, damage, excavate, alter, deface or otherwise disturb any archaeological or palaeontological site or any meteorite and destroy, damage, excavate, remove from its original position, collect or own any archaeological or palaeontological material or object or any meteorites. Various other actions are also prohibited.

In addition, the NHRA empowers a responsible authority to, when it has reasonable cause to believe that any activity or development which will destroy, damage or alter any archaeological or palaeontological site is under way, and where no application for a permit has been submitted and no heritage resources management proceedings in terms of Section 38 have been followed, to inter alia serve notices to cease the activity, investigate the matter and where mitigation is required, recover the costs from the owner or occupier of the land on which it is believed an archaeological or palaeontological site is located or from the person proposing to undertake the development if no application for a permit is received within two weeks of the order being served[104].

The NHRA furthermore empowers a responsible heritage resources authority to, after consultation with the owner of land on which an archaeological or palaeontological site or a meteorite is situated, serve a notice on the owner or any other controlling authority, to prevent activities within a specified distance from such site or meteorite.

The Act also provides for SAHRA to conserve and generally care for burial grounds and graves protected in terms of the NHRA and it may make such arrangements for its conservation as it sees fit[105].

Heritage resources management

An important provision in the NHRA for the protection of karst and cave in the COH WHS is the provision in Section 38 of the Act which states that any person who intends to undertake developments categorised in the section must at the very earliest stages of initiating such development, notify the responsible heritage resources authority and furnish it with details regarding the location, nature and extent of the proposed development. The list of developments referred to in the section include:

103 Section 35(3).

104 Section 35(5).

105 Section 36(1).

- The construction of a road, wall, power-line, pipeline, canal or other similar form of linear development or barrier exceeding 300 meters in length;
- The construction of a bridge or similar structure exceeding 50 meters in length;
- Any development or other activity which will change the character of a site exceeding 5000m² in extent; or
- Involving three or more existing erven or subdivisions thereof; or
- Involving three or more erven or divisions thereof which have been consolidated within the past five years; or
- The costs of which will exceed a sum set in terms of regulations by SAHRA or the provincial heritage resources authority;
- The rezoning of the site exceeding 10 000m² in extent; or
- Any other category of development provided for in regulations by SAHRA or the provincial heritage resources authority.

The responsible heritage resources authority must, if there is reason to believe that heritage resources will be affected by such development, notify the person who intends to undertake the development to submit an impact assessment report.

The responsible heritage resource authority is empowered to decide whether the development may proceed, any limitations or conditions to be applied to the development, the application of general protections in terms of the NHRA to such heritage resources, whether compensatory action is required in respect of any heritage resources which are damaged or destroyed as a result of the development and whether the appointment of specialists is required as a condition of approval of the proposal. These provisions do however not apply to developments, which are subject to the environmental impact assessment procedures required under inter alia the Environment Conservation Act and which have been described elsewhere in this paper.[106]

Finally, the NHRA allows for compulsory repair orders to be issued with regard to heritage sites[107] and for expropriation under certain circumstances[108].

NHRA HERITAGE RESOURCES LEGISLATION: PRELIMINARY CONCLUSIONS

On a national level, the NHRA plays an important role in the protection of karst and cave within the COH WHS by way of the various statutory mechanisms referred to in this section. SAHRA and respective provincial heritage resource authorities implement the legislation. However, it should be noted that the designation of various caves in the COH WHS as national heritage sites ensures management and protection in terms of the NHRA.

106 Section 28(8).

107 Section 45.

108 Section 46.

3.2.2.12 MINING LEGISLATION

Mineral and Petroleum Resources Development Act 28 of 2002 (MPRDA)

The papers prepared by the KWG raise environmental impacts, especially to ground and surface water resources, as a significant threat to the management and protection of karst and cave. The MPRDA introduces various provisions concerning the protection of the environment including cultural resources. The Act introduces a system of rights, permits and licences, which are issued after impacts to among other things, the environment and heritage resources have been considered.

Various definitions are relevant to environmental management and protection of impacts associated with mining activities. In this regard the MPRDA states that "environment" means the environment as defined in the National Environmental Management Act 107 of 1998 ("NEMA") and "environmental management plan" means a plan to manage and rehabilitate the environmental impact as a result of prospecting, reconnaissance, exploration or mining operations conducted under the authority of a reconnaissance permit, exploration right or mining permit and "environmental management programme" means an approved environmental management programme contemplated in Section 39[109]. The MPRDA incorporates the national environmental management principles of the NEMA and states that they apply to all prospecting and mining operations, as the case may be, and any matter relating to such operation[110].

The statutory mechanisms in the MPRDA whereby karst and cave in the COH WHS may be protected are as follows:

Environmental Management Programmes and Environmental Management Plans

Section 39 states that every person who has applied for a mining right in terms of Section 22 must conduct an environmental impact assessment and submit an environmental management programme. The section also states that any person who applies for a reconnaissance permission, prospecting right or mining permit must submit an environmental management plan as prescribed.

An applicant who prepares an environmental management programme or an environmental management plan must investigate, assess and evaluate the impact of proposed prospecting or mining operations on the environment, the socio-economic conditions of any person who might be directly affected by the prospecting or mining operation and any national estate referred to in Section 3(2) of the National Heritage Resources Act, with the exception of the national estate contemplated in Section 3(2)(i)(vi) and (vii) of the Act.

Section 40 requires that the DME consults with any state department which administers any law relating to matters affecting the environment. Compliance with this section in the issuing of prospecting and mining operations will include consultations with Blue IQ Projects as an organ of state and once established, in its

109 Section 1.

110 Section 37.

capacity as Management Authority in terms of the WHCA. Section 41 concerns financial provision for rehabilitation and enables the Minister of Minerals and Energy to utilise such financial provisions for rehabilitation of environmental impacts associated with mining.

Section 45 enables the Minister to recover costs of urgent remedial measures from a mining company. Finally, Section 46 gives powers to the Minister to remedy environmental damage when a directive issued by the Minister is not being adhered to.

Integrated Environmental Management and Responsibility to Remedy

Section 38 of the MPRDA states that the holder of reconnaissance permission, prospecting right, mining right, mining permit or retention permit must at all times give effect to the general objectives of integrated environmental management laid down in Chapter 5 of NEMA. A mining operator must consider, investigate, assess and communicate the impact of his or her prospecting or mining on the environment as contemplated in Section 24(7) of NEMA (now Section 24(4)). All environmental impacts must be managed in accordance with his or her environmental management plan or approved environmental management programme and must as far as reasonably practicable, rehabilitate the environment affected by the prospecting or mining operations to its natural or predetermined state or to a land use which conforms to the generally accepted principle of sustainable development.

In addition, the MPRDA states that a mining operation is responsible for any environmental damage, pollution or ecological degradation as a result of his or her reconnaissance, prospecting or mining operations and which may occur inside and outside the boundaries of the area to which such right, permit or permission relates.

Mineral and Petroleum Resources Development Regulations (MPRDRs)[111]

The regulations contain detailed provisions pertaining to the information requirements of environmental management programmes[112] and environmental management plans[113]. In addition, the regulations specifically regulate certain impacts identified with mining operations under the heading "Pollution Control and Waste Management"[114]. These regulations generally require that impacts associated with waste disposal, air quality, water management and pollution control, disposal of waste material, soil pollution and erosion control be recorded in the environmental impact assessment report and managed in accordance with the environmental management programme. Various detailed provisions are

111 GNR 527 of 23 April 2004: Mineral and Petroleum Resources Development Regulations as amended.

112 Regulation 51.

113 Regulation 52.

114 Part IV (Regulations 63 – 73).

provided for on financial provision for rehabilitation of impacts and the compilation of a closure plan[115].

MINING LEGISLATION: PRELIMINARY CONCLUSIONS

Substantial progress has been made in the MPRDA in order to ensure that environmental impacts associated with mining is assessed and quantified. The MPRDA and the regulations contain extensive provisions on environmental management and protection. With regards to karst and cave within the COH WHS's representation of cultural heritage, impacts by mining to such cultural heritage must be assessed and adequately mitigated. Impacts on other environmental media such as air and water resources must be assessed and mitigated in terms of the MPRDA. The legal duty referred to in Section 40 of the Act now requires the DME to consult with other government departments such as DEAT, GDACE, Blue IQ Projects and DWAF in order to ensure coordination of other legal authorisation processes and that impacts are assessed in an integrated manner.

This is a positive development and although the Act specifically refers to other state departments, the duty should extend to include statutory bodies to which state departments delegate certain functions. For example the management authority constituted in terms of the World Heritage Convention Act and SAHRA constituted in terms of the National Heritage Resources Act. The Act has however limited direct application to karst and cave.

With regard to the MPRDRs, it is submitted that the extensive regulation of environmental impacts associated with mining activities will serve to manage and protect karst and cave in the COH WHS. However, it is to be anticipated that the historical legacy of the mining industry will continue to impact on the environment and karst and cave for some time. It should be noted however that the MPRDA contains various provisions regulating rehabilitation requirements in respect of historical pollution. It falls upon government and the management authority of the COH WHS and notably the Department of Minerals and Energy to implement and enforce the various provisions.

3.2.2.13 AGRICULTURAL LEGISLATION

Conservation of Agricultural Resources Act 43 of 1983 (CARA)

The relevance of agricultural legislation to the management and protection of karst and cave primarily concerns management of weeds and invader plants on karst and within caves. The objective of the CARA is to provide for control over the utilisation of the natural agricultural resources of the country in order to promote the conservation of the soil, the water sources and the vegetation and the combating of weeds and invader plants and for matters connected therewith[116].

115 Regulation 53.

116 Section 3.

The CARA does not apply to any land which is situated in an urban area, with an "urban area" meaning land which is under the control of a local authority, but excluding any commonage or any other land under the local authority's control which in the opinion of the executive officer[117] is utilised for agricultural purposes; or is sub-divided into erven or lots and public open spaces and streets which are bounded by such erven or lots and public open spaces[118].

Furthermore, the CARA does not apply to land situated within any area declared to be a mountain catchment area in terms of the Mountain Catchment Areas Act 63 of 1970. However, notwithstanding the aforementioned, the provisions of the CARA relating to weeds and invader plants also apply to land which is situated within an urban area.

The mechanisms whereby karst and cave may be protected from weeds and invader plans are through a general, prohibition on the spreading of weeds through sale or dispersion of a plant declared to be a weed by the Minister of Agriculture. Non-compliance constitutes an offence attracting fines and imprisonment[119].

The CARA also concerns the control and management of a wide range of other activities, which are indirectly relevant to the protection and management of karst and cave, insofar as the Act finds application. These include, the prevention or control of water logging or salination of land, the utilisation and protection of vleis, marshes, water sponges, watercourses[120] and water sources, the regulating of the flow pattern of run-off water, the utilisation and protection of the vegetation, the prevention and control of veld fires, the control of weeds and invader plants, the restoration or reclamation of eroded land or land which is otherwise disturbed or denuded, the protection of water sources against pollution on account of farming practices and the construction, maintenance, alteration or removal of soil conservation works[121] or other structures on land.

Under certain circumstances, the costs of the performance of any act shall be repayable by the owner[122] of the land on or in respect of which the act was

117 An "executive officer" is an officer of the Department of Agriculture designated as an executive officer by the Minister of Agriculture in terms of Section 4 of the CARA.

118 Section 2.

119 Section 5.

120 "Watercourse" means a natural flow path in which run-off water is concentrated and along which it is carried away.

121 "Soil conservation work" means any work which is constructed on land for:
the prevention of erosion or the conservation of land which is subject to erosion;
the conservation or improvement of the vegetation or the surface of the soil;
the drainage of superfluous surface or subterranean water;
the conservation or reclamation of any water source; or
the prevention of the silting of dams and the pollution of water;
but not a work which is constructed on land in the course of prospecting or mining activities.
"Conservation" in relation to the natural agricultural resources, includes the protection, recovery and reclamation of those resources.
"Natural agricultural resources" means the soil, the water sources and the vegetation, excluding weeds and invader plants.

122 "Owner" in relation to land inter alia means the person in whom the ownership in that land is vested or in whose name that land is registered, or which in the opinion of the executive officer has been purchased by any person but has not yet been

performed[123]. Powers of entry and other powers are also created with regard to the performance of acts under Section 11[124].

AGRICULTURAL LEGISLATION: PRELIMINARY CONCLUSIONS

The CARA is primarily concerned with the conservation of agricultural resources and at best finds indirect application to karst and cave through its prohibition on the spreading of weeds and invader plants. Within this context, it is of limited relevance to karst and cave but finds application within the context of concerns raised within the broader COH WHS which indirectly impacts on karst and cave.

3.2.2.14 GENETICALLY MODIFIED ORGANISMS LEGISLATION

Genetically Modified Organisms Act 15 of 1997 (GMOA)

This Act provides for measures to promote responsible development, production, use and application of genetically modified organisms. The Act aims to ensure the limitation of possible harmful consequences to the environment, management of related waste and to ensure that proper risk assessment and mitigation measures are undertaken.

The Act is only relevant to karst and cave insofar as it regulates genetic modification of organisms which may be found on or in karst and caves. "Genetically Modified Organism[125]" means an organism, the genes or genetic material of which has been modified in a way that does not occur naturally through mating or natural recombination or both.

Regulations have been published in terms of the GMOA[126]. Of particular relevance are those regulations concerned with the authorities to import, export, develop, production, release or distribution of genetically modified organisms. The Regulations govern the abovementioned activities via a permitting system, but also refer to certain exclusions from the obligation to obtain a permit. The Regulations also state that an applicant for a permit shall, besides complying with the provisions of the regulations also comply with provisions of all other laws regulating the importation and exportation of genetically modified organisms.

It should also be noted that environmental impacts associated with genetic modification are expressly governed by way of the listed activities in the Environment Conservation Act and National Environmental Management Act referred to above.

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registered in his name, means that purchaser.

123 Section 11(2).

124 Section 11(5).

125 Section 1.

126 GN 1046 in Government Gazette 26422 of 11 June 2004: Genetically Modified Organisms Act 14 of 1997, Guideline Document for work with Genetically Modified Organisms, GN 1048 in Government Gazette 26422 of 11 June 2004: Terms of Reference for sub-committees to assist the advisory committee in terms of Section 11(2) of the Genetically Modified Organisms Act 14 of 199, and GNR 1420 in Government Gazette 20643 of 26 November 1999: Genetically Modified Organisms Act 15 of 1997, Regulations as amended.

GENETICALLY MODIFIED ORGANISMS LEGISLATION: PRELIMINARY CONCLUSIONS

Although the KWG has not identified genetic modification of organisms associated with karst and cave as an issue, the provisions of this Act will nevertheless govern such activities. In addition, prior to such an activity commencing, an authorisation must be obtained in terms of the NEMA and the ECA to determine environmental impacts.

3.2.3 Provincial Perspective

3.2.3.1 PROVINCIAL LEGISLATION

This section provides a review of the provincial legislation, which may directly or indirectly manage and protect karst and cave within the COH WHS in the Gauteng and North West Provinces. Brief reference is also made to legislation in the Limpopo Province, which has adopted legislation containing progressive provisions in which the management and protection of caves are specifically addressed.

Gauteng - Nature Conservation Ordinance 1983

The Nature Conservation Ordinance contains provisions, which specifically apply to caves in Chapter IX which is headed "Trading in and Preservation of Cave Formations". The term "cave" is legally defined in Section 1 of the Ordinance to mean "… a natural geological formed void or cavity beneath the surface of the earth" and the term "cave-formation" is defined to mean "… any natural matter formed in a cave and includes a wall, floor or ceiling of a cave, flow-stone, drapery, column, stalactite, stalagmite, helectite, anthodite, gypsum flower or needle, any other crystalline mineral formation, tufadam, breccia, clay or mud formation or a concretion thereof".

Section 99 states that no person shall remove from a cave by way of sale, exchange or donation, dispose of, import into the province or export or remove therefrom a cave formation, unless he is the holder of a permit, which authorises him to do so. Section 99(2) furthermore states that no person shall convey a cave formation within the province, unless he is the holder of a permit, which authorises him to do so subject to certain provisos.

Section 99(3) states that no person shall disturb or alter the natural atmosphere of a cave. This includes the burning therein of any matter which emits smoke or gas, leave any container, rope, clothing, battery, candle, wax, food or any other object in a cave, take into a cave an aerosol container or other container containing paint, dye or other colouring agent, break open, break, remove or in any other manner tamper with an obstruction or structure erected to prevent the unauthorised entrance to a cave, break, break-off, crack or in any other manner destroy, damage, mutilate or spoil a cave-formation in a cave or engrave, paint, write or in any other manner make a mark thereon.

Any person who contravenes or fails to comply with the abovementioned provisions, is found in possession of a cave formation in respect of which there is a reasonable suspicion that it was not acquired lawfully and is unable to give a satisfactory account of such possession, shall be guilty of an offence and liable on conviction under certain circumstances to a fine not exceeding R 1 500.00 or to imprisonment for a period not exceeding 18 months or to both such a fine and such imprisonment and on a second conviction to a fine not exceeding R 2 000.00 or to imprisonment for a period not exceeding 24 months or to both such a fine and imprisonment. Although these provisions directly manage and control caves, the effectiveness of the statutory provisions are limited by the insignificant fines imposed for non-compliance with the legislation.

3.2.3.2 NORTH WEST PROVINCE - NORTH WEST PARKS AND TOURISM BOARD ACT 93 OF 1997 AND NATURE CONSERVATION ORDINANCE OF 1983

This Act provides for the establishment of the North West Parks and Tourism Board with its stated object to develop and manage protected areas and to promote and facilitate the development of tourism in the Province. Although the Act contains measures to manage protected areas including ecosystems there are no specific provisions relating to the management and protection of karst and cave as such.

It should be noted that the Nature Conservation Ordinance of 1983 was assigned to the North West Province in terms of Section 235(8) of the Constitution. It therefore appears that the provisions in this Ordinance pertaining to the protection of caves apply in the North West Province as well.

3.2.3.3 LIMPOPO PROVINCE - LIMPOPO ENVIRONMENTAL MANAGEMENT ACT 7 OF 2003

The Limpopo Province has passed the Limpopo Environmental Management Act 7 of 2003 and the Act commenced on the 1st of May 2004. The Act defines the terms “cave” and “cave-formation” by adopting a similar definition referred to in the Nature Conservation Ordinance of 1983. Chapter 10 of this Act specifically concerns the preservation of caves and cave-formations.

Section 70 provides that no person may without a permit enter or inhabit a cave or remove from a cave, be in possession of, dispose of by way of a sale, exchange or receive as a gift, give as a gift, import or bring into, or export or remove from the province, or convey a cave-formation, wild fauna and flora or any other natural matter found in a cave or any readily recognisable part or derivative of a cave formation or such fauna and flora or such natural matter. In addition, no person may deposit, dump or drain any refuse, waste, substance or thing, whether solid, liquid, gaseous or explosive into a cave or near a cave entrance, or cause or allow to enter or percolate into a cave.

Section 70(2) corresponds with Section 99(3) of the Ordinance and similarly prohibits a person from disturbing or altering the natural atmosphere of a cave in any manner including by way of burning any matter which emits smoke or gas in the cave or to leave the objects referred to in Section 99(3) of the Ordinance.

Section 71 extends the ambit of this Act beyond the provisions in the Nature Conservation Ordinance and provides for control of entry or admission and commercialisation or development of caves for tourism purposes. In terms of Section 72, the MEC has powers to take steps to develop and control any cave in collaboration with any other public or private body; take steps necessary or expedient for research with regard to caves and cave-formations and the preservation of caves and cave-formations; conduct any survey or investigation in connection with any cave or cave-formation; or collect and publish statistics and information regarding caves and cave-formations. Section 73 enables the MEC to make regulations in terms of Section 122 of the Act for the purposes of this chapter relating to various activities in caves. No regulations have as yet been published.

In terms of Section 112 of the Act a person is guilty of an offence if that person inter alia contravenes or fails to comply with any provision of the Act. A person shall upon conviction be liable to a fine or imprisonment or both such a fine and imprisonment.

Section 117 concerns the penalties to be incurred if a person is convicted of an offence. Any person that is convicted of an offence in terms of the Act is liable in the case of an offence referred to in Section 70 to a fine not exceeding R 250,000 or imprisonment not exceeding 15 years or to both such fine and such imprisonment and to a fine not exceeding four times the commercial value of the fauna, flora, cave formation in respect of which the offence was committed.

Furthermore, Section 117(2) states that any person convicted of an offence in terms of Section 70(1)(a), being the prohibited act of a person entering into a cave without a permit as well as Section 70(2)(a) and (b), referred to above, and who after such conviction persists in the act or omission which constituted such offence, shall be guilty of a continuing offence and liable on conviction to a fine or to imprisonment not exceeding 60 days of to both such fine or imprisonment in respect of every day on which he or she so persists with such act of omission.

PROVINCIAL PERSPECTIVE: PRELIMINARY CONCLUSION

Having regard to the provincial legislation referred to above, it should be evident that the Nature Conservation Ordinance which apply to caves in the COH WHS is outdated and the penalties totally inadequate. On the other hand, the respective provisions in the Limpopo Province should be applauded with respect to its regulation of various additional aspects associated with caves not covered in the Nature Conservation Ordinance and imposes adequate penalties for non-compliance. Provincial legal reform is therefore urgently required in the Gauteng province to adequately protect caves in the COH WHS.

3.2.3.4 LOCAL LEGISLATION – BY-LAWS

Mogale City Local Municipality

A review of the by-laws relating to Urban Greening and Biodiversity Preservation[127], as well as the by-laws relating to Parks and Open Spaces and

127 Mogale City Local Municipality By-laws relating to Urban Greening and Biodiversity preservation, dated 2 December 2006, issued in terms of Section 13 of the Local Government Municipal Systems Act 32 of 2000 and Section 84(1) (p) of Local Government Municipal Structures Act 117 of 1998.

Management of Trees and Facilities at Dams[128] it appears that there are no provisions directly relating to the management of karst and cave in these various by-laws.

Caves are managed and protected in terms of the City of Tshwane Metropolitan Municipality by-laws relating to Public Amenities dated February 2005[129]. Section 21 of these by-laws states that no person may pollute the atmosphere inside a cave, in or at a public amenity by, for example, the burning of combustible material. The section furthermore states that no person may break or tamper with or remove any barrier or obstacle which has been in front of a cave, in or at a public amenity. Finally the section states that no person may break, break off or damage any rock formation in a cave or anywhere else in or at a public amenity.

LOCAL LEGISLATION: PRELIMINARY CONCLUSION

It follows generally from a review of by-laws that Mogale City's by-laws offer limited assistance with regard to the direct management and protection of karst and cave in the COH WHS.

3.2.4 Common Law Liability

Legal Mechanisms to enforce legal rights and duties

Although environmental administrative, protection and enforcement measures are generally to be found in South African statutory law, aggrieved individuals or groups of individuals, when raising environmental disputes regularly utilises common law remedies.

The first type of common law remedy referred to is the Aquilian Action (Action for Damages). Several elements must be proved in a court of law, on a balance of probabilities, before a court will conclude that damages may be awarded for the loss incurred. The elements include that a wrongful act or omission had to be committed or omitted, intention or negligence (fault), a link between the conduct and the damage sustained (causation) and damages must have actually been incurred[130].

The second type of remedy available in common law and which is often used within the context of environmental legal disputes is the interdict. The purpose of an interdict (injunction) is to prevent harm before it occurs, or to prevent the continuation of a presently existing unlawful situation. An interdict is usually an order to refrain from the doing of an unlawful act, but it may, in appropriate circumstances, impose a positive duty to abate a nuisance (a mandatory interdict).

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128 Mogale City Local Municipality, Bylaws relating to parks and open spaces management of trees and facilities at dams issued in terms of Section 13 of the Local Government Municipal Systems Act 32 of 2000, and Section 84(1) (p) of Local Government Municipal Structures Act 117 of 1998.

129 Local Authority Notice 265: City of Tshwane Metropolitan Municipality: Publication of the City of Tshwane Metropolitan Municipality Bylaws relating to Public Amenities. Dated 9 February 2005 (Notice Number 360/2005).

130 Neetlingh, Potgieter, Visser: Deliktereg, Second Edition 1992 and
Glazewski, J: Environmental Law in South Africa, Second Edition 2005, chapter 18, paragraph 18.3.

A mandatory interdict may also be granted against an official or public body to require that body to perform its duty. A successful legal application based on interdict must show that certain elements are present namely in the existence of clear legal right, injury actually committed or reasonably apprehended, the absence of any other ordinary remedy and nuisance.

COMMON LAW LIABILITY: PRELIMINARY CONCLUSION

From a legal management and protection point of view, common law remedies may be of limited assistance in order to protect karst and cave. Legal action is an expensive process, which almost always involves an element of uncertainty and risk as to the verdict. Furthermore, it is often difficult to prove the element of causality in relation to environmental pollution and degradation such as those associated with water resources in particular. The allocation of fault may also prove to be problematic under these circumstances. Finally, judicial precedent in relation to environmental pollution and degradation has not yet developed to a level where certainty may be gained from previous precedent with regards to damages associated with environmental pollution and degradation.

3.2.5 Policy Review

For purposes of this paper, it is assumed that a reference to "policy" documentation denotes an inclusive term, which refers to guidelines and reports developed by government in order to guide administrative decision by government officials tasked with environmental management and protection, which includes karst and cave.

Although of limited relevance to the legal review being undertaken in this legal paper, as these "policies" do not invoke legal rights and duties and are not enforceable per se, aspects thereof may be incorporated into permits, licences and other authorisations issued in terms of the various statutes referred to in this legal paper. As such, they may become enforceable in an indirect sense.

It appears that no departmental guidelines or other documentation has been produced in relation to caves and in this regard the conclusion reached by R Ellis and A Grove in the KWG paper titled: "Legal Aspects of Karst and Cave Use in the Cradle of Humankind World Heritage Site"[131] is confirmed. With regard to karst, it is noted that from the abovementioned KWG paper that a number of guideline documents relating specifically to karst have been identified. In this regard the authors refer to departmental guidelines by the Department of Public Works[132] as well as the Department of Water Affairs and Forestry[133] which relate to the development of infrastructure in dolomite and assessment and management of groundwater resources in dolomite respectively.

131 See paragraph 6.2.

132 Department of Public Works: Appropriate Development of Infrastructure on Dolomite: Guidelines for Consultants.

133 Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic areas in South Africa (The Dolomite Guideline).

The authors also identify other guideline documents which concern environmental aspects relevant to the management and protection of karst and cave. The guideline documents mentioned, primarily concern the protection of water resources. In addition, consideration could also be given to other departmental documentation such as:

- National Water Resources Strategy: Our Blueprint for Survival" - DWAF 2004;
- Discussion Document: "A National Strategy for Integrated Environmental Management in South Africa – DEAT 1998";
- Guideline Document for Work with Genetically Modified Organisms;
- Hazardous Wastes in South Africa – DEAT 1992;
- National Waste Management Strategies and Action Plans for South Africa.

There appears to be no white or green papers specifically concerned with the management and protection of karst and cave. The following papers concern aspects of indirect relevance to the management and protection of karst and cave:

- White Paper on Integrated Pollution and Waste Management for South Africa;
- A Policy on Pollution Prevention, Waste Minimisation, Impact Management and Remediation;[134]
- Green Paper on Development and Planning;[135]
- White Paper: A Minerals and Mining Policy for South Africa, Department of Minerals and Energy;[136]
- White Paper on Environmental Management Policy for South Africa (Final);[137]
- White Paper on South African Land Policy;[138]
- White Paper on Agriculture;[139]
- White Paper on Conservation and Use of South Africa's Biological Diversity;[140]
- White Paper on Spatial Planning and Land Use Management: Wise Land Use.[141]

Guidelines on karst and cave management should be introduced to provide the necessary guidance to all relevant stakeholders. These guidelines could serve to inform any operational rules referred to in the administration regulations referred to in the regulations to the National Environmental Management: Protected Areas Act, referred to in this paper. The guidelines could also serve as a

134 N227/2000 in Government Gazette 20978 of 17 March 2000.

135 GN 227 in Government Gazette 20978 of 17 March 2000.

136 October 1998, N2359/1998 in Government Gazette 19344 of 20 October 1998.

137 N749/1998, Government Gazette 18894 dated 15 May 1998.

138 Dated April 1997.

139 Dated 1995.

140 GN 1095/1997 in Government Gazette 18163 dated 28 July 1997.

141 N1648/2001 in Government Gazette number 22473 dated 20 July 2001.

decision making tool when an Authority, to be formally established in terms of the World Heritage Convention Act, is required to take a decision on development and the undertaking of all other activities requiring an environmental impact assessment in terms of the various statutes referred to above.

3.2.6 Problem Statement

The literature and legislative review undertaken indicates that certain difficulties may be identified with regard to the current legal state, pertaining to the management and protection of karst and cave. These are:

- There is no single dedicated body of legislation concerned with the management and protection of karst and cave in a holistic and integrated manner. There are various international, national and provincial legislative provisions which cumulatively comprise the legal framework for the protection of karst and cave referred to in this legal paper. Of these legislative provisions reviewed, very few directly concern management and protection of karst and cave. In addition, most of these provisions concern caves in particular and are to be found in the provincial and local legislation. There are also no international conventions, national statutes or regulations dedicated exclusively to the management and protection of karst and cave.
- The legal provisions reviewed are derived from statutes concerned with various aspects of environmental regulation and protection, land use regulation and protection, agricultural management and protection and heritage resource management and protection. The diversity of legislation by necessary implication results in fragmentation and a proliferation of management structures and management tools, such as management plans and frameworks. For example, the various statutes provide for integrated management plans, integrated development plans, air quality management plans, environmental management programmes and plans for the mining industry and heritage agreements incorporating site management plans in respect of heritage resource protection and management. There appears to be an emphasis on integration but a general lack of coordination of these various statutory planning mechanisms. As such, there appears to be a need for a coordinated approach to the planning of management measures and protection in respect of karst and cave within the COH WHS.
- The broad ambit of certain bodies of legislation, notably the National Environmental Management: Biodiversity Act, as well as the National Environmental Management: Protected Areas Act and in particular the regulations promulgated in terms thereof, has resulted in significant overlap of measures to manage bio-diversity vis-à-vis protected areas. In particular, the extent of regulations promulgated in terms of the Protected Areas Act, insofar as they relate to the management of world heritage sites in particular, appear to have overtaken those management mechanisms that are available in the World Heritage Convention Act as far as the COH WHS is concerned.

- Notwithstanding the fact that various statutory provisions concern, albeit in an indirect fashion, the management and protection of karst and cave, the enforcement of the various provisions under discussion poses a significant problem. It is trite that state departments and various statutory bodies concerned with the management and protection of the environment, land use, planning and heritage resource protection are experiencing difficulties with the capacity to enforce legislation. It is also significant to note that in those instances where statutory provisions directly concern management and protection of caves, these provisions are to be enforced at provincial and local government levels where the greatest capacity problems are experienced.
- There are no guidelines which are specifically concerned with the management and protection of karst and cave. The development of these guidelines is essential to facilitate decision making with regard to the management and protection of karst and cave as well as enforcement for non-compliance with operational rules, regulations and other statutory provisions.

3.2.7 Towards Integrated Legal Management and Protection of Karst and Cave in the COH WHS – Response (Actions Required)

Having regarded the current state of legal management and protection of karst and cave, as well as the problems identified hereinabove it is concluded and recommended that the following response/actions be considered:

- Firstly, by way of a regulatory response, it was initially concluded and recommended that action should be taken to formalise Blue IQ Projects appointment as the Authority in terms of the World Heritage Convention Act in respect of the COH WHS. However such appointment/declaration has been formalised by a notice published in the Government Gazette.
- It is furthermore concluded that legal certainty will be derived from gazetting the designation as required in terms of the World Heritage Convention Act.
- However, notwithstanding the above, it appears from the notice published in the Government Gazette that the wording of the notice does not clearly identify which provincial MEC has been declared as the Authority, although it is assumed that based on previous notices published in the Government Gazette, the reference to a MEC refers to the MEC of Agriculture, Conservation and Environment.
- It should also be noted that although the declaration of the Authority has now been formalised, the powers and duties of the Authority have been limited to the duties referred to in Section 13(2). The Act clearly states that Section 13(1) concerns the powers of an Authority whilst Section 13(2) concerns the duties. The notice curiously refers to both the powers and duties in Section 13(2). Unfortunately, by limiting the powers and duties to Section 13(2) it appears that none of the powers in Section 13(1) have been given to the Authority. This is unfortunate as it strictly fails to provide the Authority with the powers in Section 13(1) to perform the duties in Section 13(2) and does not contribute to legal

certainty. Furthermore, important powers referred to in Section 13(1) (m) such as inter alia the powers to initiate, assist, comment on or facilitate any application under the Development Facilitation Act, 1995, or other applicable development, planning or management law relating to or affecting a World Heritage Site, which constitutes an important management mechanism, appears to have been lost to the Authority together with other important management powers in Section 13(1).

- In addition, the formal establishment of an Authority for the COH WHS in terms of the World Heritage Convention Act will ensure that such Authority draws upon the extensive management powers provided for in the regulations to the National Environmental Management: Protected Areas Act. These regulations are to be implemented by a management authority, legally defined as the organ of state or other institution or person in which the authority to manage the protected area is vested.
- Secondly, the Authority should, commence with the coordination of all the management measures undertaken by Blue IQ Projects and SAHRA and incorporate it into the integrated management plans to be developed in terms of the World Heritage Convention Act.
- This exercise may serve to integrate as well as coordinate the various planning requirements of the legislation referred to in this paper and provide an opportunity to incorporate various guidelines and operational measures in respect of karst and cave situated in the COH WHS which may not presently be regulated in terms of current legislation and regulations. The protection of karst and cave should form a clearly defined and dedicated component of the development of an integrated management plan.
- Thirdly, the Authority should assess its role within the context of the environmental legal framework referred to in this legal paper.
- The statutory management mechanisms referred to in this legal paper can essentially be divided into two categories. The first category relates to those statutory provisions of which the implementation and enforcement falls within the legal mandate of other state departments or statutory bodies such as DWAF, DME and SAHRA and various other bodies concerned with environmental protection. In addition, certain provisions are to be implemented and enforced by provincial and local government. In all of these instances the relevant authority or body is mandated to enforce the legislation under its jurisdiction and not the Authority in terms of the World Heritage Convention Act. Under these circumstances, the Authority should, play a coordinating and facilitating role in order to ensure that the legislation mandated to such a government department or statutory body is effectively enforced within the COH WHS to ensure the management and protection of karst and cave.
- The statutory mandate to undertake such a coordinating and facilitating role is founded in the powers and duties referred to in the World Heritage Convention Act and in particular those sections which require inputs from the Authority into

various Development Facilitation Act procedures, as well as other planning measures within national, provincial and local government spheres. However, it appears from the relevant Government Notice that these powers have not been given to the designated Authority.

- In addition, the regulations promulgated in terms of the National Environmental Management: Protected Areas Act state in Regulation 19(1) (b) that the Authority may determine the nature and extent of a strategic or environmental impact assessment required for a development which enables such an authority to determine the scope as well as the level to which such an assessment must be undertaken.
- It is also significant to note that Regulation 19(2) states that no commercial activity or activity contemplated in Section 50 of the Act, which requires an environmental impact assessment to be undertaken in terms of the Act or any other law may be implemented before a management authority has approved, with or without conditions, the environmental impact assessment before it is submitted to the relevant authority for approval.
- An Authority designated in terms of the World Heritage Convention Act may have significant input into the statutory authorisation process, the legal mandate of which resorts with other state departments, levels of government or statutory bodies. As such, the Authority could manage impacts to karst and cave associated with mining, undertaking of all the listed activities referred to in this legal paper, heritage impact assessments, impacts required in terms of biodiversity management and protection as well as genetic modification.
- The second category of legislation relates to those provisions, which are to be implemented and enforced by the Authority itself. For example, within this context, reference can be made to the provisions in the World Heritage Convention Act pertaining to the conclusion of agreements or the compilation of the Integrated Management Plan. Similarly, the regulations in terms of the National Environmental Management: Protected Areas Act contains various duties and obligations to be exercised by a management authority, being for example the Authority designated in terms of the World Heritage Convention Act.
- Whereas the implementation of the first mentioned legislation through intervention and coordination may require relatively limited infrastructure and resources, the implementation of those provisions, which require direct action, implementation and enforcement from an Authority, will be resource intensive.
- It is recommended that the Authority proceed to establish a monitoring system to identify applications for all types of authorisations requiring an environmental assessment before a decision is taken, within the COH WHS. As such, other state departments or statutory bodies must inform the Authority of applications submitted for development, water use licensing, prospecting and mining operations, atmospheric emission licences, undertaking of listed activities and change in land use within the COH WHS. A Memorandum of

Understanding (MoU) could serve as the legal vehicle whereby inter-governmental duties to communicate regarding applications for authorisation within the COH WHS could be formalised. In addition, communication by land owners or communities within the COH WHS to the Authority, of the undertaking of activities should be promoted.

- An Authority designated in terms of the World Heritage Convention Act should proceed to implement the regulations in terms of the National Environmental Management: Protected Areas Act. The relevant Authority must ensure that authorised officials (legally defined to mean an employee of a management authority, or any other person, acting as such on the written authorisation of a management authority and includes an environmental management inspector appointed in terms of Section 31B of NEMA), operating within the COH WHS, receive training to apply the regulations with regard to the protection of karst and cave in particular.
- Once the regulatory systems of indirect intervention and direct management and enforcement are established, consideration could be given to undertaking of a feasibility study to determine whether the development of dedicated sub-ordinate legislation (i.e. regulations) are required in order to manage and protect karst and cave.
- Furthermore, by way of a management response, it is recommended that the KWG produce, as soon as possible, a Guideline Document in respect of the management and protection of karst and cave in order to inform the Integrated Management Plan to be developed by the Authority. The Guideline Document can also serve as a useful guide to develop operational rules in terms of the World Heritage Site Administration Regulations.
- Finally, this legal paper serves as a legal baseline from where further action should be identified and recommended. It is recommended that further detailed legal assessment be given with regard to the development of an Integrated Environmental Management Plan in order to ensure coordination with the legislation referred to in this paper, specialist legal advice on the Authority's power of enforcement and legal training of authorised officials (being Authority employees) as referred to in the administration regulations issued under the National Environmental Management: Protected Areas Act as well as environmental management inspectors appointed in terms of the National Environmental Management Act. Training should in particular refer to the environmental legal framework for the management and protection of karst and cave referred to in this chapter.

3.3 Conclusions And Recommendations

Having regard to the legal framework identified in this legal paper as well as the abovementioned problem statements and response/actions required for the management and protection of karst and cave in the COH WHS, the following conclusions are reached:

- The legislation referred to in this chapter is primarily concerned with the regulation of aspects having an indirect bearing on the management and protection of karst. There is no legislation directly concerned with the management of karst although reference is made to aspects associated with karst in the World Heritage Convention, the World Heritage Convention Act and National Heritage Resources Act and other legislation concerned with the protection of environmental media such as water, air and soils. Therefore, karst situated within the COH WHS, presently derives indirect benefit by virtue of the status of the area as a world heritage site, national heritage site or protected area. There is therefore no immediate need for additional statutory measures dedicated to the management and protection of karst within the COH WHS in view of the fact that existing available statutory management measures appear to be adequate.
- With regard to caves situated in the COH WHS, existing statutory management and protection measures appear to be adequate. It is also noted that whereas limited direct references in legislation were identified with regard to karst, direct references to caves are to be found in national, provincial and local legislation. Unfortunately, with regard to provincial legislation applicable to the COH WHS it is concluded that such legislation is out of date and ineffective. It was found that the statutory provisions in the Limpopo Province legislation were progressive especially as far as the criminal sanctions are concerned. With regard to by-laws, laws relevant to the COH WHS in particular are disappointing in as far as management and protection of caves are concerned. Notwithstanding the aforementioned, there is no immediate need for additional statutory measures dedicated to the management and protection of caves within the COH WHS in view of the fact that existing available statutory management measures appear to be adequate.
- It is recommended that resources be allocated to focus on the development of guidelines on karst and caves to be incorporated into planning (i.e. Integrated Management Plans), operational rules (i.e. applicable within the COH WHS in terms of the Administration Regulations under the NEMPAA), statutory enforcement mechanisms and resources (i.e. Authority Officials and Environmental Management Inspectors) and training (i.e. community, property owners, economic sectors and enforcement), before specific legislation is developed to manage karst and cave in the COH WHS.
- The justification for the development of dedicated legislation becomes more compelling in respect of karst and cave that may not be situated within the confines of world heritage sites, natural heritage sites, provincial heritage sites or other protected areas in general. However, under these circumstances, it is recommended that the feasibility be assessed of developing additional legislation or to utilise the existing mechanisms identified in the national legislation to manage and protect such karst and cave.

- In addition to the conclusions reached on the statutory mechanisms whereby karst and cave may be managed and protected, it is also concluded and recommended that guidelines for the management of karst and cave should be developed as the first point of departure. As previously stated, the guidelines will serve to assist decision making, empowerment (education) and enforcement of measures to protect karst and cave in the COH WHS. Once developed for the COH WHS, these guidelines may serve as the basis for the development of national guidelines to be followed by legislative development.
- It is recommended that legal training of authorised officials employed by a management authority as well as environmental management inspectors be provided with technical and legal training regarding the legal framework in respect of the management and protection of karst and cave. Emphasis should be placed on rights and obligations associated with the various statutory mechanisms and remedies in the event of non-compliance.

ISSUE PAPER 4 THE STATE OF KARST ECOLOGY RESEARCH IN THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

J.F. Durand and D. Peinke

ABSTRACT

Although South Africa has one of the largest and oldest dolomitic deposits in the world, housing a host of organisms, very little research has been done on karst ecology in South Africa. The development of the Cradle of Humankind World Heritage Site as a major tourism attraction makes it imperative to do a thorough survey of the organisms that depend on karst ecosystems in this region. A management plan for karst ecosystems would be the first step towards the conservation of this sensitive and unique part of the biodiversity and natural heritage of South Africa.

4.1 Introduction

The karst system in the northern part of South Africa consists of a 2.2 billion year old carbonate-rich swath which extends from the North West Province, through Gauteng, to Mpumalanga and the southern parts of Limpopo Province. Over millions of years, solution cavities, common in this karst system, have given rise to a network of caves, sinkholes and aquifers. The remains of animals, including hominids, have accumulated for over three million years in many of these caves and sinkholes, and have petrified as part of cave-fills. The presence of these fossils proves the importance of caves as shelter for large mammal carnivores and hominids in the past.

In karst systems, aquifers and solution cavities, such as caves, caverns and dolines, still provide shelter to a variety of terrestrial and aquatic subterranean organisms. Solution cavities are unique, light deprived habitats, which under the right circumstances (i.e. the presence of water), can support intricate ecosystems that may house a multitude of organisms representing Monera, protists, fungi and animals. The light-deprived environment within subterranean solution cavities would preclude the possibility of plants growing there. Plants are absent from caves, except for in cave entrances and in the upper reaches of dolines, because their range is determined by the availability of light.

Many cave-dwelling organisms have become obligatory stygobites, which reproduce, feed and spend their whole life underground. Their morphological adaptations to the subterranean environment often make it impossible for them to live elsewhere. Other organisms such as certain bat species need caves for roosting, hibernation and reproduction, but hunt outside caves. There are also organisms such as porcupines, leopards and humans who are temporary or opportunistic cave dwellers and could under different circumstances, or other times of the year, find shelter elsewhere.

4.2 Problem Statement

Cave systems are dynamic, and new solution cavities form as old ones become filled in or collapse. Caves also provide a natural shelter for many species. This gives rise to the precarious situation where a sensitive ecological community may occur in a cave containing fossils and flowstone formations. Caves and fossils are the main geotourism and palaeotourism attractions in the Cradle of Humankind World Heritage Site (COH WHS), visited annually by thousands of tourists, learners and researchers who in turn have a negative impact on the rock formations and cave ecosystems.

Unfortunately tourist, educational and research activities, together with urbanisation and pollution, pose the greatest threats to karst ecology. Water containing acidic and toxic effluent from gold mines is released into the rivers and wetlands of the North West Province. Industrial waste from Gauteng is similarly released into the rivers. These pollutants will eventually seep into the groundwater and from there into the karst system of the North West Province and Gauteng, including the COH WHS. Mining of dolomite and calcite in karst systems have a major detrimental effect on karst ecosystems in those areas, which is also the case in the COH WHS.

Poor farming practices also pose a threat to karst ecology. The excessive abstraction of water can cause the water table and the level of water bodies within caves to fall.

Water in caves is important for the survival of water-dependent organisms, including bats that need a certain level of humidity in the cave. Insecticides and fertiliser, used on the horticultural and fruit-producing smallholdings in Krugersdorp District and grain farms in the eastern part of the North West Province, are accumulating in the soils and will eventually seep into the underlying karst system, wrecking havoc on the karst ecology in those areas, including the COH WHS.

Urbanisation is perhaps one of the most immediate threats to karst ecology in the COH WHS. New housing complexes and informal housing are encroaching on the COH WHS. Ecologically insensitive urbanisation negatively affects the indigenous fauna and flora, which poses a major threat to bats that depend on the insects that occur in these habitats. Any threat to the bat populations which roost in caves also has a detrimental effect on those organisms that depend on bats for bringing nutrients into the caves.

Disturbingly little is known of the ecological constituents and the interaction and interdependence between different biotic and abiotic components of South African karst systems. The physiological parameters necessary for their survival is also not fully understood. There is awareness of a few of the more noticeable cave organisms, but there is ignorance about the systematics, distribution and behaviour of the majority of the rest of the cave organisms.

Different subterranean organisms have different needs, and while some are highly vulnerable, others are much hardier and are more tolerant to negative impacts on their environment. Bats may abandon a roost due to human disturbance, while amphipods, fungi and microorganisms would be impervious to most human activities. In turn, amphipods, fungi and microorganisms would be much more sensitive to a drop in the water table than bats.

Without the necessary knowledge of karst ecology and an effective management plan for the karst system of the region, South Africa risks the ignominy of allowing part of its unique biodiversity to disappear and that in one of the first World Heritage Sites declared in South Africa shortly after the promulgation of the Biodiversity Act.

4.3 Discussion of the Current State of Knowledge on Troglobitic Organisms in the COH WHS

4.3.1 Literature review

The cave environment is usually subdivided into three zones. The twilight zone is near the entrance and is where the most diverse fauna occurs. The middle zone is in complete darkness, but its variable temperature supports several species, some of which may commute to the surface. The obligate troglobites occur in the deep zone, which is in complete darkness and has a constant temperature (Poulson and White, 1969).

Cave-dwelling organisms are subdivided into troglobites and troglophiles. Troglobites include those animals that are obligatory cave dwellers, for part or whole of their life cycle. Troglobites are characterised by the degree of troglomorphy which they have undergone in response to the dark, damp subterranean environments where they have to survive. Troglomorphy usually includes the loss of pigmentation and sight, as well as the attenuation of antennae and limbs. Troglophiles are animals that live in caves temporarily or opportunistically, usually only for shelter.

A separate subdivision of aquatic fauna exists (Gilbert *et al.*, 1994). In some cases this subdivision coincides with the subdivision of cave organisms, especially in the subterranean aquatic environments. Although subterranean amphipods are often called troglobites, they are actually stygobites (or sometimes called stygobionts) because they are confined to groundwater and not to the caves where they were originally observed by researchers. Most stygobites have undergone troglomorphy due to convergent evolution because of the similar conditions that exist in subterranean habitats, whether aquatic or in caves above water (Danielopol *et al*., 1994). Species that occur in both epigean (surface aquatic) and hypogean (subterranean aquatic) habitats usually have not undergone troglomorphy and are called stygophiles. Aquatic species that live in epigean environments are called stygoxen.

Although there are many troglobites, troglophiles, stygobites and stygophiles worldwide, bats and arthropods are the two main animal groups that dominate the present cave ecology in South Africa.

4.3.1.1 BATS

South Africa has a remarkable diversity of mammals, including bats. Rodents constitute almost 40 percent of the mammals worldwide, while bats constitute almost 30 percent. Although there are no endemic bat species in South Africa, there are more bat species than rodent species in South Africa (Rautenbach, 1985).

Many of the caves, sinkholes, abandoned mine tunnels, and buildings in the COH WHS serve as roosting sites for bats, contributing to the high biodiversity of the region. The region is characterised by a variety of habitats, including streams, vleis, grassland and hills, which support a distinct floral ecotone between the northern Bushveld and southern Grassland Biomes (Krige, 2004). This varied environment in turn supports a rich diversity of fauna, including the insects on which the bats depend.

The insectivorous cave dwelling *Nycteris thebaica* (common slit-faced bat), *Myotis tricolor* (Temminck's hairy bat), *Miniopterus schreibersii natalensis* (Schreiber's long-fingered bat or Natal clinging bat), *Rhinolophus blasii* (peak-saddle horseshoe bat) and *Rhinolophus clivosus* (Geoffroy's horseshoe bat) have been reported from the "dolomite caves in the Krugersdorp District" (Rautenbach, 1982; Taylor, 2000).

Some of these species, such as the *Miniopterus schreibersii,* have a very wide range, and occurs in the form of several subspecies in Africa, south of the Sahara, southern Eurasia and Australia (Smithers, 1983). The most detailed research on bats in the COH WHS has been done by M. van der Merwe of the Mammal Research Institute at the University of Pretoria in the 1970s (Van der Merwe 1973a, 1973b, 1973c, 1975, 1977, 1978, 1979). This research focused on the roosting, migration and reproduction strategies of the vespertilionid bat *Miniopterus schreibersii natalensis*. During his research between 1957 and 1969, he banded more than 21 800 bats, of which 16 900 were *Miniopterus schreibersii natalensis* (Van der Merwe, 1989). Later research included a report on longevity in Schreiber’s long-fingered bat based on recaptures of these banded individuals (Van der Merwe, 1989). *Miniopterus schreibersii natalensis* seem to prefer savannah-bushveld, coastal forest and the grassland of the Gauteng Highveld and the Drakensberg Mountains (Taylor, 2000). Research on the faecal remains of bats indicates that they mainly eat beetles and moths at the Sengwa Wild Life Research Area in Zimbabwe, whereas research at De Hoop Nature Reserve in the Western Cape has shown that they eat moths, flies and bugs (Fenton and Thomas, 1980).

Rhinolophus clivosus has a wide distribution in Africa and also occurs in the Middle East. It is a common resident in caves and abandoned mines in the COH WHS. Its preferred habitat is savannah-bushveld, but it also occurs in open grassland and the Drakensberg Mountains and even in deserts (Rautenbach, 1982; Smithers, 1983; Taylor, 2000). Herselman (1980) reports that *Rhinolophus clivosus* has a feeding range of up to 10 km from its roost. It feeds mainly under the tree canopy, and according to the insect remains found in its roosts, it seems as if they feed mainly on moths and small beetles (Rautenbach, 1982).

Rhinolophus blasii is less common but has a wider distribution than *Rhinolophus clivosus*, occurring in Eurasia. *R. blasii* has similar roosting needs as *R. clivosus* and therefore also occurs in the COH WHS where it inhabits caves (Smithers, 1983; Taylor, 2000). Rautenbach (1982) reports that *Rhinolophus* hibernates in COH WHS caves.

Nycteris thebaica has a wide distribution in Africa and also occurs in the Middle East and although they have a wide habitat tolerance, they seem to prefer savannah-bushveld (Smithers, 1983). They are clutter foragers and gleaners, which feed mostly on longhorn grasshoppers and moths (Fenton, 1975; Taylor, 2000).

Myotis tricolor is indigenous to East and Southern Africa (Smithers, 1983). It seems to prefer woodland areas, and also occurs in drier, more open habitats and mountainous areas (Smithers, 1983; Taylor, 2000). Its distribution seems however to be governed by the presence of caves (Watson, 1990). They have also been documented in abandoned mine tunnels and often share their roosts with other bat species, in particular the *Miniopterus schreibersii* and *Rhinolophus* species (Smithers, 1983).

Certain bat species, such as *Miniopterus schreibersii,* have very particular humidity and temperature needs and would therefore be found mostly in caves where these requirements are met (Van der Merwe, 1973b). Other bat species are more adaptable and would roost in rocky crevices, abandoned mine tunnels, roof overhangs, plants, and caves. *Nycteris thebaica*, *Myotis tricolor*, *Miniopterus schreibersii natalensis*, *Rhinolophus blasii* and *Rhinolophus clivosus* would often roost in the same caves (Rautenbach, 1982; Taylor, 2000).

House-dwelling bats, such as the Cape serotine (*Eptesicus capensis*) and the yellow house bat (*Scotophilus dingani*) have also been recorded in the Krugersdorp District. These bats live in association with humans and may therefore pose an ecological threat to the cave-dwelling bats as urbanisation continues in and around the COH WHS.

Eptesicus capensis occurs over the greater part of Africa, in the region south of the Sahara, and has a very broad habitat tolerance, from forests to deserts (Smithers, 1983; Taylor, 2000). They often roost in suburban areas in roofs and are drawn to lights at night to feed on the insects, which are attracted by the lights, and they feed on different insects such as beetles, lacewings, moths, bugs and flies, depending on availability (Taylor, 2000).

Scotophilus dingani occurs over a wide area in Africa south of the Sahara, as well as the southernmost tip of the Arabian Peninsula and the islands of Madagascar, Réunion and Mauritius (Smithers, 1983). It prefers savannah bushveld and coastal forests but also often occurs in the roofs of suburban houses. It is a clutter feeder and feeds on a wide range of insects including beetles, bugs, flies, termites, moths and lacewings (Taylor, 2000).

Unfortunately roof-roosting bats are amongst those bat species that are attracted to the insects attracted by lights. These bats include the Cape serotine

(*Eptesicus capensis*) and yellow house bat (*Scotophilus dingani*) in the Krugersdorp District, which compete with the cave-roosting bats for food resources. In addition, the sound frequencies emitted by mercury vapour lights, which are commonly used as street lights, interfere with the echolocation of bats which emit constant frequency calls such as *Rhinolophus* species. *Eptesicus capensis* and *Scotophilus* sp. produce frequency modulated calls and seems impervious to the frequencies emitted by street lights. There are already house bats in the COH WHS and with the increase of urbanisation on the periphery of the COH WHS and the erection of more buildings within the COH WHS, more roosting sites will be created for house bats. Street lights will further add to the disruption of the cave bat hunting environment and at the same time benefit house bats.

4.3.1.2 ARTHROPODS

The arthropods that have been reported from caves within the COH WHS include millipedes, spiders, lice, insects and amphipods. Only the amphipod *Sternophysinx filaris* (Holsinger and Straskraba, 1973) and spiders (Dippenaar and Myburgh, 2005) have received any mention in scientific publications so far.

4.3.1.3 AMPHIPODS

Amphipods are peracarid crustaceans, which are, probably next to the nematodes, the most ubiquitous animals on earth. They occur in environments as varied as the sea floor to mountain tops, where they can inhabit marine, freshwater, brackish and even damp soil in terrestrial environments. Most live on or in sediment under water but some are planktonic. The Order Amphipoda contains nearly 7 000 described species, which are subdivided into four suborders: the Gammaridea, Caprellidea, Hyperiidea and Ingolfiellidea (Bousfield, 1978). The vast majority of amphipods belong to the Suborder Gammaridea which contains all the freshwater and subterranean taxa, and includes over 1 000 genera and over 5 500 species (Holsinger, 2003).

Gammaridean amphipods constitute an important component of the aquatic and subterranean ecology worldwide. Some gammarids are epigean but the majority described so far is stygobitic. There is a high level of endemism amongst subterranean amphipods due to the distributional restraints that they are subjected to. The amphipods that occur in southern Africa are all endemic to this region.

Eight stygobitic species belonging to the Superfamily Crangonyctoidea (Bousfield, 1978), Family Sternophysingidae (Holsinger, 1992), occur in caves and springs from KwaZulu-Natal, Mpumalanga, Limpopo, Gauteng, and North West Provinces, to central Namibia (Griffiths, 1996).

The first member of the Sternophysingidae was discovered in Irene, near Pretoria, by Rev Noel Roberts and Mr J. Hewitt of the Albany Museum in Grahamstown. More amphipods, which Mr Austin Roberts and Mr Paul Methuen presumed belonged to the same species as that in Irene, were collected at “two large caves” at the Makopane Caves (clearly the well-known amphipod-bearing Ficus Cave and Peppercorn’s Cave) (Holsinger, 1992). The amphipods were described and named *Eucrangonyx robertsi* by Methuen (1911a, 1911b). Methuen recognised its position within Gammaridea and its affinities to *Crangonyx* of North America.

Subsequently *Eucrangonyx* was sunk in favour of *Crangonyx* by Schellenberg (1936) and later *Crangonyx robertsi* was renamed *Sternophysinx robertsi* by Holsinger and Straskraba (1973). Holsinger and Straskraba (1973) also described *Sternophysinx filaris* from Sterkfontein Caves.

Sternophysinx transvaalensis was reported from surface streams in the northern part of the Drakensberg Mountains (Barnard, 1949). Holsinger and Straskraba (1973) reassigned these amphipods, initially misidentified by Barnard (1949) as *Crangonyx robertsi*, to *Sternophysinx transvaalensis.* Subsequently, *Sternophysinx transvaalensis* were reported from springs in the Nash Nature Reserve in the COH WHS, by Salome Tasaki (2006).

Griffiths (1981) described *Sternophysinx alca* from Peppercorn's Cave and Ficus Cave near Makopane (Potgietersrus). Griffiths (1991) described *Sternophysinx basilobata* from Boesmansgat Cave near Kuruman and *Sternophysinx hibernica* from Naos Cave near Windhoek, Namibia. Holsinger (1992) described *Sternophysinx calceola* from Matlapitse Cave near Trichardtsdal and Tasaki (2006) reported members of the same species at Koelenhof Cave in the COH WHS. Griffiths and Stewart (1996) described *Sternophysinx megacheles* from Boesmansgat Cave near Kuruman.

An interesting and as yet unexplained relationship exists between two different species of amphipods observed at four different localities. *Sternophysinx filaris* occurs in conjunction with *Sternophysinx calceola* at Koelenhof Cave in the COH WHS (personal observation). This reflects the situation at Chaos Cave near Potchefstroom where these two species also occur sympatically (Griffiths and Stewart, 1996). *Sternophysinx robertsi* occurs with *Sternophysinx alca* at Peppercorn's Cave and Ficus Cave near Makopane (Potgietersrus) (Holsinger, 1992). *Sternophysinx basilobata* occurs in conjunction with *Sternophysinx megacheles* at Boesmansgat Cave near Kuruman (Griffiths, 1991; Griffiths and Stewart, 1996). The larger *Sternophysinx megacheles*, *S. alca* and *S. calceola* are all equipped with strong gnathopods, compared to the more abundant, smaller and delicate *S. basilobata*, *S. robertsi* and *S. filaris*. *Sternophysinx alca* and *S. calceola* crawl around the bottom of cave pools, while *S. robertsi* and *S. filaris* are active surface swimmers (Holsinger, 1992; Griffiths and Stewart, 1996). At this stage it is not yet known whether the same niche separation exists between *Sternophysinx megacheles* and *S. basilobata* (Griffiths and Stewart, 1996). Preliminary evidence (Dr Jacques Martini quoted by Griffiths and Stewart, 1996) could indicate that the larger and less numerous species could prey upon the smaller and more numerous species.

It is necessary to clarify an important point which is the subject of considerable misunderstanding – it is generally assumed that since amphipods have been observed in subterranean water bodies, especially caves, that they are troglobites and that they are limited to these environments. The fact that some species such as *Sternophysinx filaris*, *S. calceola*, *S. robertsi* and *S. transvaalensis* have such a wide distribution is often met with incredulity. The fact that most

Sternophysinx amphipods were observed in the past in water bodies in caves does not imply that they do not occur elsewhere in groundwater. In fact, "subterranean lakes" are merely the top surface of the water table visible in caves.

Amphipods occur within groundwater, including underground lakes, aquifers, interstitial spaces between pebbles, grains of sand, and springs, and are therefore much more widespread than previously thought. In other words, rather than being troglobites due to their incidental occurrence in cave lakes, amphipods are stygobites due to their ubiquitous occurrence in groundwater.

Due to the dark environment in which stygobitic amphipods live, they have undergone convergent evolution, similar to that of troglobites, and have acquired troglomorphic adaptations, including reduced or absence of pigmentation and eyes and the attenuation of appendages, usually antennae or pereopods. Barnard (1949) remarked that freshwater amphipods are "cryptozoic, meaning they live under stones or in crevices or amongst vegetation, dead leaves and other detrital matter on the bottoms of streams. All these habitats, to the animals themselves, are "caves"."

The occurrence of amphipods in caves is not extraordinary or unique according to Barnard, (1949) who argued that amphipods have a wide distribution in freshwater systems in South Africa and mentions the fact "that the stream flows through or issues from a topographical feature, called by human beings a cave, is immaterial." He also recognised that the diverse and wide distribution of gammarid amphipods in surface streams from the Western Cape to the top of the Drakensberg Mountain to caves in the Limpopo Province are mainly due to "the presence of permanent water and absence of liability of scouring floods".

4.3.2 The food web and energy flow within karst systems

Since the mammalian predators and cave-dwelling hominids abandoned the caves in the COH WHS, bats have become by far the most important active importers of organic matter into the caves. Bats are therefore one of the most important links between the photosynthetic process outside the cave and the troglobitic end consumers within the cave. The food web above the water table in caves consists as far as we know, of micro-organisms, fungi, crustaceans and insects that feed on the bat guano and spiders, millipedes and predatory insects that feed on the coprovores in turn.

The success and survival of the bats, depends directly on the vegetation types, which support the insects they feed on (Gelderblom *et al.*, 1995). The availability of food, which varies seasonally due to climatological factors such as rainfall, has a direct correlation to the numbers of bats in an area (McDonald *et al.*, 1990). A loss in the habitats that bats depend on (due to urbanisation or farming), would clearly lead to their demise.

The preferred habitats and food of the different species of bats in the COH WHS differ slightly, allowing their roosting and feeding ranges to overlap. Different species of bats may at certain times of the year also share roosts, and could even be found in the same clusters (Van der Merwe, 1973a; Smithers, 1983;

McDonald *et al.*, 1990). There might also be some degree of resource partitioning amongst *Miniopterus schreibersii* and *Rhinolophus clivosus* in the COH WHS similar to that reported in De Hoop Nature Reserve by McDonald *et al.* (1990). Fenton and Thomas (1980) warn against the categorization of bats as "beetle, moth or fly specialists" due to the fact that many are opportunistic feeders that will change their feeding strategies according to the availability of insects. Different species of bats are active at different times of the night, use different hunting strategies (i.e. capturing insects in full flight and gleaning and speed of flight) they also hunt in different areas (i.e. over water bodies, grassland and under tree canopies) (Fenton and Thomas, 1980; McDonald *et al.*,1990).

The food web in karst is complex and is linked to the photosynthetic and possibly also to non-photosynthetic energy sources. Various anthropogenic impacts threaten the viability of the karst ecosystem (Durand, 2008).

4.3.2.1 BAT FAECES

It has been postulated that troglobites, including amphipods, subsist *inter alia* on bat faeces (Holsinger, 1988). Holsinger (1992) however reported that there were several bat species at Matlapitse Cave near Trichardtsdal at the time amphipods were collected and that there were more amphipods in the pools that contained less bat faeces.

4.3.2.2 ALLOCHTHONOUS EPIGEAN FOOD SOURCES

Allochthonous epigean food sources sustain many aquatic animals (Steward and Davies, 1990), and this seems to be the case in karst systems as well (Barr and Holsinger, 1985; Holsinger, 1988). Amphipods, which are considered to be the most diverse, widespread and populous crustacean taxon, are known detritivores and would feed on any organic material in the water, including the carcasses of their dead or leaf litter washed into the karst system from outside.

4.3.2.3 BACTERIA

Bacteria have long been suspected to be a food source for troglobites (Poulson and White, 1969). Although amphipods are renowned detritivores, they also feed on the bacteria growing on the decaying allochthonous food sources. Bacteria growing on underwater surfaces produce a biofilm that serves as a food source for many groundwater invertebrates including amphipods (Gilbert *et al.*, 1994). Autolithotrophic bacteria may also serve as a food source, especially in interstitial spaces in hypogean habitats.

4.3.2.4 FUNGI

In the past, fungi have been overlooked as a food source of subterranean animals. Organic material is broken down by fungi and bacteria and the nutrients made available to small subterranean animals. It seems likely however, that the animals, such as amphipods, also feed on the fungi directly (Dickson and Kirk, 1976; Kostalos and Seymour, 1976).

There could also be a whole and essentially separate food web below the water table consisting of bacteria, fungi and amphipods. They also feed on the organic film surrounding the sand grains on the floor of the body of water. This organic film consists primarily of bacteria and fungi. At this stage it is not known which of these bacteria are autolithotrophic and which are organotrophic. Ultimately amphipods form a link in the food web by serving as food for other invertebrates and fish (Bousfield, 1978)

4.4 Unpublished Information On Cave Ecology In The COH WHS

The following unpublished but potentially useful information is available from the sources listed below. Access to cave locality information is, however, strictly controlled by the various organisations and will only be made available under exceptional circumstances.

Report of current but unpublished research being conducted at universities, GDACE and the NFI (Transvaal Museum):

- University of Johannesburg (UJ), Zoology Department, Karst Ecology Research coordinator: J.F. Durand

The Zoology Department of the UJ has been conducting research on karst ecology, aquatic health and geotourism in the COH WHS over the past five years. Research projects include: the aquatic health and the management of stream fisheries; the distribution of bats, the study of the feeding behaviour and distribution of amphipods; the study of the microbiology associated with amphipods; and the interaction between organisms in the karst ecosystem of the COH WHS. Some of these projects have been done in conjunction with the Water Research Commission. In our research on caves, we have come across many invertebrates, including arthropods such as millipedes, spiders, lice and insects. Except for the preliminary work done by Ansie Dippenaar on cave spiders, no survey of these organisms has been done. These organisms will be the focus of future research of the Department of Zoology of the University of Johannesburg.

- University of Pretoria, Department of Zoology, Mammal Research Institute, Researcher: Mac van der Merwe

Prof. Mac van der Merwe is one of the best-known bat specialists in South Africa. He is actively researching bat reproduction, migration, roosting and feeding habits country-wide and has published several papers on these topics. He has done the most extensive research on a bat community that roosts in caves within the COH WHS.

- University of Pretoria, Faculty of Veterinary Science, Department of Paraclinical Sciences, Researcher: Jan Myburgh

Jan Myburgh has been collecting spiders in caves for many years. He and Ansie Dippenaar of the Agricultural Research Council are cooperating on cave spider research.

- Gauteng Department of Agriculture, Conservation and Environment (GDACE), Researcher: Dean Peinke

GDACE's cave database currently contains information on 65 caves in the COH WHS. Detailed cave descriptions, photographs and information on the occurrence of bats and other fauna are available for 43 of these; eight of which have been identified as important roost sites for the following cave roosting bats; *Myotis tricolor* (Near threatened), *Miniopterus schreibersii* (Least concern), *Rhinolophus clivosus* (Least concern) and *Nycteris thebaica* (Least concern). As part of their ongoing efforts to locate and protect these sensitive environments, GDACE, working in collaboration with the Cradle of Humankind World Heritage Site Management Authority, will be surveying a further 60 caves in the COH WHS during the course of 2005. A more detailed bat research and monitoring programme will also be launched towards the end of 2005.

- Transvaal Museum of the Northern Flagship Institute (NFI), Researcher and Collections Manager: Teresa Kearney

The mammal collection of the Transvaal Museum contains numerous specimens, particularly of cave-dwelling bats, that have been collected from this region over the preceding 100 years or more. GDACE is currently extracting the COH WHS data from the overall database and will use this to look at trends and historical distributions.

Unpublished or grey information in the possession of the Transvaal Museum, Northern Flagship Institute (NFI), caving societies and the Gauteng and Northern Regions Bat Interest Group:

- Transvaal Museum of the Northern Flagship Institute (NFI)

After years of faunal surveys and bat research conducted in the COH WHS, mainly by Naas Rautenbach, interest in the area has dropped off. The Transvaal Museum maintains an extensive collection of specimens, including bats and amphipods from the COH WHS, and the addition of new specimens to the collection is welcomed.

- Southern African Speleological Association (SASA)

SASA and its affiliated organisations (Speleological Exploration Club, Cave Exploration Rescue and Adventure Club and the Potch Potholers) have a wealth of information on the location of caves within the COH WHS. Although the exact number of caves is not known, it is believed to be considerable. These groups also all publish cave descriptions and articles on cave outings in their newsletters and bulletins and these will almost certainly contain some useful information.

- Cave Research Organisation of Southern Africa (CROSA)

CROSA similarly has information on the location of caves within the COH WHS. They also conduct regular outings and publish articles, which may be of value in their newsletters.

- Gauteng and Northern Regions Bat Interest Group (GNORBIG)

GNORBIG plays an important role in the surveying the distribution of bat populations in Gauteng, Limpopo and Mpumalanga Provinces. Although surveys have been done in the Hennops River area on the northern rim of the COH WHS, very little work has been done in the COH WHS proper. Many members of GNORBIG are also members of the caving societies. GNORBIG also publish articles on the distribution and behaviour of bats in their newsletter.

4.5 Recommendations

Research required - research gaps

There is a pressing need to do a thorough systematic description of all the organisms living in caves, fountains, surface streams and aquifers, and their distribution in the COH WHS. After establishing this baseline information, it is important to determine the ecological needs and physiological parameters of cave organisms, as well as the interaction between interspecific relationships between subterranean organisms within the karst system and between troglophiles and species outside the caves.

One of the major gaps in our knowledge concerns the diverse invertebrate communities within caves.

The energy flow of the karst ecosystem should also be studied in order to understand extra- and intra-karst nutrient relationships.

The primary producers within the karst ecosystem should be identified and studied, which would include studies on the fungi and bacteria.

The distribution, population density and reproductive success of the bat populations in the COH WHS and Limpopo Province should be monitored constantly.

4.6 Summary

It is imperative that a survey be done on the karst ecosystem of the COH WHS and surrounding areas in order to compile an inventory of karst-dependent organisms and their distribution. It is equally important to determine the interrelationships between karst-dependent organisms and their abiotic and biotic environment, in order to draw up a responsible management plan for the conservation of karst ecosystem and the utilisation of the karst system for scientific, tourism and educational purposes. An ecologically responsible solution has to be found in order to protect our extremely valuable bat populations, which are in turn crucially important for the survival of the unique and vulnerable troglobitic invertebrate and fungi populations. These delicate ecosystems can also be utilised as an ecotourism attraction and enhance the uniqueness of the COH WHS.

REFERENCES

BARNARD KH (1949) A fresh-water amphipod from Mont-aux-Sources. Annals of the Natal Museum 11, 523-525.

BARR TC and HOLSINGER JR (1985) Speciation in cave faunas. Ann. Rev. Ecol. Syst. 16, 313-337.

BOUSFIELD EL (1978) A revised classification and phylogeny of amphipod crustaceans. Transactions of the Royal Society of Canada (4th Series) 16, 343-390.

DANIELOPOL PL, CREUZÉ DES CHÂTELLIERS M, MOESZLACHER F, POSPISIL P and POPA R (1994) Adaptations of Crustacea to interstitial habitats: a practical agenda for ecological studies, Basic attributes of groundwater ecosystems and prospects for research. Groundwater ecology (Gilbert, J, Danielopol DL and Stanford JA, eds.), Academic Press, California.

DICKSON GW and KIRK PW (1976) Distribution of heterotrophic microorganisms in relation to detritivores in Virginia caves. The distributional history of the biota of the southern Appalachians. Part IV, Algae and Fungi. (Parker BC and Roane, MK, eds.). University Press of Virginia, 205-226.

DIPPENAAR-SCHOEMAN A and MYBURGH J (2009) A review of cave spiders (Arachnida: Aranae) from South Africa. Transactions of the Royal Society of South Africa 64 (1), 53-61.

DURAND JF (2008) Die karst-ekologie van Suid-Afrika met spesiale verwysing na die Wieg van die Mensdom Wêrelderfenisgebied. Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie 24 (4), 5-15.

FENTON MB (1975) Observations on the biology of some Rhodesian bats, including a key to the Chiroptera of Rhodesia, Life Sci. Contr. R. Ont. Mus. 104, 1-27.

FENTON MB and THOMAS DW (1980) Dry-season overlap in activity patterns, habitat use and prey selection by sympatric African insectivorous bats. Biotropica 12 (2), 81-90.

GELDERBLOM CM, BRONNER GN, LOMBARD AT and TAYLOR PJ (1995) Patterns of distribution and current protection status of the Carnivora, Chiroptera and Insectivora in South Africa. South African Journal for Science 30, 103-114.

GILBERT J, STANFORD JA, DOLE-OLIVIER MJ and WARD JV (1994) Basic attributes of groundwater ecosystems and prospects for research. Groundwater ecology (Gilbert, J, Danielopol DL and Stanford, JA, eds.). Academic Press, California.

GRIFFITHS CL (1981) The freshwater Amphipoda (Crustacea) of South and South West Africa. Annals of the South African Museum 83, 79-97.

GRIFFITHS CL (1991) Two new crangonyctoid amphipods from southern African caves (Crustacea). Cimbebasia 13, 81-89.

GRIFFITHS CL and STEWART BA (1996) Two new freshwater amphipods from South Africa (Crustacea, Amphipoda). Bolletino del Museo Civico de Storie Naturale de Verona 20, 75-87.

HERSELMAN JC (1980) The distribution and status of bats in the Cape Province. Internal Report, Department of Nature and Environmental Conservation of the Cape.

HOLSINGER JR (1988) Troglobites: the evolution of cave-dwelling organisms. American Scientist 76, 147-153.

HOLSINGER JR (1992) Sternophysingidae, a new family of subterranean amphipods (Gammaridea: Crangonyctoidea) from South Africa, with description of Sternophysinx calceola, new species, and comments on phylogenetic and biogeographic aspects. Journal of Crustacean Biology 12 (1), 111-124.

HOLSINGER JR (2003) What are amphipods? http://web.odu.edu/sci/biology/jrh/what is.htm

HOLSINGER JR and STRASKRABA M (1973) A new genus and two new species of subterranean amphipod crustaceans (Gammaridae) from South Africa. Annales de Speleology 28, 69-79.

KOSTALOS M. and SEYMOUR RL (1976) Role of microbial enriched detritus in the nutrition of Gammarusminus (Amphipoda). Oikos 27, 512-516.

KRIGE A (2004) Floristic study of the silver vegetation of Kalkheuvel West in the Cradle of Humankind World Heritage Site, North West Province, South Africa.

Botany Honours Research Report, University of Pretoria.

MCDONALD JT, RAUTENBACH IL and NEL JAJ (1990) Roosting requirements and behaviour of five bat species at De Hoop Guano Cave, southern Cape Province of South Africa. South African Journal for Wildlife Research 20 (4), 157-161.

METHUEN PA (1911a) On an amphipod from the Transvaal. Proceedings of the Zoological Society of London 2, 948-957.

METHUEN PA (1911b) Transvaal Crustacea, Part 2, Notice of a freshwater amphipod from South Africa. Annals of the Transvaal Museum 3, 96-101.

POULSON TL and WHITE WB (1969) The cave environment. Science 165 (3897), 971-981.

RAUTENBACH IL (1982) Mammals of the Transvaal. Ecoplan Monograph No.1, Pretoria.

RAUTENBACH IL (1985) Bat research at the Transvaal Museum. Transvaal Museum Bulletin 21, 17-20.

SCHELLENBERG A (1936) Die Amphipodengattungen um Crangonyx, ihre Verbreitung und ihre Arten. Mitteilungen Zoologischen Museum Berlin 22, 31-43.

SMITHERS RHN (1983) Mammals of the southern African subregion, University of Pretoria.

STEWARD BA and DAVIES BR (1990) Allochthonous input and retention in a small mountain stream, South Africa. Hydrobiologia 202, 135-146.

TASAKI S (2006) The presence of stygobitic macroinvertebrates in karstic aquifers: a case study in the Cradle of Humankind World Heritage Site. Unpublished MSc Dissertation, University of Johannesburg.

TAYLOR PJ (2000) Bats of southern Africa: guide to biology, identification and conservation, University of Natal Press, Pietermaritzburg.

VAN DER MERWE M (1973a) Aspects of temperature and humidity in preferred hibernation sites of the Natal clinging bat Miniopterus schreibersii natalensis (A. Smith, 1834). Zoologica africana 8 (1), 121-134.

VAN DER MERWE M (1973b) Aspects of hibernation and winter activity of the Natal clinging bat, Miniopterus schreibersii natalensis (A. Smith, 1834), on the Transvaal Highveld. South African Journal for Science 69, 116-118.

VAN DER MERWE M (1973c) Aspects of social behaviour in the Natal clinging bat, Miniopterus schreibersii natalensis (A. Smith, 1834). Mammalia 37, 379-389.

VAN DER MERWE M (1975) Preliminary study of the annual movements of the Natal clinging bat. South African Journal for Science 71, 237-241.

VAN DER MERWE M (1977) Reproduction of the Natal clinging bat, Miniopterus schreibersii natalensis (A. Smith, 1834), DSc Thesis, University of Pretoria.

VAN DER MERWE M (1978) Postnatal development and mother-infant relationships in the Natal clinging bat, Miniopterus schreibersii natalensis (A. Smith, 1834). Proceedings of the fourth international bat research conference, Kenya, 309-322. National Academy of Arts and Science.

VAN DER MERWE M (1979) Foetal growth curves and seasonal breeding in the Natal clinging bat Miniopterus schreibersii natalensis. South African Journal of Zoology 14, 17-21.

VAN DER MERWE M (1989) Longevity in Schreiber's' long-fingered bat. South African Journal of Wildlife Research 19 (2), 87-89.

WATSON JP (1990) Westward range extension of Temminck's hairy bat in South Africa and Lesotho. South African Journal for Wildlife Research 20 (3), 119-121.

ISSUE PAPER 5 THREATS TO THE KARST ECOLOGY OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

J.F. Durand

ABSTRACT

Gauteng is the province with the largest and fastest growing population in South Africa. The province is also the smallest and therefore the most densely populated region in South Africa. Fast-growing urbanisation is characterised by the growing need for new water resources and growing pressure on the existing sanitation and waste management infrastructure. Groundwater provides an obvious alternative additional water supply for the growing water needs of Gauteng. Unfortunately the abstraction of groundwater poses a serious threat to karst ecology. In addition, mining activities, poor waste management principles, poor farming practices, urbanisation and pollution threaten not only karst ecology but also the potability of surface and groundwater in Gauteng. The karst ecology of the Limpopo and North West Provinces are subject to similar but fewer environmental pressures than that of Gauteng.

5.1 Introduction

Since the Karst Working Group was formed, the palaeontological sites of Taung near Buxton in North West Province and Mokopane's Valley between Mokopane and Polokwane in the Limpopo Province have been declared World Heritage Sites. Although the main focus of this report is the karst system of the central part of the Cradle of Humankind World Heritage Site (COH WHS) to the north of Krugersdorp, it should not be seen in isolation, since karst aquifers connect the surface streams and the water table in North West, Limpopo and Gauteng Provinces. Pollution of the groundwater, surface streams or aquifers in one province would inevitably spread to the adjacent provinces. Many elements of the biota, such as the amphipods and bats that occupy the groundwater and caves, are found in the caves of Gauteng, Limpopo and North West Provinces.

The COH WHS is situated to the north of Krugersdorp on the border of Gauteng and North West Province. The Taung World Heritage Site is situated approximately 480 km to the south-west of Krugersdorp and Mokopane's Valley World Heritage Site is situated approximately 300 km to the north-east of Krugersdorp. The anthropogenic factors in these three provinces that have the greatest impact on the karst system in the COH WHS include farming, mining, urbanisation, industry, sport and tourism. These anthropogenic disturbances in addition to structural damage and pollution pose a serious threat to aquatic ecosystems (Loeb and Spacie, 1994).

The reasons why the conservation of the karst system in the COH WHS should become one of the main priorities of the government, NGOs and public sector are numerous. The COH WHS houses not only one of the largest deposits of Plio-Pleistocene fossils in the world, but also numerous indigenous bat species and endemic invertebrate species of which several are dependent on the karst system in this area. The factors, which may lead to the extinction of such species, as identified by IUCN (1994), are all applicable to the situation in the COH WHS. These include recorded or predicted population decline, small populations and restricted distribution.

The COH WHS is also the only World Heritage Site at this stage in Gauteng, and could become the main tourist attraction of this province. In addition, the karst system in Gauteng, North West and Limpopo Provinces probably contains more water than the total volume of surface water stored in rivers and dams in these provinces and may become an essential additional water supply for human consumption. The karst system in these provinces is already being utilised by several towns as their primary source of water (Bredenkamp and Xu, 2003).

5.2 Mining

5.2.1 Limestone and dolomite mining

Limestone and lime have probably more uses in industry than any other natural product (Martini and Coetzee, 1976). Limestone and dolomite form the backbone of the cement industry, and are also used as flux in metal melting and to neutralise acidic soils. Burnt lime is used in the sugar and gold industry, in water purification and in the extraction of uranium oxide (Martini and Wilson, 1998).

Limestone and dolomite mining entail the destruction of vast areas of karst deposits. Limestone mining in Gauteng, North West and Limpopo Provinces date to more than a century ago, when the demand for lime increased for use in the gold extraction process and in the building industry. Limestone mining exposed many cave breccia deposits of which several contained fossils. In fact, it was miners which alerted the scientific community to the presence of fossils at Taung WHS, Mokopane's Valley WHS and many other sites in the COH WHS.

Many cave habitats are also destroyed and altered in the limestone and dolomite mining process. The damage to the cave structure can be seen in many of the caves in the COH WHS including Sterkfontein, Wonder Cave, Haasgat, Bolt's Farm, Gladysvale and the lime quarry at Mokopane's Valley were travertine deposits and flowstone formations have been mined. Although mining has ceased in many of the fossil sites, other human activities including caving, tourism, education and excavations have taken its place.

Limestone and dolomite mining have had a negative impact on the structural integrity of the karst system in the area. Cave habitats have been destroyed and the natural flow of water through the karst system has been interfered with and altered in the process. Chemicals such as diesel and petrol (commonly used to fuel pumps, generators and other machinery) that have been used in the mining process and the resulting carbon dioxide have also had a negative effect on the karst system.

To compound the situation even further, illegal mining activities are still taking place in the COH WHS. Evidence of mining (especially open-quarry slate and dolomite mining) and brickworks is a common sight in the COH WHS. The negative visual impact of open quarries is considerable since little has been done to rehabilitate the mines in the area (West Rand District Municipality, 2005).

The cumulative effect of the irritation of mining activities such as blasting, drilling, bulldozing on the one hand and throngs of visitors to caves on the other, in addition to the large scale destruction of cave features and the accompanying pollution of the karst system, would be the main reason why many sites such as Sterkfontein and Wonder Cave have effectively been abandoned by bats and other troglophiles. On the other hand, abandoned mines in the COH WHS that are not used as tourist attractions are readily settled by colonies of Horseshoe bats (*Rhinolophus* species) (Rautenbach, 1982; Taylor, 2000), *Nycteris thebaica*, *Miniopterus schreibersii* and *Myotis tricolor* (Peinke, 2005).

5.2.2 Gold mining

5.2.2.1 ABSTRACTION AND DISCHARGING OF WATER FROM GOLD MINES

The Witwatersrand Group, from which more than half of the world's gold has been extracted, is situated in close proximity to the dolomites of the Malmani Subgroup constituting the karst system in North West Province and Gauteng. Certain gold mines in the West Rand are situated below karst aquifers that have to be dewatered to allow mining (Morgan and Brink, 1981; Warwick *et al.*, 1987). The massive abstraction of water from the mines in this region led to sinkholes forming over a widespread area in North West in the 1960s (Kleywegt and Pike, 1982).

The discharge of particle-rich effluent from gold mines and the proximity of slimes dams, tailings and rock dumps can also cause structural damage to aquatic systems by flooding, clogging, altering streams and wetlands and interfering with the normal drainage of the karst system. Increased addition of mine effluent into existing streams can alter the aquatic environment irrevocably. Blesbokspruit in the East Rand, for instance, was originally a meandering non-perennial stream without reeds. The daily input of megalitres of eutrophic water from mine and industrial effluent, sewage effluents, the construction of roads and embankments across parts of the stream in addition to the runoff from rock dumps and slimes dams in the area caused it to turn into a permanent wetland colonised by reeds (Haskins, 1998).

Mining activities may also alter the flow of groundwater especially when water is pumped from the mines for safety and economical reasons (Enslin *et al*., 1976; Dreybrodt, 1996). Originally the karst aquifer in Gauteng and North West was partitioned into compartments by syenite dykes with a north-south orientation. The primary flow of underground water was in a westerly direction prior to mining. Decantation of the groundwater originally took place over the dyke boundaries as a series of springs into the Wonderfonteinspruit (Swart *et al*., 2003). However, due to mining activities, the dolomitic aquifer in the region of the mine was dewatered which caused the water level to drop in four of the compartments and the associated springs to dry up. In addition, mining activities perforated the dykes dividing the aquifer into compartments, which caused the original compartments to act as one (Swart *et al*., 2003).

5.2.2.2 ACID MINE DRAINAGE, TOXIC CHEMICALS AND HEAVY METALS

The structural damage caused by the pumping of water from gold mines into surface water bodies such as the Wonderfonteinspruit, Tweelopiespruit, Klip River, Blesbokspruit, Rietspruit, Suikerbosrand River, Mooi River and many others is only part of the problem. In addition, the water released from the mine is contaminated with acid, toxic chemicals and heavy metals (Kleywegt, 1977).

A similar situation applies to the placing of tailings, rock dumps, low-grade ore stockpiles and slimes dams. The runoff from slimes dams enters the drainage network that feeds into the surface water, karst system and groundwater. In the past slimes dams were built on top of karst in the West Rand, East Rand and Klerksdorp area because it tended to be more stable due to the fact that the excess water drained directly into the karst system below.

Acid mine drainage (AMD)

During the mining process, rocks, which are situated far below the surface, are brought to the surface where they are crushed. Gold is extracted by means of chemical processing and the resulting silt is stored in slimes dams. The crushing and chemical processing expose and mobilise pyrite (FeS_2), a natural sulphur-rich component of the rock that is then exposed to the atmosphere and water. The oxidised sulphates, in combination with water, produce sulphuric acid that in turn reacts with the silt and gravel to release and mobilise the metals it contains. The acids and released metals are found in the rivers and groundwater which have been contaminated by the runoff from slimes dams, tailings, rock dumps and mine effluent (Coetzee, *et al.*, 2006, Hobbs & Cobbing, 2007).

The situation regarding the pumping of effluent from the gold mines in the North West Province and Gauteng is deteriorating rapidly. This situation is worsened by the fact that the water table is returning to its original level in areas that have been extensively mined for over a century in Gauteng and the North West Province. Megalitres of water were abstracted on a daily basis from these mines in order to continue mining operations for almost 120 years. After these mines reached the end of their productivity, however, they were abandoned and since then the water in the mines has accumulated, causing the water table to rise again. Unfortunately the chemical consistency of the water is influenced by the mine tunnels and stopes honeycombing the quartzites and dolomites in that area. The water that is flushed through these mines is progressively becoming more acidic as it works its way up to the surface, bearing with it toxic and radioactive metals.

The result of the rising water table within the mine shafts is that fountains that dried up decades ago due to mining activities, have opened up again since 2002, decanting toxic acid mine effluent instead of clean drinkable water as it did a century ago. Fourie (2005) reports that the first known incident of decanting was when water began to flow from one of the old mine shafts of Harmony Gold Mine (Pty) Ltd (Randfontein Operations) and then started to issue water from a borehole upstream from the Krugersdorp Game Reserve. Subsequently, two dry springs in the Krugersdorp Game Reserve started to flow again. Many animal deaths have been reported at Krugersdorp Game Reserve since the decanting started (Fourie, 2005). Between 7 and 15 megalitres are decanting daily into streams feeding into the Tweelopiespruit which is a tributary of the Crocodile River (Fourie, 2005; Krige, 2006; Hobbs & Cobbing 2007).

AMD threatens the structural stability of the karst system because dolomite is easily dissolved by acid. There is the real threat of excessive karstification in this area with sinkholes and dolines forming in areas where acidic water is forced upwards from the mines through the dolomites on top (Hodgson *et al*., 2001). The flow of the water through the karst system will be influenced by widening fissures, surface collapses and the formation of new fountains and opening of old dry springs (Swart *et al*., 2003). The Gauteng Department of Agriculture, Conservation and Environment (GDACE) has voiced its concern that the water released into the Tweelopiespruit will fill the dolomitic compartments under the COH WHS, thereby threatening the stability of the fossil sites of the area (Fourie, 2005).

The problem of AMD is obviously much bigger than the threat to the COH WHS alone. AMD is issuing from the 15 active and 29 closed gold mines in the northern part of the Vaal Barrage catchment, the main water supply for Gauteng. The ingestion of sulphates in excess of 600 mg/ℓ can lead to vomiting and diarrhoea. The mine effluent from Harmony Gold contains 4500 mg sulphates, 1200 mg of iron and 16 mg of uranium per litre at the point of decant (Fourie, 2005; Coetzee *et al.*, 2006; Krige, 2006). In addition acid mine drainage (AMD) leads to the decimation of aquatic life in the water bodies into which mine effluent is discharged (Roback and Richardson, 1969; Jooste and Thirion, 1999).

Cyanides

Gold is extracted by means of a complex process involving the crushing of the ore, treatment with cyanide, activated carbon treatment, heat, chemical processing and ore electrolysis (Korte and Coulston, 1998). The "Heap Leach" gold recovery process involves the application of a cyanide solution (NaCN) to low grade ore in order to dissolve the gold. The cyanide is poured over and allowed to percolate through huge piles of ore that can cover hundreds of acres. After the leaching process (which can take several days to months) has been completed, the resulting cyanide/gold liquid is stored in ponds after which it undergoes further treatment (Sternkamp, 1992).

The ore piles and storage ponds are lined with plastic sheets, but these often tear causing the cyanide mixture to leach into the ground and from there into the groundwater or to spill into the nearby streams. Cyanide is a lethal substance that may damage the nervous, cardiovascular and respiratory systems of animals that ingest or inhale it (ATSDR, 1993). The lethal dose for humans is 1-3 mg per kilogram of body weight (Korte and Coulston, 1998).

The "Carbon in Pulp" (CIP) and the "Carbon in Leach" (CIL) methods have been used primarily to extract gold on the West Rand mines. These processes involve the addition of cyanide to the slimes produced by milling the ore into a fine powder. Activated carbon particles are added to the mix to adsorb the gold solubilised by the cyanide. After the extraction of the gold-bearing particles from the slimes, the slimes are pumped into a tailings dam after ferrous sulphide or ferrous chloride has been added to neutralise the cyanide. Depending on the quality of these chemicals, the tailings dam may produce a cyanide leachate that can contaminate the groundwater.

Even though strict measures are taken at mines to prevent accidental spillage, cyanide still leaches from operational areas. Cyanide evaporates in the form of hydrogen cyanide gas (HCN) into the atmosphere where it has a half-life of 267 days (Atkinson, 1985), while the half-life of NaCN in anaerobic soil is estimated at 1-2 years (Wolf *et al.*, 1988). The use of cyanide in the mining process holds serious implications for the ecology, both aquatic and terrestrial (Albersworth, 1992; Marquardt and Schäfer, 1994; Korte and Coulston, 1995).

Metals

Mine effluent contains several pollutants that are detrimental to aquatic systems. Some of the toxic components in mine effluent, in addition to sulphates and sulphuric acid, are: cyanides, manganese, aluminium, iron, nickel, zinc, cobalt, copper, lead, radium, thorium and uranium (Venter, 1995). Every one of these elements is toxic, depending on its concentration and the length of time that the organism is exposed to it. Radium, thorium and uranium are also radioactive. Streams and rivers in these provinces that have been polluted by mine effluent include the Blesbokspruit Ramsar Site that was placed on the Montreux Record in July 1996 in response to its contamination by large volumes of effluents discharged from the adjacent gold mine, industries and sewage works.

The physiological and histopathological effects in aquatic organisms due to exposure to metals have been studied for decades by researchers at the Department of Zoology at the University of Johannesburg (formerly the Rand Afrikaans University) amongst others. There is overwhelming evidence that bioaccumulated metals pose serious health risks to both invertebrates and vertebrates, including humans (Smith and Heath, 1979; Venter, 1995; Adendorff, 1997; Jooste and Thirion, 1999). Depending on the species of fish, certain metals accumulate in certain parts of the body. Copper, iron, lead and zinc may accumulate in the liver, manganese, nickel and zinc may accumulate in the gills and iron, copper, nickel and lead accumulate in the skin (Adendorff, 1997). Similarly, metals accumulating in the tissues of macro-invertebrates will vary from one species to the next. In general iron, zinc, nickel, copper, manganese and lead are absorbed by freshwater macro-invertebrates (Adendorff, 1997). The rate of accumulation and toxicity of these metals are determined by the salinity, acidity and hardness of the water (Moore and Ramamoorthy, 1984). The absorption of metals may cause necrosis, tumours, cancer and the general impairment of the liver, gills, cardiovascular system and urogenital system.

Researchers often overlook the fact that, in the process of mining for gold, radioactive heavy metals such as uranium, thorium and radon are also unearthed. In the past uranium production was directly dependent on gold production (Von Backström, 1976; Cole, 1998). The slimes dams, tailings and rock dump sites all leach uranium and its daughter products. The effluent from mines as well as the runoff from slimes dams contaminate the surrounding streams and rivers with uranium while the dust blowing from slimes dams contaminate the air with uranium dust. In many cases the squatters occupying vast areas in Gauteng and North West Province rely on the uranium-contaminated streams in the vicinity as their only source of water. Uranium also accumulates in the river sediment and will continue to have a serious negative impact on the water chemistry as long as it leaches out of mine works (Winde and Van der Walt, 2004; Coetzee *et al*., 2006).

Uranium is probably more dangerous than most other heavy metals due to its toxic as well as radioactive properties. There are three major ways that humans and other terrestrial vertebrates may be contaminated by uranium: though ingestion, inhalation and absorption through the skin (Durakovic, 1999). In the case of aquatic organisms the gills particularly would also be vulnerable to heavy metals. Research has shown that parenteral absorption of uranium is extremely dangerous and certain authors believe it to be the most toxic metal (Kobert, 1906; Hursh *et al.* 1969).

The absorption of uranium leads to the destruction of kidney and liver functions (Chittenden and Lambert, 1889; Garnier and Marke, 1921). It also acts as a powerful neurotoxin that causes blindness, paralysis and loss of coordination (Verne, 1931). Uranium also causes chromosome aberrations in sperm, blood and other connective tissue diseases, leads to changes in the immune and endocrine systems and contributes to the prevalence of malignant diseases, including cancer (Zhu *et al*., 1944; Jackson, 1910; Conrad *et al*., 1996; Baur *et al*., 1996; Zaire *et al*., 1996; 1997; Bigu, 1994; Shanahan *et al*., 1966; Au *et al.*, 1996).

5.3 Farming

Poor farming practices pose a dire threat to karst ecology. Spraying of crops and land with pesticides, use of fertiliser and certain aspects of animal husbandry, have serious ecological implications when practiced within a karst system or in its catchment. Research in the USA has shown that pesticides are more commonly found in unconsolidated and karst aquifers than in other bedrock aquifers and that unconfined aquifers are more easily contaminated than confined aquifers (Water Research Commission, 1995). Loss of foraging habitat also threatens the survival of bat populations. Research has shown that fragmentation and degrading of natural habitats that accompany agriculture are major threats to bat populations (Walsh and Harris, 1996a; 1996b).

5.3.1 Irrigation

Irrigation poses the same structural dangers to the karst system as the decanting of water from mines in the region. Excessive abstraction of groundwater may also lead to the lowering of the water table, the drying out of caves and the formation of sinkholes. Water in caves is crucial for the survival of water-dependent organisms, including bats that depend on a certain level of humidity in a cave (Van der Merwe, 1973a). Waterborne agrochemicals in farming areas differ from those chemicals that are emitted from mines, although they could have similar destructive effects on the ecology.

Salinisation of the soil is one of the ecological disasters that accompany irrigation (Meybeck *et al.*, 1989). During excessive irrigation, salts are dissolved and mobilised in the soil. In some cases the salt is dissolved at deeper levels and then brought to the upper surface of the soil as the water evaporates, thereby leaving a high concentration of salts in the soil. Salinisation could lead to habitat loss that includes the loss of vegetation and associated erosion and the disappearance of insects and other animals that originally occupied that habitat with dire consequences for the bats in that region. In addition, the mobilised dissolved salts may enter the groundwater when more water is added to leach salts from the soil.

5.3.2 Pesticides

Crop spraying contributes to the buildup of pesticides in the soil and groundwater. The runoff can also contaminate streams and wetlands. No in-depth investigation has been done to establish the prevalence, distribution and concentration of pesticides in groundwater in South Africa as yet, while there are no regulations to control pesticide contamination of the water resources in South Africa (London and Rother, 1998; Usher *et al*., 2004; London *et al*., 2005).

The dangers of pesticide contamination of the water resources have recently been illustrated when Endosulfan, Chlorpyrifos, Azinphos-methyl, Fenarimol, Iprodione, Deltamethrin, Penconazole and Prothiofos were detected in groundwater in an agricultural area in the Western Cape (Dalvie *et al*., 2003). All available evidence points towards widespread pesticide contamination of soil, surface water and groundwater in South Africa (Greichus *et al*., 1977; Weaver, 1993; Grobler, 1994).

Pesticides, which include insecticides, fungicides and herbicides and other agrichemicals, have been and are still being used by many of the farmers in and around the COH WHS. In addition to habitat loss, the use of insecticides poses one of the most critical dangers for the conservation of biodiversity within the COH WHS. The runoff of pesticides and their derivatives enter the surface water bodies and ultimately accumulate in the ground and groundwater where they continue to poison organisms for many years after application (National Water Quality Assessment Pesticide National Synthesis Project. 1995). Whereas pollutants and toxins may be flushed out of a contaminated surface stream or wetland by rain, it is not the case in groundwater where the toxins may linger for many years (Premazzi and Ziglio, 1995).

Certain poisons such as polychlorinated hydrocarbons are extremely stable and remain active in the environment for many years, even decades after their original application. This results in their accumulation in the tissues of aquatic and terrestrial vertebrates, including humans (Bot *et al*., 1986; Kang *et al*., 1997). Bioaccumulation of pesticides can occur even if organisms are exposed to small doses of poison over a long time. If predators feed on poisoned prey, one of the effects of bioaccumulation is that the higher up the toxins are transferred into the food pyramid, the more concentrated they become. This is invariably fatal to the predators, which are the natural enemies of the targeted pests.

Bioaccumulation occurs when an animal ingests other organisms that have been exposed to smaller dosages, even sub-lethal doses, of poison, which accumulates in its body. This is a common phenomenon in long-lived insectivores such as bats (Geluso *et al*., 1976; Swanepoel *et al*., 1999). In a well-documented case the Mexican free-tailed bat, *Tadarida brasiliensis mexicana* dwindled from 8.7 million individuals at Carlsbad Cavern, New Mexico in 1936 to 200 000 in 1973 due to the use of DDT as an insecticide used on the cotton fields in the vicinity (Elliott, 1998). Similarly, several colonies of grey bats (*Myotis grisescens*) were killed by Dieldrin in Missouri (Clark, 1988).

The evidence for the deterioration of health of humans exposed over a long time to low doses of pesticides is overwhelming. Some of the complications caused by environmental toxins mentioned by London *et al.* (2005) include cancer as well as the deterioration of the immune, reproductive, respiratory and neurological systems (Maroni and Fait, 1993; Schettler *et al.* 1996; Gray and Ostby, 1998; Dalvie *et al*., 1999; Porter *et al*., 1999; Kirkhornand Schenker, 2002; Colosio *et al*., 2003). Although these studies were done on farm workers and other human subjects that have been exposed to low doses of pesticides over a long period, the conclusions drawn regarding the toxicity of environmental pesticides are as valid for karst-dwelling organisms as for humans.

The effect of the transference of toxins from the target animal to its predator is vividly illustrated in the case where bats pass on the toxins to their nursing young. It has been found that insecticides are passed on by insects that have been exposed to sub-lethal doses to bats that feed on them (McDonald *et al*., 1990). The adult female bats, which are subjected to sub-lethal doses of pesticides ingested along with their prey, pass it on to their nursing young (Geluso *et al*., 1981). This may cause massive mortality of the young in maternity colonies in and adjacent to agricultural areas (McDonald *et al.*, 1990; Rautenbach, 1985).

For the best part of a century farmers in the vicinity of all three of the COH WHS sites have been using DDT, Dieldrin and organophosphates to spray their fields and orchards. Even today, the Sterkfontein area is well known for its fruit and flower farms. The agricultural holdings to the north of Krugersdorp, around Mokopane's Valley and Taung are all within the feeding ranges of the cave-dwelling bats that live in these areas. Even insecticides used in farming areas several kilometers away could pose a danger to cave dwelling bats such as *Rhinolophus clivosus* and *Miniopterus schreibersii* which have feeding ranges of up to 10 km from their roosts (Herselman, 1980; McDonald *et al*., 1990).

The migratory habits of *Miniopterus schreibersii* or Schreiber's long-fingered bat, might have contributed to its survival. *Miniopterus schreibersii* that hibernates in the COH WHS has maternity roosts in Mokopane's Valley in the Limpopo

Province. This strategy fortuitously removes the colony and therefore the vulnerable pups from Gauteng in spring to summertime when most of the soft fruit are grown and sprayed in the area. Before the farm was expropriated recently, limited agricultural activities have been undertaken in the area around Mokopane's Valley. Similar activities were also conducted in a smaller area and on a smaller scale in the mountainous area around Mokopane's Valley than in the Krugersdorp District.

5.3.3 Fertilisers

Nitrate-based fertiliser is widely used in agricultural areas leading to the accumulation of high nitrate concentrations in soil, surface water bodies and groundwater (Usher *et al.*, 2004). Research has shown that non-point source contamination of groundwater by sulphates and nitrates was caused by the application of agricultural fertilizer, while point source contamination was caused by pit latrines and the inappropriate storage and disposal of agricultural chemicals (Waller and Howie, 1988; Usher *et al*., 2004).

Nitrates are some of the chemical pollutants most commonly found in the aquifers of the world (Spalding and Exner, 1993). Except for the threat of eutrophication, nitrates are not particularly dangerous as a toxin. However, nitrate is metabolised to nitrite in the gastrointestinal tract of animals, including humans (United States Environmental Protection Agency, 1998). Exposure to nitrite may cause anoxemia that may lead to tissue damage and even death, cancer and birth defects (Eddy and Williams, 1987). Unfortunately, as in the case of pesticides, there are as yet no regulations or monitoring programme to control the use of nitrates in South Africa.

Nitrates also lead to the salinisation of soil and the eutrophication of water bodies. Both phenomena have detrimental effects on the ecology and pose a serious threat to the karst ecology that is ultimately dependent on surface and groundwater conditions. Eutrophication of water and soil due to sulphates and nitrates leads to anoxic conditions which cause anoxic bacteria to proliferate with the subsequent habitat loss to aerobic organisms (Ehrlich, 1990).

Nitrates and bacteria also pass into the soil, surface water, groundwater and karst ecosystem from the dairy farm and a piggery inside the COH WHS with the resulting deterioration of the aquatic habitat and the invasion of exotics in the riparian zone and subsequent habitat loss to indigenous species (Van Staden, 2003). Pit latrines and French drains are also used by the majority of households and industries within the COH WHS and on the periphery of the COH WHS north of Krugersdorp (Durand, 2007).

5.4 Urbanisation

5.4.1 Habitat loss

Urbanisation is perhaps the biggest immediate threat to karst ecology in the COH WHS north of Krugersdorp. New housing complexes and informal settlements are encroaching on the COH WHS. The construction of both high-density security villages and informal settlements involves habitat loss. Ecologically insensitive urbanisation impacts negatively on the indigenous fauna and flora that supports the cave dwelling bats in the region. This domino effect will ultimately have a negative impact on organisms in the karst ecosystem that depend on the nutrients brought into the cave in the form of bat faeces and corpses.

Loss of foraging habitat threatens the survival of bat populations. Research has shown that fragmentation and degrading of habitats that accompany urbanisation due to the removal of indigenous species are major threats to bat populations. Urban areas show a notable reduction in number and diversity of insects that can be utilised by bats (Geggie and Fenton, 1985).

5.4.2 Alien species

Habitat degradation is amplified by the introduction of alien species that not only displace indigenous fauna and flora, but may also become invasive. Van Staden (2003) records several alien species that invaded the riparian zone of the Bloubankspruit that runs through the COH WHS resulting in habitat degradation. One of the reasons why exotic plants are often preferred to indigenous species is that they are often more resistant to indigenous species of insects and other pests. In cases where the species are not resistant, they are treated with pesticides. In either case the plants that should serve as food for the insects, which in turn are utilised as food by the bats, are excluded from the food web or become a source of toxins when treated with pesticides.

5.4.3 Habitat for competitive species

Urbanisation also creates artificial roosting sites for house-dwelling bats. Although these are indigenous to South Africa, they did not occur in great numbers in the COH WHS before the appearance of anthropogenic structures. Roof-dwelling bats include the Cape Serotine (Neoromica capensis) and the Yellow House Bat (Scotophilus dingani) both of which have been recorded in the Krugersdorp District.

Street lights attract and condense insects in great numbers which in turn attract foraging bats (Rydell and Racey, 1995). Certain bats, notably roof-roosting bats, are attracted to the lights whereas cave-dwelling bats tend to avoid street lights. It seems as if the sound frequency emitted by mercury vapour lights, commonly used in street lights, interfere with the echolocation of bats such as Rhinolophus species which produce constant frequency calls. On the other hand, bats such as Neoromica capensis and Scotophilus sp., which produce frequency modulated calls, seem to be unaffected by street lights.

Roof-dwelling bats pose an ecological threat to the cave-dwelling bats such as Nycteris thebaica (Common Slit-faced Bat), Myotis tricolour (Dominick’s Hairy Bat), Miniopterus schreibersii fatalness (Schreiber's long-fingered bat or Natal clinging bat), Rhinolophus blasii (Peak-saddle horseshoe bat), Rhinolophus simulator and Rhinolophus clivosus (Geoffroy's horseshoe bat) since they compete for the same food resources. This threat will become more serious as urbanisation continues in and around the COH WHS, as more roosting sites will be created for house bats. Food resources will become scarcer due to habitat degradation, fragmentation and loss. Street lights will further exclude cave bats from the limited food resources while at the same time benefiting house bats.

5.4.4 Pollution and waste management

Pollution can influence cave ecology in several different ways. Since many cave habitats are dependent on water, the pollution of water entering the karst system and recharging the natural cave reservoirs could have a devastating and long-term effect on cave ecosystems.

Many factors can contribute simultaneously to the degradation of the karst system. Studies have shown that urbanisation contributes to the degradation of groundwater as well as cave environments (Pride *et al.*, 1988; Reddell and Elliott, 1994). In the well studied case of Blesbokspruit, the water quality was mainly influenced by the total dissolved salts in the waste water discharged by several industries, the gold mine and the sewage works in the area. The eutrophic water showed high concentrations of sulphates, phosphates, nitrites/nitrates and ammonia in addition to metals (Haskins, 1998). Thousands of cubic metres of treated sewage and industrial effluent are released on a daily basis by the Percy Stewart municipal sewage works near Krugersdorp into the Blougatspruit which is a tributary of the Bloubankspruit which runs through the COH WHS (Fourie, 2005).

It has been shown that where pollutants leach into the groundwater, a plume of pollutants emanates from landfills (Cherry, 1983). The fact that a large landfill is situated next to the R28 between Diepkloof Township and Krugersdorp adjacent to the karst system should be a matter of concern.

5.5 Caving, Tourism and Palaeontological Excavations

Caves have been utilised by humans since the dawn of humankind and therefore they have continued to retain their attraction to humans. Even in historical times humans have lived in caves, or at least have utilised caves either as temporary dwellings, hiding places or for storage. In South Africa, Mokopane's Cave, Sudwala Cave, Waenhuiskrans and Heerenlogement, to name but a few, have been occupied periodically in recent historical times.

Caves are used today as tourist attractions, for caving, education and for research. Caving activities occur in many of the hundreds of caves in Gauteng, North West and Limpopo Provinces whereas tourism is limited to only a few caves. Caves such as Wonder Cave, Sterkfontein and Mokopane's Cave are three of the main tourist attractions in Gauteng and the Limpopo Province. Geotourism and palaeotourism may become the backbone of the tourism industry in Gauteng.

Unfortunately visitors to caves disturb the residing organisms. There is also reason to believe that excessive human traffic through a cave may cause structural damage to the cave in the form of heightened levels of CO_2 and the accidental or malignant breaking of flowstone formations and pilfering of crystals. However, in a well-ventilated cave with little biodiversity, relatively few brittle or accessible flowstone formations, especially in the case where previous limestone mining activities have caused profound structural damage, there should be fewer objections to its use as a tourist cave.

Caving and palaeontological excavations occur unfortunately in caves that are used by Myotis tricolor, Miniopterus schreibersii and Rhinolophus clivosus as hibernacula or as maternity roosts. Cavers sometimes wade through or dive in water bodies occupied by amphipods. Whereas the amphipods seem to be impervious to short-term human interference, bats can be much more susceptible to human interference.

5.6 Use of Caves as Dump Sites

It is a disturbing fact that caves have been used for decades as dumping sites. As in the case of old disused mine shafts, carcasses of cattle that died of diseases such as Anthrax were dumped in caves in the previous century. Many cavers and researchers were witness to this practice. In the case of inert materials it is unsightly and an environmental nuisance, but it can become a serious environmental problem in the case where toxic waste and carcasses are dumped in a cave (Durand, 2007).

5.7 Recommendations

5.7.1 Regulatory response required

The phasing out of insecticides in and around the COH WHS would be one of the most important steps towards the conservation of the biodiversity within the COH WHS. For the best part of a century the fruit and flower farmers in the vicinity of the COH WHS have been using DDT, DDT-derivatives and organophosphates to spray their fields. The use of insecticides has a detrimental effect on the breeding efficiency and survival of bat populations (Rautenbach, 1985). The region in and around the COH WHS falls within the feeding range of bats living in caves in this area and the high level of agricultural and horticultural activity in the region (where insecticides are widely used) is a matter of great concern. For example, Rhinolophus clivosus has a feeding range of up to 10 km (Herselman, 1980). Although the dosages ingested by adult bats may be sublethal, the toxins are passed on to the nursing young with fatal results and can cause massive mortality among them (McDonald *et al*. 1990).

House bats should be excluded from buildings in the vicinity of the COH WHS in order to minimise numbers and avoid detrimental competition for limited food resources with cave-roosting bats. There are simple and non-lethal methods to do this.

Caving, palaeontological excavations and tourist activities in caves which are used by Myotis tricolor, Miniopterus schreibersii and Rhinolophus clivosus as hibernacula or maternity roosts, should be regulated (Durand, 2008).

At this stage the country is suffering from a lack of knowledge concerning the condition and nature of groundwater, aquifers and karst systems, as well as a lack of adequate guidelines for better management and enforcement of existing policies concerning these natural resources. There is also ignorance about the role of groundwater in supporting the ecology, linking ecosystems and interacting with the surrounding environment (Toth, 1999). This leads to the uncontrolled abstraction, over-exploitation, deterioration and pollution of South Africa's groundwater resources. It is of crucial importance that an integrated groundwater management plan should be developed. Currently there is a lack of a multi-disciplinary approach to groundwater management and a tendency to approach the different components of the hydrological cycle in isolation and not in an integrated, holistic way (Bredenkamp and Xu, 2003).

Serious thought should be given to the effectiveness of the mining regulations as defined by the Mineral and Petroleum Resources Development Act of 2002 (Republic of South Africa, 2002) which holds the holder of the mining permit liable for compliance with the Act until an unconditional closing certificate has been issued by the Department of Minerals and Energy (DME). At this stage there are less than a handful of active mines in the Gauteng and North West Provinces. Effluent is issuing from over 30 mines, most of which are abandoned. From the inability and reluctance of the active mines to control their current effluent and other ecological disasters, it is becoming clear that they will not be able to obtain closure in the foreseeable future either (Van Eeden, *et al*., 2006). If measures are not put in place timeously, the government will be faced with the unfortunate situation where it will have to take responsibility for more than a century of large scale ecological destruction and the associated ecological chaos, which includes the pollution of the main source of water for tens of millions of people, while mining companies will cry bankruptcy, blame defunct mining companies that mined in the region before them and point fingers at industries and the informal settlements around them (Templeton, 2005; Fourie, 2005).

5.7.2 Management response required

The Department of Water Affairs and Forestry (DWAF) has determined substance-specific National Water Quality Guidelines for the protection of freshwater ecosystems. This is in addition to the National Water Quality Guidelines for domestic, industrial, agricultural and recreational use. These guidelines determine the maximum concentrations for aluminium, ammonia, arsenic, boron, cadmium, chlorine, chromium, copper cyanide, fluorides, lead, manganese, mercury, molybdenum, selenium, vanadium and zinc in water. The threshold levels of each toxic substance at which chronic and acute toxicity occurs in aquatic biota are tabled in these guidelines. These criteria should be used in water quality evaluation, impact assessment and during the setting of discharge permit conditions for industries, mines and municipalities (Roux *et al*., 1996). Similarly the

Department of Water Affairs and Forestry sets the limits for pH and suspended solids in the water.

DWAF regulates the protection, use, development, conservation and control of the freshwater resources in South Africa by means of the National Water Act of 1998 (Republic of South Africa, 1998) and the Policy and Strategy for Groundwater Quality Management in South Africa of 2000 (Republic of South Africa, 2000), in order to ensure adequate supply and acceptable quality of freshwater (Usher *et al*., 2004). However, the source directed, resource directed and remediation strategies should be integrated to ensure sustainable utilisation of groundwater. Unfortunately, the effectiveness of legislation is only as good as the ability to implement these regulations by monitoring the quality of the resource as well as the possible threats to the resource. All this depends ultimately on the ability and willingness to enforce legislation (Van Eeden, *et al.*, 2009).

Caves in South Africa should be classified according to their ecological and geological sensitivity as has been done in other countries (e.g. Elliot, 2001a). GDACE should, with the help of scientists and cavers, assess the caves in the COH WHS, compile an inventory and classify caves according to their sensitivity. Open caves would have few sensitive features and could be opened for recreation with permission of the land owner. Entrances to caves or parts of caves that house endangered species or sensitive habitats, or are dangerous, or have pristine geological formations or palaeontological deposits, should be restricted or closed off. A permit to enter restricted caves for scientific or conservation work could be issued by GDACE.

There is often a conflict in priorities where cavers or scientists have blocked up passages or erected grills or gates across cave entrances to prevent other adventurers, cavers and the general public from entering. Unfortunately these gates block the flight of bats living in these caves. If a gate or grill has to be installed, horizontal bars with gaps of a certain size should be used to allow bats to fly through (Elliot, 2001b).

Currently the negative effect of mine effluent released in the North West Province has not yet been detected in the karst ecosystem of the COH WHS, but the fact that the same amphipods occur in the Potchefstroom area as in the COH WHS, would indicate that the two areas are connected by aquifers. The implication is that pollutants may spread from one pocket of the karst system to adjacent pockets. This situation poses a serious threat to the karst ecology in the COH WHS.

In order to conserve the karst ecosystem, baseline studies should be undertaken to determine the composition, distribution and population densities of karst-dependent species. Monitoring programmes should be set up to establish the waxing and waning of population numbers and to determine the general well-being of populations and their direct environment. The dependency and interaction between the groundwater and the cave ecosystem should also be determined and monitored. The karst ecology forms an ecotone between groundwater and surface habitats where an intricate food web comprising microfauna, bacteria and fungi exists (Toth, 1999; Marmonier *et al*., 1997). If any of these ecological links disappear it will have a domino effect on the rest of the system that could have serious implications for endemic species.

The survival of karst-dependent species, such as bats and amphipods, depend on the conservation of areas much larger than the caves themselves (Durand, 2008). Water from the whole catchment, which feeds into the karst system, has an impact on the ecology. Of greater concern at this stage is that the karst system forms a continuous aquifer as can be concluded from the presence of the same species of amphipod in the COH WHS north of Krugersdorp and in caves in the Potchefstroom District. This situation has been amplified by the fact that mining has breached many of the dykes that have originally partitioned the aquifer into pockets. Polluted water can now travel fast over large distances to pollute cave systems and groundwater further away.

An environmental management plan that should include a larger area than the immediate roosting sites of a bat population should be put in place if that population is to survive (Elliott, 1998). The grassland and riparian habitat occupying tens of square kilometers around the caves provide food and water to the cave-dwelling bats. If this habitat is encroached on any further, it will have dire consequences for the already diminished bat populations in the area. Since approximately half of the core area of the COH WHS north of Krugersdorp is occupied by private nature reserves, it is recommended that the commercial farms be expropriated over time and incorporated into a larger conservation area.

The existence of commercial farms within the core area of the COH WHS is problematic from a conservation point of view. Standard farming practices such as the use of agrochemicals, abstraction of water as well as feedlots degrade the karst environment. The use of pesticides should be phased out in an area of at least 10km radius from caves that are inhabited by bats if the bat populations are to be restored to their original numbers. The release of mine effluent, industrial effluent and treated sewage into rivers that are part of the karst catchment should be prohibited. Waste dumps, slimes dams, tailings, rock dumps and low grade ore stockpiles should be removed from the karst catchment. Alien plants growing in the COH WHS area should be eradicated.

Because of the ecological problems associated with urbanisation such as alterations to the drainage patterns, nutrient and moisture inputs, the generation of waste and pollution, the introduction of aliens and habitat loss, it is important that urbanisation is limited on the periphery of the COH WHS. Directives on the introduction of open spaces, banning of exotics, bat-proofing of buildings and erection of bat-friendly street lights must be considered for the urban edge on the periphery of the COH WHS.

Certain caving practices should be prohibited. There is a tendency amongst certain cavers and landowners to erect gates over cave entrances. This is purported to prevent innocent members of the public from injuring themselves or from damaging cave formations. Other cavers who were not party to the erection of the gate would in some instances break the lock and put another in its place, or erect another gate in front of the previous one. The practice of gating or blocking of entrances is detrimental to bats and has lead to the extermination of several bat populations (Macgregor, 1993; Elliott, 1996, 2001a).

South African caves should be classified according to their ecological and geological sensitivity as has been done in other countries (Elliott, 2001b). An inventory of South African caves should be compiled by GDACE in conjunction with scientists and cavers to classify caves according to their sensitivity. Caves open to the public like Sterkfontein and Wonder Cave would typically have few sensitive features and would be open for recreation with permission of the land owner. Access to caves or sections of caves that house endangered species, have sensitive habitats, are dangerous, or which have pristine geological formations or palaeontological deposits, should be restricted to certain interest groups or closed off to everyone except researchers who monitor the conditions in the cave. A permit could be issued by GDACE to enter restricted caves for monitoring, scientific or conservation work.

Palaeontological excavations should be undertaken in a sensitive way. Two palaeontological sites (Mokopane’s Valley in the Limpopo Province and Gladysvale in the COH WHS) house the ecologically sensitive species Miniopterus schreibersii natalensis (Schreiber's long-fingered bat or Natal clinging bat) at different times of the year. In winter, Schreiber's long-fingered bat uses Gladysvale as a hibernacularium and in summer it uses caves in the Mokopane’s Valley as maternity roosts. Excavation activities during those times of the year that coincide with the bats’ occupation of the caves may have severe detrimental effects on the bat populations.

5.7.3 Monitoring required

The water quality of the groundwater and surface streams should be constantly monitored, especially in the light of the recent influx of mine effluent into the COH WHS. The presence of agrochemicals and metals in the groundwater should be tested and monitored on a regular basis.

After determining the populations of the karst ecosystem, including troglodytes, troglophiles, stygobites and stygophiles in both epigean and hypogean habitats, it is important that these communities continue to be monitored on a regular basis. Stygobites such as amphipods can be used for hypogean water health monitoring programmes in a similar way that epigean invertebrates are used in SASS4 scoring in surface water health monitoring programs.

It is imperative to monitor bat roosts to determine whether conservation practices are sound within Gauteng, North West and Limpopo Provinces. Although Miniopterus schreibersii has a very wide distribution range, their numbers are decreasing, mostly due to habitat loss and they have been classified as Lower Risk (Near Threatened) in the 1996 IUCN Red List of Threatened Animals (Taylor, 2000). It is essential that the migration and roosting habits of bats within the COH WHS and the caves in Mokopane's Valley be monitored. Van der Merwe reported 4000 Miniopterus schreibersii natalensis individuals at the hibernacula at Gladysvale (Long One Cave and American Cave) in the COH WHS and 50 000 individuals at Peppercorn's Cave in Mokopane's Valley which was used as a maternity roost in

1986. The survival of Schreiber's long fingered bat in this subregion depends on the success of its annual migration to the colder caves in Gladysvale to hibernate in winter and to the warmer caves in Mokopane's Valley in spring to pup (Van der Merwe, 1973b; 1975). Unfortunately both areas are the focus of palaeontological excavations, which would naturally be to the detriment of the bats roosting at those localities.

5.8 Summary

Urbanisation and the resulting habitat loss and pollution from industries and mining activities are the greatest threats to karst ecology in Gauteng. Mining poses the main threat to karst ecology in North West, while there should also be some concerns about certain farming practices in North West and Limpopo Provinces. Of the three areas the Limpopo Province is probably the least threatened, an assumption that is reflected by the relative abundance of troglophiles and stygobites occurring in this region. Of all the anthropogenic impacts, mining and agriculture are the greatest dangers to karst ecology due to their irreversible effects, scale of destruction and long-term pollution whereas caving, tourism and palaeontological excavations pose the least danger because of their low impact and small scale interference with karst ecology. At this stage it seems as if the cost to inhibit present, remedy past and prevent future anthropogenic damage to the soil, surface water, groundwater and karst ecology will cost more than the wealth ever generated by the mines and industries in these areas.

REFERENCES

ADENDORFF A (1997) Effects of mining activities on selected aquatic organisms. PhD Thesis, Rand Afrikaans University, Johannesburg.

ALBERSWORTH D (1992) Poisoned profits: Cyanide Heap Leach Mining and its impact on the environment. National Wildlife Federation, Washington, D.C., USA.

ATKINSON R (1985) Kinetics and mechanisms of the gas-phase reactions of the hydroxyl radical with organic compounds under atmospheric conditions, Chem. Rev. 85, pp. 159-161.

ATSDR (Agency for Toxic Substances and Disease Registry) (1993) Toxicological profile for cyanide, US Department of Health and Human Services.

AU WW, WILKINSON GS, TYNING SK, LEGATOR MS, AL ZEIN R, HALLBERG L and HEO MY (1996) Monitoring populations for DNA repair deficiency and for cancer susceptibility, Environ. Health Perspect. 104 Suppl. 3, pp. 579-584.

BAUR X, RIHS HP, ALTMEYER P, DEGENS P, CONRAD K and MEHLHORN H (1996) Systemic sclerosis in German uranium miners under special consideration of antibody subsets and HLA Class II alleles, Respiration 63, pp. 368-375.

BIGU J (1994) Theoretical considerations regarding the migration of 22Rn and 220Rn from uranium and thorium bearing underground environments, Health Phys, 67, pp. 60-64.

BOT J, SWEET S and HOLLINGS N (1986) A guide to the use of pesticides and fungicides in the Republic of South Africa, Department of Agriculture and Water Supply, South Africa.

BREDENKAMP DB and XU Y (2003) Perspectives on recharge estimation in dolomitic aquifers in South Africa, In: Groundwater recharge estimation in Southern Africa (Xu, Y and

Beekman HE, eds.) UNESCO International Hydrological Programme Series no. 64, UNESCO, Paris, pp. 65-79.

CHERRY JA (1983) Migration of contaminants in groundwater at a landfill: A case study, J. Hydrology 13 (1, 2), pp. 1-198.

CHITTENDEN RH and LAMBERT A (1889) Untersuchungen über die physiologische Wirkung der Uransalze, Zeitschrift für Biologie 25, pp. 513-532.

CLARK DR (1988) Environmental contaminants and the management of bat populations in the United States, In: Management of Amphibians, Reptiles, and Small Mammals in North America (U.S. Fish and Wildlife Service, ed.), Flagstaff, Arizona, Symposium July 19-21, 1988, 409-413.

COETZEE H, WINDE F and WADE PW (2006) An Assessment of Sources, Pathways, Mechanisms and Risks of Current and Potential Future Pollution of Water and Sediments in Gold-Mining Areas of the Wonderfonteinspruit Catchment. Water Research Commission, Report No 121/06.

COLE DI (1998) Uranium, In: Mineral Resources of South Africa (Wilson. MGC and Anhaeusser CR, eds.), Handbook 16, Council for Geoscience of South Africa, 740.

COLOSIO C, TIRAMANI M and MARONI M (2003) Neurobehavioral effects of pesticides: State of the art, Neurotoxicol. 24, pp. 577-91.

CONRAD K, MEHLHORN J, LUTHRE K, DORNER T and FRANK KH (1996) Systemic lupus erythematosus after heavy exposure to quartz dust in uranium mines: clinical and serological characteristics, Lupus 5, pp. 62-69.

DALVIE MA, CAIRNCROSS E, SOLOMON A and LONDON L (2003) Contamination of rural surface and ground water by endosulfan in farming areas of the Western Cape, South Africa, Environmental Health: A Global Access Science Source, 2 (1). http://www.pubmedcentral.gov/articlerender.fcgi?artid=153526

DALVIE MA, WHITE N, RAINE R, MYERS JE, LONDON L, THOMPSON ML and CHRISTIANI D (1999) Long-term respiratory health effects of the herbicide paraquat among Western Cape farm workers, Occup. Environ. Med. 56, pp. 391-396.

DREYBRODT W (1996) Principles of early development of karst conduits under natural and man-made conditions revealed by mathematical analysis of numerical models, Water Resources Research 32, pp. 2923-2935.

DURAKOVIC A (1999) Medical effects of internal contamination with uranium, Croatian Medical Journal 40 (1), pp. 49-66.

DURAND JF (2007) Challenges associated with living in karst environments such as the historic Cradle of Humankind World Heritage Site. New Contree 54, pp. 75-98.

DURAND JF (2008) Die karst-ekologie van Suid-Afrika met spesiale verwysing na die Wieg van die Mensdom Wêrelderfenisgebied. Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie 24 (5), pp. 5-15.

EDDY F and WILLIAMS E (1987) Nitrate and freshwater fish, Chemical Ecology 3 (1), pp. 1-38.

EHRLICH HL (1990) Geomicrobiology, 2nd edition, Marcel Dekker, New York, 646 pp.

ELLIOTT WR (1996) The evolution of cave gating - How the philosophy and technology have changed, American Caves 9 (2), pp. 9-15.

ELLIOTT WR (2001a) Cave Gating Criteria, http://www.utexas.edu/depts/tnhc/.www/biospeleology/handouts/

ELLIOTT WR (2001b) Cave Classification and Management, http://www.utexas.edu/depts/tnhc/.www/biospeleology/handouts/

ELLIOTT WR (1998) Conservation of the North American cave and karst biota, In: Subterranean Ecosystems (Wilkens, H, Culver DC and Humphreys, WF, eds.), Ecosystems of the World 30, Elsevier, Amsterdam, pp. 665-689.

ENSLIN JF, KLEYWEGT RJ, BEUKES JHT and GORDON-WELSH JF (1976) Artificial recharge of dolomitic ground-water compartments in the Far West Rand Gold Fields of South Africa, Geological Survey of South Africa, Report 0249.

ERASMUS B, DURAND JF and NEL A (2007) Die gebruik van Amfipoda (Sternophysinx filaris) vanaf die Sterkfonteingrotte as bioindikatore om die effek van landboukundige chemikalieë op karst-ekologie te bepaal. Die Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie, 27 (1), pp. 70

FOURIE M (2005) A rising acid tide, Johannesburg Mail and Guardian, South Africa, 12 April 2005.

GARNIER M and MARKE J (1921) L'intoxication chronique par le nitrate d'urane en injection quotidienne chez le lapin, Comptes rendus des seances de la societe de biologie et des filiales (Paris) 107, pp. 938-40.

GEGGIE JF and FENTON MB (1985) A comparison of foraging by Eptesticus fuscus (Chiroptera: Vespertilionidae) in urban and rural environments, Canadian Journal of Zoology 63, pp. 263-266.

GELUSO KN, ALTENBACH JS and WILSON DE (1976) Bat mortality: pesticide poisoning and migratory stress, Science 194, pp. 184-186.

GELUSO KN, ALTENBACH JS and WILSON DE (1981) Organochloride residues in young Mexican free-tailed bats from several roosts, American Midland Naturalist 105, pp. 249-257.

GRAY LE and OSTBY J (1998) Effects of pesticides and toxic substances on behavioural and morphological reproductive development: endocrine versus nonendocrine mechanisms, Toxicol. Ind. Health 14, pp. 159-184.

GREICHUS YA, GREICHUS A, AMMAN BD, CALL DJ, HAMMAN DCD and POTT RM (1977) Insecticides polychlorinated biphenyl and metals in African ecosystems, Hartbeespoort Dam, Transvaal and Voëlvlei Dam, Cape Province, Republic of South Africa, Arch. Environ. Contam. Toxicol. 6, pp. 371–383.

GROBLER DF (1994) A note on PCBs and chlorinated hydrocarbon pesticide residues in water, fish and sediment from the Olifants River, Eastern Transvaal, South Africa, Water SA. 20, pp. 187–194.

HASKINS C (1998) Blesbokspruit, South Africa, Information sheet for the site designated to the List of Wetlands of International Importance in terms of the Convention on Wetlands of International Importance especially as Waterfowl Habitat, South African Wetlands Conservation Programme, Gauteng Nature Conservation.

http://www.ext.grida.no/soesa/nsoer/resource/wetland/blesbokspruit_ris.htm

HERSELMAN JC, 1980, The distribution and status of bats in the Cape Province, Internal Report, Department of Nature and Environmental Conservation of the Cape.

HOBBS PJ and COBBING JE (2007) A hydrological assessment of acid mine drainage impacts in the West Rand Basin, Gauteng Province. Report No CSIR/NRE/WR/ER/2007/0097/C. CSIR.

HODGSON FDI, USHER BH, SCOTT R, ZEELIE S, CRUYWAGEN LM and DE NECKER E. (2001) Prediction techniques and preventative measures relating to the post-operational impact of underground mines on the quality and quantity of groundwater resources, Water Research Commission of South Africa, Report No. 699/1/01.

HURSH JB, NEUMAN NF, TORIBARA T, WILSON H and WATERHOUSE C (1969) Oral ingestion of uranium by man, Health Phys. 17 (4), pp. 619-621.

IUCN (1994) IUCN Red List Categories, prepared by IUCN Species Survival Commission, IUCN, Gland, Switzerland, p. 21.

JACKSON DE (1910) On the pharmacological action of uranium, Am. J. Physiol. 26, pp. 381-395.

JOOSTE S and THITION C (1999) An ecological risk assessment for a South African acid mine drainage, Water Science and Technology 39 (10-11), pp. 297-303.

KANG YS, MATSUDA M, KAWANO M, WAKIMOTO T and MIN BY (1997) Organochlorine pesticides, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins and dibenzofurans in human adipose tissue from western Kyungnam, Korea, Chemosphere 35, pp. 2107-2117.

KIRKHORN SR and SCHENKER MB (2002) Current health effects of agricultural work: Respiratory disease, cancer, reproductive effects, musculoskeletal injuries, and pesticide-related illnesses, J. Agric. Saf. Health 8, pp. 199-214.

KLEYWEGT RJ (1977) Memorandum oor die moontlike gevaar wat geskep word deur water vanaf die "Western Areas Gold Mining Co. Ltd." na die Rietspruit te laat vloei, Geological Survey of South Africa Technical Report No. 0141.

KLEYWEGT RJ and PIKE DR (1982) Surface subsidence and sinkholes caused by lowering of the dolomitic water-table on the Far West Rand Gold Field of South Africa, Annals of the Geological Survey of South Africa, 16.

KOBERT R (1906) Lehrbuch der Intoxikationen, 2. Stuttgart: Ferdinand Enke Publishing Co., pp. 321-323.

KORTE F and COULSTON F (1995) From single-substance evaluation to ecological process concept: The dilemma of processing gold with cyanide, Ecotoxic. and Environ. Saf. 32, pp. 96-101.

KORTE F and COULSTON F (1998) Some considerations on the impact on ecological chemical principles in practice with emphasis on gold mining and cyanide, Ecotoxicol Environ Saf. 41(2), pp. 119-29.

KRIGE WG (2006) Hydrological/chemical aspects of the Tweelopie-/Riet-/Blaauwbankspruit with specific reference to the impact water, decanting from the Western Basin Mine Void, has on the system. Unpublished Report, Harmony GM Co. Ltd.

LOEB SL and SPACIE A (1994) Biological monitoring of aquatic systems, Lewis Publishers, London, 381pp.

LONDON L, DALVIE MA, NOWICKI A and CAIRNCROSS E (2005) Approaches for regulating water in South Africa for the presence of pesticides, Water SA 31 (1).

LONDON L and MYERS JE (1995) Critical issues in agrochemical safety in South Africa, Am. J. Ind. Med. 27 (1), pp. 1–14. Not in the text

LONDON L and ROTHER A. (1998) People, Pesticide and the Environment: Who bears the brunt of backward policy in South Africa? New Solutions 10, pp. 339-350.

MACGREGOR J (1993) Responses of winter populations of the federal endangered Indiana bat (Myotis sodalis) to cave gating in Kentucky In: Proceedings of the National Cave Management Symposium (Foster, DL, ed.), October 23-26, 1991, Bowling Green, Kentucky. American Cave Conservation Association, pp. 364-370.

MARMONIER P, WARD JV and DANIELPOL DL (1997) Biodiversity in groundwater/ surface water ecotones: central questions In: Groundwater/Surface Water Ecotones: Biological and Hydrological Interactions and Management Options.

MARONI M and FAIT A (1993) Health effects in man from long-term exposure to pesticides. A review of the 1975-1991 literature. Toxicol. 78, pp. 1-174.

MARQUARDT H and SCHÄFER SG (1994) Lehrbuch der Toxikologie, B.E. Wissenschafts -Verlag, Mannheim, Deutschland, pp. 555-558.

MARTINI JEJ and COETZEE CB (1976) Kalksteen en dolomiet In: Delfstowwe van die Republiek van Suid-Afrika (Coetzee, CB, ed.), Geological Survey of South Africa, pp. 291-294.

MARTINI JEJ and WILSON MGC (1998) Limestone and Dolomite In: Mineral Resources of South Africa (Wilson MGC and Anhaeusser CR, eds.), Handbook 16, Council for Geoscience of South Africa, 740 pp.

MCDONALD JT, RAUTENBACH IL, and NEL JAJ (1990) Roosting requirements and behaviour of five bat species at De Hoop Guano Cave, southern Cape Province of South Africa, South African Journal for Wildlife Research 20 (4), pp. 157-161.

MEYBECK M, CHAPMAN D and HELMER R (eds) (1989) Global Freshwater Quality: A First Assessment, Blackwell Reference, Oxford, 306 pp.

MOORE JW and RAMAMOORTHY S (1984) Heavy metals in natural waters, Applied monitoring and impact assessment, Springer-Verlag, New York, pp. 268.

MORGAN DJ and BRINK AB (1984) The far West Rand dolomites, Proceedings of the International Conference on Ground Water Technology, Johannesburg, South Africa, 2, pp. 554-573.

National Water Quality Assessment Pesticide National Synthesis Project (1995) Pesticides in ground water - current understanding of distribution and major influences.

PORTER W, JAEGER JW and CARLSON IH (1999) Endocrine, immune and behavioural effects of aldicarb (carbamate), atrazine (triazine) and nitrate (fertiliser) mixtures at groundwater concentrations, Toxicol. Ind. Health 15, pp. 133-150.

PREMAZZI G and ZIGLIO G (1995) Regulations and Management, In: Pesticide Risk in Groundwater (Vighi, M and Funari, E eds.), Chapter 10, Boca Raton, CRC Lewis Publishers, pp. 203–240.

PRIDE TE, HARVEY MJ, OGDEN AE and SMITH WP (1988) Water quality and benthic community structure of caves receiving urban runoff, NSS Bulletin 53, p. 15.

RAUTENBACH IL (1982) Mammals of the Transvaal, Ecoplan Monograph No.1, Pretoria.

RAUTENBACH IL (1985) Bat research at the Transvaal Museum. Transvaal Museum Bulletin 21, pp.17-20.

REDDELL JR and ELLIOTT WR (1994) The impact of urbanization on endemic cave fauna in Travis and Williamson counties, Texas. National Speleological Society, NSS Convention 1994 Program, Abstracts, p. 49.

Republic of South Africa (1998) National Water Act of 1998.

Republic of South Africa (2000) Department of Water Affairs and Forestry (DWAF). Policy and Strategy for Groundwater Quality Management in South Africa of 2000.

Republic of South Africa (2002) Mineral and Petroleum Resources Development Act of 2002.

ROBACK SS and RICHARDSON JW (1969) The effects of acid-mine drainage on aquatic insects, Proc. Acad. Nat. Sci. Phil. 121, pp. 81-99.

ROUX DJ, JOOSTE SHJ and MACKAY HM (1996) Substance-specific water quality criteria for the protection of South African freshwater ecosystems: Methods for derivation and initial results for some inorganic toxic substances, South African Journal of Science 92 (4), pp. 198-206.

RYDELL J and RACEY PA (1995) Street lamps and the feeding ecology of insectivorous bats, Symposia of the Zoological Society of London 67, pp. 291-307.

SCHETTLER T, SOLOMON G, BURNS P and VALENTI M (1996) Generations at Risk. How Environmental Toxins may affect Reproductive Health in Massachusetts, Greater Boston, Physicians for Social Responsibility, Massachusetts Public Interest Research Group (MASSPIRG) Education Fund, Cambridge.

SHANAHAN EM, PETERSON D, ROXBY D, QUINTANA J, MORELY AA and WOORWARD A (1966) Mutation rates at the glycophorin A and HPRT loci in uranium miners exposed to radon progeny, Occupational and Environmental Medicine 53, pp. 439-444.

SMITH MJ and HEATH AG (1979) Acute toxicity of copper, chromate, zinc and cyanide to freshwater fish: Effect of different temperatures, Bull. Environ. Contam.Toxicol. 22, pp. 113-119.

SPALDING R and EXNER M (1993) Occurrence of nitrate in groundwater – a review, Journal of Environmental Quality 22, pp. 392-402.

STERNKAMP J (1992) Gold: A watershed year? Annual Survey and Outlook, Eng. Mining J., April 1992.

SWANEPOEL RE, RACEY PA, SHORE RF and SPEAKMAN JR (1999) Energetic effects of sub-lethal exposure to lindane on pipistrele bats (Pipistrellus pipistrellus), Environmental Pollution 104, pp. 169-177.

SWART CJU, JAMES AR, KLEYWEGT RJ and STOCH EJ (2003) The future of the dolomitic springs after mine closure on the Far West Rand, Gauteng, RSA, Environmental Geology 44 (7), pp. 751-770.

TAYLOR PJ (2000) Bats of southern Africa: guide to biology, identification and conservation, University of Natal Press, Pietermaritzburg.

TEMPLETON A (2005) Acid river rocks the Cradle of Humankind, April 14 2005, Independent Online (IOL)

TOTH J (1999) Groundwater as a geologic agent: An overview of the causes, processes, and manifestations, Hydrogeology Journal 7, pp. 1 –14.

United States Environmental Protection Agency (1998) Technology Transfer Network, http://www.epa.gov/ttnuatwl/hlthef/eth-phth.html

USHER BH, PRETORIUS JA, DENNIS I, JOVANOVIC N, CLARKE S, CAVE L, TITUS R and XU Y (2004) Identification and prioritisation of groundwater contaminants and sources in South Africa's urban catchment, Water Research Commission Research Report, No 1326/1/04.

VAN DER MERWE M (1973a) Aspects of temperature and humidity in preferred hibernation sites of the Natal clinging bat Miniopterus schreibersii natalensis (A. Smith, 1834), Zoologica africana 8 (1), pp. 121-134.

VAN EEDEN ES, LIEFFERINK M and DURAND JF (2009) Legal issues concerning mine closure and social responsibility on the West Rand. TD: The Journal for Interdisciplinary Research in Southern Africa 5 (1) pp. 51-71

VAN STADEN S (2003) A case study on the use of habitat assessments and biological indices for the management of recreational stream fisheries, Unpublished MSc Dissertation, Rand Afrikaans University, Johannesburg.

VENTER AJA (1995) Assessment of the effects of gold-mine effluent on the natural aquatic environment, PhD Thesis, Rand Afrikaans University, Johannesburg.

VERNE J (1931) Lesions histologiques des centres nerveux superieurs chez le lapins soumis a l'intoxication chronique part l'urane, Annales d'anatomie pathologique 8, pp. 757-758.

VON BACKSTRÖM JW (1976) Uraan In: Delfstowwe van die Republiek van Suid-Afrika, (Coetzee CB, ed.), Department of Mining, Geological Survey of South Africa, pp. 221-227.

WALLER BG and HOWIE B (1988) Determining nonpoint source contamination by agricultural chemicals in an unconfined aquifer, Dade County, Florida, Procedures and Preliminary Results, In: Groundwater Contamination: Field Methods (Collins AG and Johnson AI, eds.), ASTM Special Technical Publication 963, American Society for Testing and Materials, Philadelphia, pp. 459-467.

WALSH AL and HARRIS S (1996a) Foraging habitat preferences of vespertilionid bats in Britain, Journal of Applied Ecology 33, pp. 508-518.

WALSH AL and HARRIS S (1996b) Factors determining the abundance of vespertilionid bats in Britain: geographic, land class, and local habitat relationships, Journal of Applied Ecology 33, pp. 519-529.

WARWICK DW, BRACKLEY IJ, CONNELLY RJ and CAMPBELL G (1987) The dewatering of dolomite by deep mining in the West Rand, South Africa, In: Proceedings of the 2nd Conference on Sinkholes and Environmental Impacts of Karst, (Beck, Wilson, Orlando, USA, pp. 349-358.

Water Research Commission (1995) Pesticides in ground water – current understanding of distribution and major influences. National Water Quality Assessment Pesticide National Synthesis Project.

WEAVER JMC (1993) A preliminary survey of pesticide levels in groundwater from a selected area on intensive agriculture in the Western Cape, Report to the Water Research Commission, Pretoria, Division of Water Technology, CSIR.

WEST RAND DISTRICT MUNICIPALITY (2005) Cradle of Humankind World Heritage Site State of the Environment Report, Compiled by Strategic Environmental Focus and Bohlweki Environmental.

WINDE F and VAN DER WALT IJ (2004) The significance of groundwater-stream interactions and fluctuating stream chemistry on waterborne uranium contamination of streams – a case study from a gold mining site in South Africa, Journal of Hydrology 297, pp. 178-196.

WOLF K, VAN DEN BRINK WJ and COLON FJ (1988) Altlastensanierung, Zweiter Internationaler TNO/BMFT Kongreß über Altlastensanierung (April 11-15), Kluwer Academic Publishers, Dordrecht/Boston/London.

ZAIRE R, GRIFFIN CS, SIMPSON PJ, PAPWORTH DG, SAVAGE JR and ARMSTRONG S (1996) Analysis of lymphocytes from uranium mine workers in Namibia for chromosomal damage using fluorescence in situ hybridization, Mutat. Res. 371, pp. 109-117.

ZAIRE R, NOTTER M, RIEDEL W and THIEL E (1997) Unexpected rates of chromosomal instabilities and alterations of hormone levels in Namibian uranium miners, Radiation Res. 147, pp. 579-584.

ZHU SP, HU QY and LUN MY (1994) Studies on reproductive toxicity of enriched uranium [abstract], Chun Hoa Yu Fang (China) 28 (4), pp. 219-222.

ISSUE PAPER 6 HYDROLOGY OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE: GEOLOGY, SURFACE AND GROUNDWATER

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ABSTRACT

The Cradle of Humankind World Heritage Site (COH WHS) is an approximately 800 km^2 trapezoidal area some 40 km northwest of Johannesburg, South Africa. The COH WHS is underlain by the karstified Malmani Dolomites of the Chuniespoort Group. Pre-Bushveld folding and late-Bushveld bedding sub-parallel ductile deformation mylonites sliced the stratigraphy into an imbricate-stacked duplex. A re-activated left lateral WNW trending shear system acts as the principle control of cavern and karst form development upon the area. An episode of Quaternary regional up-warping on an ENE trending transcontinental axis has tilted the emergent plateau slightly towards the N and has caused a significant drainage reversal over the whole karst region. Younger streams have aggressively incised northward draining gorges, capturing the previous drainage pattern. High yielding karst aquifers are developed in the chert-rich Eccles and Monte Christo Formations of the Malmani dolomites. The karst aquifer, which represent the only water resource for many towns, rural settlements and farms in the region, is compartmented by near vertical dykes and silicified faults, as well as by bedding sub-parallel ductile mylonitic thrust planes and refolded folds. Due to the duality of the aquifer recharge, storage and discharge processes, Karst aquifers have very complex and original characteristics, complicating their development and management. Once contaminants have entered the system they spread rapidly affecting large bodies of fresh water. For the sustainable management and development of the groundwater resources of the COH WHS, an improved understanding of the delineation of groundwater resource units, drainage patterns of ground and surface water as well as the regional water quality is necessary.

6.1 Introduction

The major part of the Cradle of Humankind World Heritage Site is underlain by the Malmani Dolomite of the Chuniespoort Group. The site consists of an ± 800 km^2 trapezoidal area some 40 km Northwest of Johannesburg in the province of Gauteng, South Africa. It extends from Krugersdorp in the Southwest to Hartbeespoort Dam in the Northeast, a distance of 37 km with an average width Northwest to Southeast of 20 km (**Figure** 6.1). The Malmani Dolomite is the most common karstified rock in South Africa and is demonstrated in the over 200 caves found in the Cradle of Humankind World Heritage Site (COH WHS). The term karst is used to describe a terrain generally underlain by limestone or dolomite, in which the landforms are formed by the dissolution of rock (karstification) and in which the drainage is underground in solutionally enlarged fissures, conduits and caves (Karst Commission, International Association of Karst Hydrogeologists, 1999).

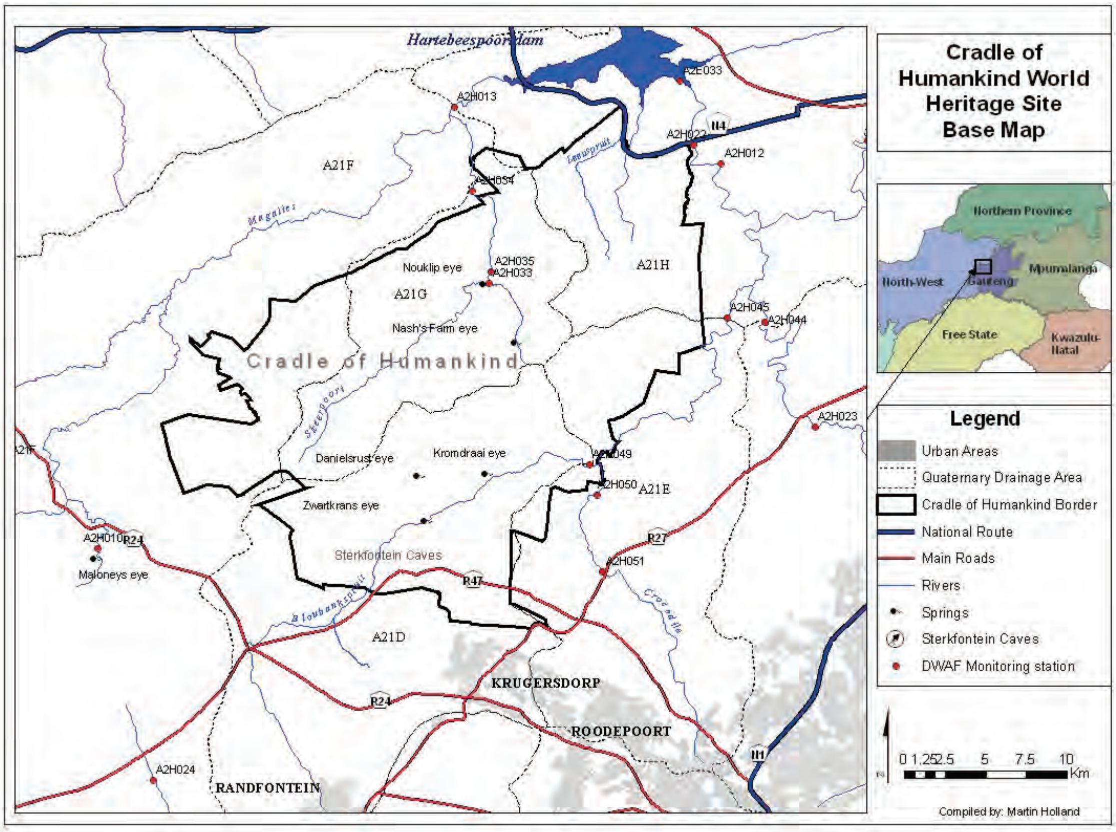

Figure 6.1: Location map of study area

The Malmani Dolomites were formed in a shallow early Proterozoic epeiric sea (Clendennin, 1989). The lithology in this area consists essentially of shallow marine stromatolitic dolostone and has been subdivided into five Formations (geological units) of alternating chert-poor and chert-rich dolomite. The dolomite is capped by a palaeo-karst of coarse grained chert made up of re-cemented broken clasts (breccia) beneath the overlying base of the Pretoria Group. A palaeo-karst is karst that formed at a specified time in the past, and has been exhumed and revealed by erosion of later strata.

Compared with classic karst areas of Europe and America, the regional Karst of the COH WHS is very different and perhaps unique. The Karst of the Malmani Dolomite is a world important example of a Karst developed on a very old dolomite. Therefore, the lithologies have been subjected to deep burial, tectonization, folding, uplifting, and prolonged episodes of natural loss of soil and rock debris in the interior of the Kaapvaal Craton. Another important and well documented characteristic of the regional karst of the Malmani dolomite is its subdivision into 'compartments' isolated hydrologically from each other by impervious near vertical dykes of dolerite and syenite, as well as by silicified faults. The major compartments of the COH WHS, according to the various geohydrological studies in the Krugersdorp area done by Fleisher (1981), Foster (1984), Bredenkamp *et al.*, (1986) and Kuhn (1986) are the Zwartkrans and Tweefontein compartments. However, the bulk of the COH WHS dolomites have not been investigated and therefore a deficiency of data exists. Recent work by A.A. Jamison (in preparation) established that many more fractures and dykes exist, and have also identified considerable deformation in the COH WHS, which suggests more complex Karst systems are present.

Perhaps the most significant result of karstification is the development of highly permeable zones of large storage capacity, capable of sustained groundwater extraction from high-yielding boreholes. Many towns, rural areas and farming practices in South Africa, rely on the dolomites of the Chuniespoort Group as their only water resource (Barnard 2000). However, because of the origin of the karst features, these resources are not always exploitable aquifers, groundwater storage being in some cases negligible or impossible to develop. The heterogeneity of karst aquifers makes it difficult to quantify and predict the movement of groundwater and contaminants through and/or between different aquifer zones. In many instances it is difficult to quantify a sustainable water balance that would prevent over-use of the groundwater resource. This paper presents a review of the state of scientific knowledge and identifiable gaps that need to be addressed in order to adequately manage the water resources of the Cradle of Humankind World Heritage Site.

6.2 Conceptual Framework

Karst is commonly considered as the result of the solution process of carbonate rocks, named "karstification". As infiltrating rainwater is in equilibrium with the carbon dioxide in the atmosphere (~0.035%) and the soil zone (up to a few percent), it contains a weak carbonic acid (H_2CO_3). The weakly acidic groundwater circulating through the dolomitic succession causes dissolution of the carbonate minerals, resulting in the development of open cavities and caves. The process may be represented as follows:

$$CaMg(CO_3)_2 + 2H_2O + 2CO_2 \rightarrow Ca^{2+} + Mg^{2+} + 4HCO_3^-$$

For this reason karst aquifers are often characterised by a dual or triple porosity, comprising of solutional voids, fractures and the rock matrix (intergranular pores). While the fractures and the rock matrix provide predominately storage potential, the conduits act additionally as drains. Hence a fast advective transport of contaminants with significant tailing effects similar to fractured aquifers can be expected, emphasizing the vulnerability of karst aquifers. In a simplified (vertical) conceptual model of the karst aquifer, an epikarst zone might be present in the unsaturated zone (Gunn, 1986). The epikarst zone either allows diffuse infiltration, or concentrates the flow into vertical conduits such as fracture and fault zones (**Figure** 6.2). If sinkholes or swallow holes are present, they break and bypass the epikarst zone (Bakalowicz, 2005). Most theoretical and practical problems result from the duality of the aquifer recharge, storage and discharge processes. As a result, researchers all over the world are besieged with the flow and storage associated with karst aquifers (e.g. Pinault *et al.*, 2001; Kiraly, 2003; Scanlon *et al.*, 2003).

Scientific investigations of the karst regions in South Africa started in the early sixties (De Kock, 1964; Brink and Partridge, 1965). Since this time many investigations have been carried out by geologists, hydrologists and geomorphologists. Therefore, different approaches prevailed in karst studies, each with their own concepts and methods. On the one hand, karst evolution and the cycle of karst development associated with the regional dolomite have long attracted attention from South African geologists (Marker, 1972; Martini and Kavalieris, 1976; Marker, 1980; Wolmarans, 1986; Martini *et al.*, 2003). On the other hand, investigations on the groundwater potential of the regional dolomite became necessary when more groundwater was required for the growing population and the impact of the gold mining activities needed to be addressed. This led to numerous large-scale and widespread groundwater investigations carried out by Enslin and Kriel (1967), Fleisher (1981), Foster (1984), Bredenkamp *et al.*, (1986), Kuhn (1986), Bredenkamp (1995) and Barnard (1997).

Although these studies initiated groundwater management in karst terrains, it was only recently that the management of groundwater reached a higher level of sophistication. The role of groundwater, with recharge as a critical parameter for determining its sustainable use, is becoming increasingly important in the emerging Integrated Water Resource Management (IWRM) paradigm (Xu and Beekman, 2003). In addition, groundwater recharge is the key element in quantifying the groundwater component of the Reserve, which consists of the quantity and quality of water that should be set aside to meet basic human needs and to sustain aquatic ecosystems (Hugo *et al.*, 2004). At the same time, groundwater recharge is also the most difficult parameter to determine. The reliability of the quantitative assessment is often questionable because of simplifying assumptions and uncertainties of some key parameters like evapotranspiration, conductivity and storativity that are required

Reliable estimation of groundwater recharge has been the focus of many studies and recently Xu and Beekman, (2003), Kinzelbach *et al.*, (2002) and Bredenkamp *et al.*, (1995) made much progress in this respect. Given the heterogeneity of karst aquifers it is widely accepted that no single estimation technique can successfully determine groundwater recharge. One of the simplest and most effective methods to derive the recharge is to relate the average flow of a spring to the rainfall that has occurred over its recharge area. Delineation of the recharge area could however be difficult. The reliability of water balance methods, like the Cumulative Rainfall Departure Method and Darcian methods such as the saturated flow volume or numerical flow models, depend on the availability of essential data which are often lacking. For this reason, natural groundwater tracers provide a supplementary way to assess and compare the characteristics of groundwater recharge. Recently more studies rely on chemical (e.g. chloride) and isotope tracer (e.g. ^{2}H, ^{3}H or ^{18}O) approaches to estimate recharge (Bredenkamp *et* *al.*, 1995; Wood and Sanford, 1995; Beekman *et al.*, 1996; Bredenkamp, 2000; Kinzelbach *et al.*, 2002).

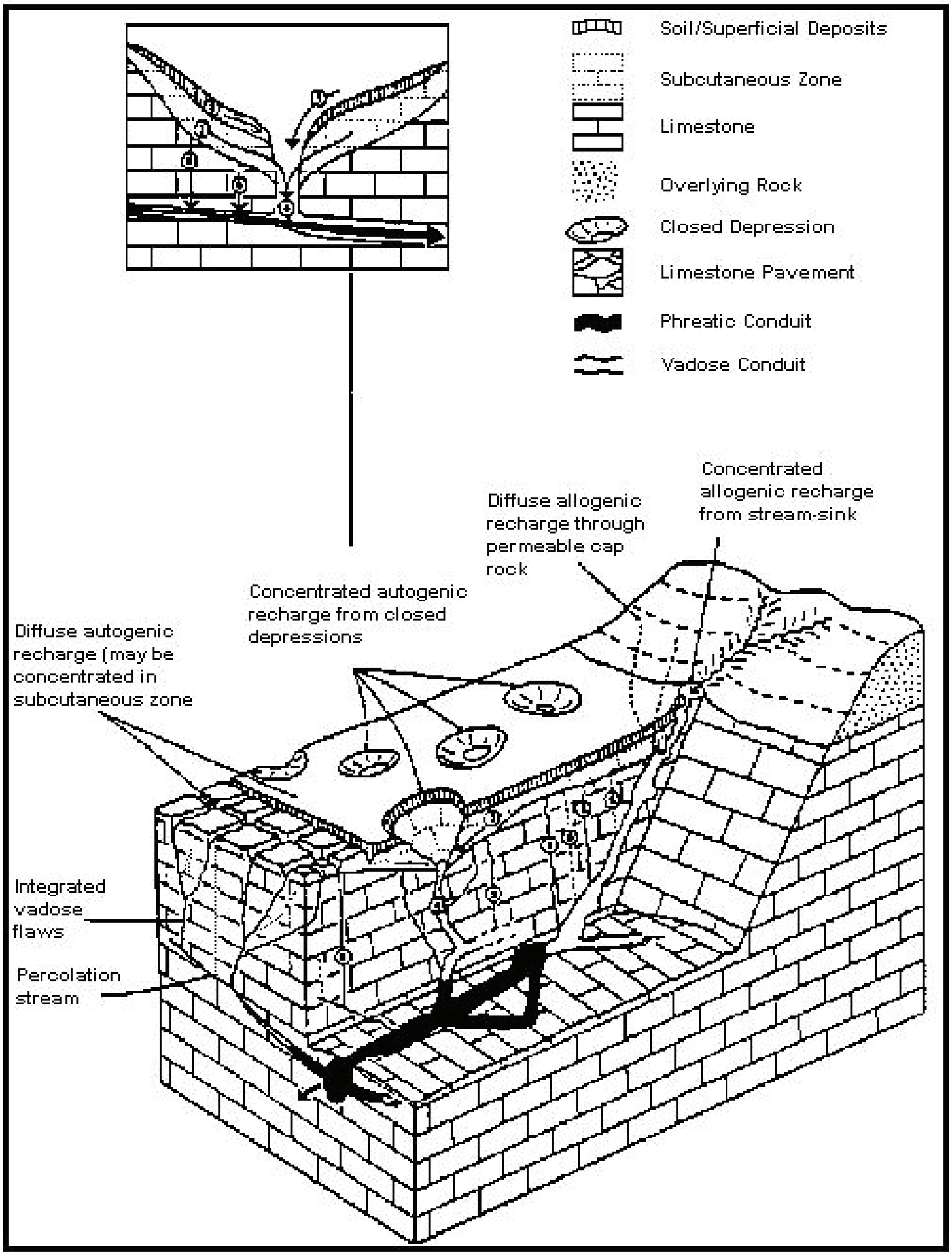

Figure 6.2: Conceptual model of a karst aquifer (From Gunn, 1986).

In addition Bredenkamp and Van Wyk (2000) has used environmental ^{14}C concentrations in dolomitic aquifers to derive quantitative/qualitative assessments of recharge, and determined the groundwater in storage as multiples of the recharge of an aquifer (Bredenkamp and Vogel in press). However, several postulations are necessary to apply the ^{14}C method in carbonates (Kinzelbach, 2002).

The methods available for quantifying groundwater recharge depend on the different sources and processes of recharge. It remains essential to know each of the method's limitations in terms of applicability and reliability (e.g. Kinzelbach *et al.* 2002), especially in heterogeneous karst aquifers where its evolution exerts a distinct influence on the groundwater recharge. Therefore, to comprehend the dynamics of a karst aquifer, it is necessary to understand the recharge processes and the hydrodynamic flow systems that are controlled by the permeability of the aquifer and exchange of water between the different layers and compartments. Yet, to describe the hydrology of the Karst system effectively, a sound geological and conceptual hydrogeological model verified by tracer tests is essential.

6.3 Geological Setting

The northwestern boundary of the COH WHS runs along the crestal ridge of the Klapperkop quartzite of the Timeball Hill Formation of the Pretoria Group. The southeastern boundary runs over the western part of the Johannesburg granite dome and its associated ridges of gold bearing Witwatersrand Formations forming the faulted rim of the Witwatersrand basin. Dipping off the western flank of the Johannesburg Dome with a disconformable contact is the basal Formation of the Transvaal Supergroup consisting of the Black Reef Quartzite Formation underlying the Malmani Dolomite subgroup of the Chuniespoort Group (**Figure** 6.3).

Based on the abundance of chert, the subgroup has been subdivided into five dolomitic Formations (Table 6.1). However, the Frisco Formation at the top is poorly exposed in the COH WHS. The chert-rich Eccles Formation and especially the Monte Christo Formations have good water-bearing and storage characteristics. The Oaktree and Lyttelton Formations are characteristically chert poor with only the occasional thin band of chert and have a low groundwater potential.

The present karst forms and geomorphology have been created by the interplay of ancient and recent erosion cycles on lithologies that have undergone many episodes of deformation, which are only now being studied and analysed. These regional deformation events have been documented from a growing number of geological studies of the dolomites surrounding and within the Bushveld Complex (Hartzer, 1987; Du Plessis and Clendennin, 1989; Bumby *et al.*, 1998; Obbes, 1995; Jamison *et al.*, 2004). Recent detailed mapping and analysis in the greater COH WHS has identified pre-Bushveld folding and late-Bushveld bedding sub-parallel ductile deformation mylonites which slice the stratigraphy into an imbricate stacked duplex (parts overlapping like roof-tiles) (Andreoli, 1988; Harley and Charlesworth, 1992; Courtnage *et al.*, 1995). Mylonites are formed as fine grained laminated rock by extreme plastic deformation and milling of rocks during movement on faults, under high strain in deformation zones at depth.

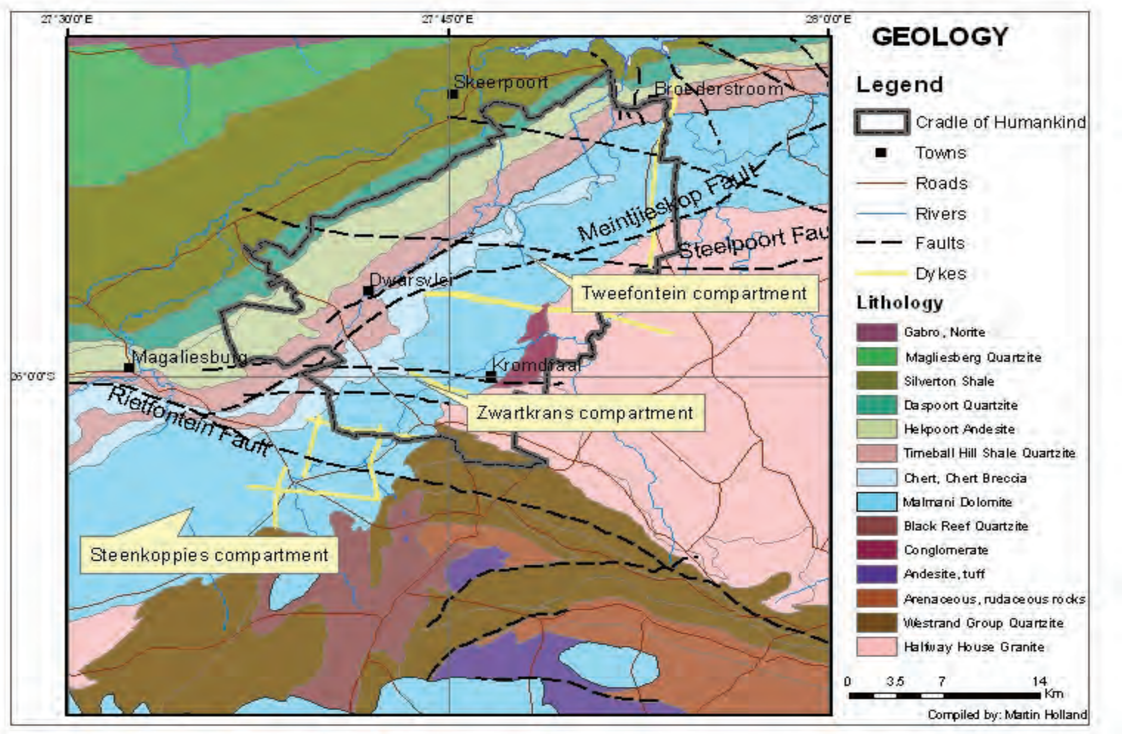

Figure 6.3: Regional geology of the Cradle of Humankind.

Table 6.1: Lithostratigraphy of the geology of the region, area of investigation highlighted (Source: SACS, 1980:205).

Sequence	Group	Formation	Thickness (m)	Lithology
TRANSVAAL	PRETORIA	Timeball Hill	270-660	Shale, Diamictite, Klapperkop Quartzite and ferruginous quartzite. Graphitic and sitly shale.
		Rooihoogte	10-150	Quartzite, Shale, Bevets Conglomerate Member and Breccia.
	CHUNIESPOORT	Frisco	30	Chert-free dolomite with some primary limestone and carbonaceous shale at the base.
		Eccles	490	Chert-rich dark dolomite with stromatolitic and oolitic bands. Chert increases to the top.
		Lyttelton	290	Chert-free dark dolomite with large stromatolites and sometimes with wad.
		Monte Christo	740	Alternate layers of chert-rich and chert-poor light coloured dolomite with stromatolites and oolites.
		Oaktree	330	Chert-poor dark dolomite with interbedded layers of carbonaceous shale at the base, decreasing to the top and sometimes with wad.
		Black Reef Quartzite	25-30	Shale and Quartzite. Arkosic Grit

The dolomites and Pretoria Group have subsequently been folded and fractured by a re-activated left lateral WNW trending shear system which has imprinted sub-parallel deformation zones at about 10 km intervals parallel to the Rietfontein Wrench Fault System as the principle control of cavern and karst form development upon the area (**Figure 6.4:**). Most of the caves, dolines, sinkholes and fissures are located on the WNW shear zones and in close relationship to impervious bedding sub-parallel mylonitic cherty slate horizons (Jamison *et al*., 2004). The final phase of re-juvenating of these fractures occurred as a result of epeirogenic warping and uplift along the Griqualand-Transvaal axis (Partridge and Maud, 1987; Moore and Larkin, 2001), during the Late Cretaceous Era, which initiated the present Karst cycle on the Craton interior.

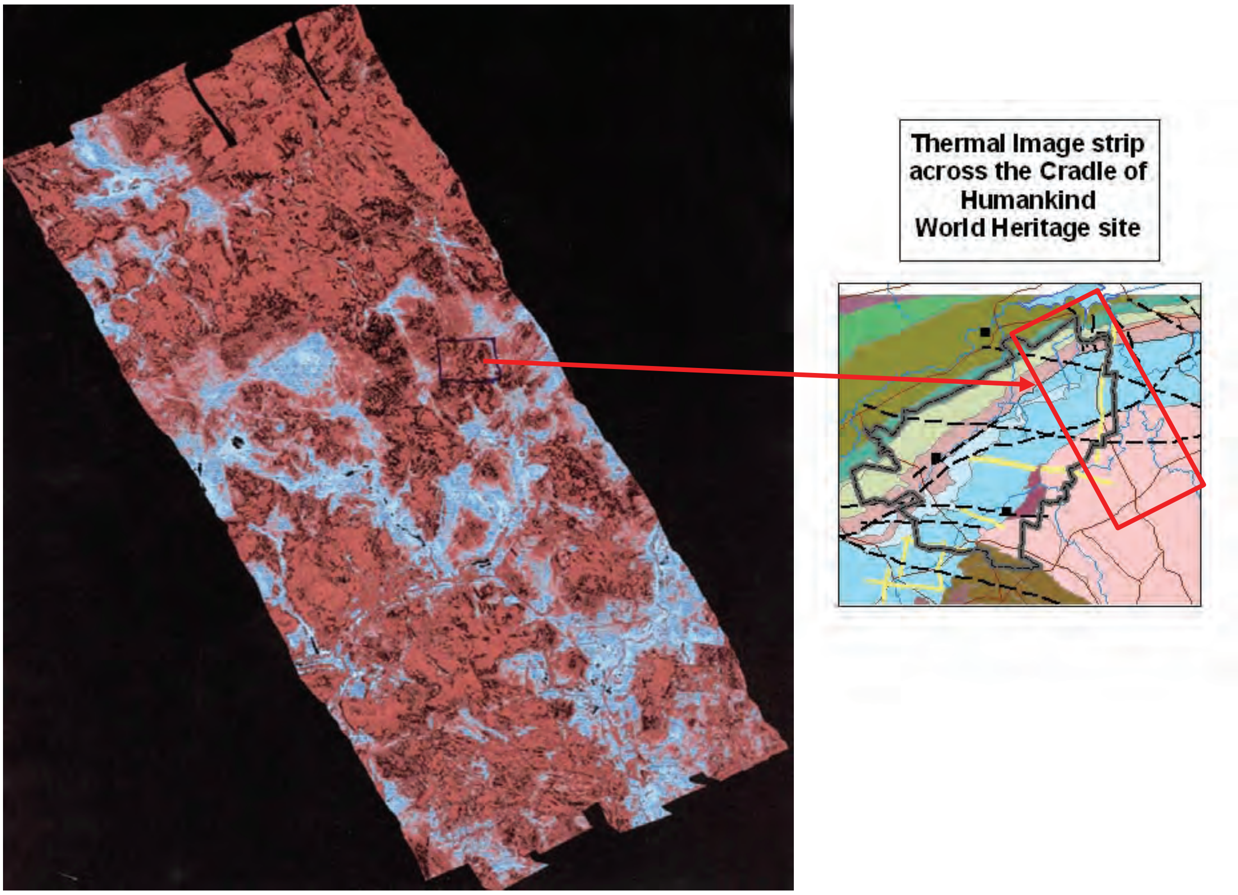

Figure 6.4: Colour table enhanced thermal image of the central Cradle area showing the cold wet surface areas in blue, marking the saturated compartments, and the bounding linear structure zones (Adapted from image taken by Anglo American Geophysical Services (Jamison, 2001)).

Subsequent to the breakup of the super-continent of Gondwanaland (250 million years ago), the dolomites have been uplifted into a high interior plateau and the overlying Karoo cover rocks relatively rapidly stripped off by erosion to reveal a pre-Karoo palaeo-karst surface (King, 1963; Wilkins *et al.*, 1987). An episode of Quaternary regional upwarping on an ENE trending transcontinental axis has caused significant drainage reversal over the whole karst region. The emergent plateau has tilted slightly towards the north and the younger streams have aggressively incised northward draining gorges, capturing the previous drainage pattern and exploiting zones of structural weakness (Wellington, 1941). Renewed karstification of this rejuvenated surface has taken place over the Pleistocene Period accompanied by climatic changes of the Highveld Plateau pluvial cycles.

Therefore, the dolomites are not only compartmented by near vertical dykes and silicified faults but also by bedding sub-parallel ductile mylonitic thrust planes and refolded folds. As a result of fracture reopening in the Tertiary epeirogenic warping of the dolomite plateau, solution along the WNW trending fracture zones was enhanced and a new cycle of karstification of the dolomite ensued. The present caves and karst features would thus be expected to occur as perched water tables, and complex recharge and flow regimes within and between compartments are controlled by an inherited structural and lithological framework (**Figure** 6.4) (Jamison, 2001).

6.4 Water Resources

The characterizing features of karst aquifers are the open conduits, which provide low resistance pathways for groundwater flow and which often short-circuit the granular or fracture permeability of the aquifer. Conduit flow often has more in common with surface water than with groundwater. In karst regions, surface water becomes groundwater when it sinks into the streambed or into swallow holes and might resurface when it emerges from springs. Hence karst hydrology requires a combination of surface water concepts and groundwater concepts. The surface features of the COH WHS dolomites can often be related to the sub-surface bearing characteristics e.g. valleys of surface drainage coincide with fractured zones in karstified dolomite. The low density of runoff drainage suggests high recharge and predominance of water flow underground, which eventually drains into surface streams at eyes or impermeable barriers or emanates as springs.

6.4.1 Surface water

The surface water in the COH WHS forms a part of the upper Crocodile River sub-system and is located within the Crocodile (West) and Marico Water Management Area as described by the Department of Water Affairs and Forestry (DWAF). The COH WHS forms part of the A21 Tertiary drainage region. The Quaternary drainage regions involved are A21D, A21E, A21F, A21G and A21H. The area experiences a sub-humid warm climate typical of the Transvaal Highveld. Rain occurs predominantly as thunderstorms during summer, mostly between November and February. The mean annual precipitation (MAP) over the area varies between 600-700mm (DWAF, 1992). A very a high potential evapotranspiration with a mean annual evaporation (MAE) of about 1 700 mm prevails (DWAF, 1992).

The dolomitic Formations underlain by the COH WHS generate little surface run-off, creating an area virtually devoid of surface drainage channels. Some drainage characteristics include:

- A generally dendritic (branching form) drainage pattern of low density;
- On satellite images of the area, various structurally controlled intermittent drainage channels could be identified;
- The southern part of the COH WHS is drained towards the north-east by the Bloubankspruit and its tributaries to the Crocodile River, which feeds the Hartbeespoort Dam;
- In the central part of the COH WHS the riverbed of the Skeerpoort drains north to Magalies River; it is fed from springs, as well as by surface runoff during periods of high rainfall;
- Several perennial springs are present, namely Nouklip-, Kromdraai- and Zwartkrans Eye, with discharges of more than 5 liters per second. These points of outflow are generally associated with topographic lows next to diabase dykes or formation contacts, but are not yet monitored on a continuous basis.

The hydrology of the catchment has been significantly influenced by man. Water is abstracted from the surface water systems for irrigation and, to a lesser extent, for urban, industrial and mining purposes (DWAF, 1992). The natural runoff is increased through effluent return flows from industries, mines, municipal sewage works and increased runoff due to paved surfaces of urbanised areas. The major effluent return flows affecting the COH WHS are the Randfontein sewage works and the Krugersdorp (Percy Stewart) sewage works. Both sewage works emit effluent into the wetlands along the Rietspruit and Blougatspruit which flows into the Bloubankspruit before it reaches the COH WHS. A report on the hydrology of the upper Crocodile River sub-system completed by DWAF (1992) estimated that this sewage works combined account for 7.1 x $10^6 m^3$ return flow annually into the Bloubankspruit tributaries. This accounts for approximately 35 percent of the total mean annual runoff at the downstream gauging station (A2H049 Bloubankspruit) (**Figure** 2). The impact of these return effluent flows on the water quality of the COH WHS is discussed in a different Issue Paper, but not yet completely understood.

Various surface water monitoring points from the Institute for Water Quality Studies at DWAF are found along the Magalies River, Crocodile River and Bloubankspruit (**Figure** 6.5). A series of flow and chemical data exist for these gauging stations, however, no catchment management, river health programme or monitoring programme exist. In order to determine the trends in changes in the surface water quality and quantity, more frequent data feed and a much denser array of surface water monitoring points are required.

6.4.2 Groundwater

The dissolution process in the dolomite karstification, has been more active in the chert-rich dolomite, due to higher porosity developing in the brittle, fragmented, cherty horizons being accessed by deeper penetrating fractures and fissures. Along the dykes the contacts represent zones of high transmissivity that act as zones of preferential flow. For this reason the Monte Christo and Eccles Formations are the most productive aquifers with high recharge, large storage capacities and their capability of sustaining high rates of abstraction from boreholes drilled into deep cavernous or fractured dolomite. In the absence of surface drainage channels, recharge from runoff is not a dominant factor in the COH WHS, however, the Bloubankspruit does have some surface runoff from Blougatspruit, Tweelopiespruit, springs but even more so drains sewage return effluent. The Rietspruit that feeds the Bloubankspruit shows a declining discharge, which indicates significant losses to the aquifer (influent stream). According to Vegter's (1995) national scale map of recharge, recharge varies from 13 percent of the MAP (Mean Annual Precipitation) in the southern part to 10 percent of the MAP in the northern parts of the COH WHS. These approximations are confirmed by studies done on the Zwartkrans and Steenkoppies compartments by Bredenkamp *et al*., (1986).

Groundwater in the Zwartkrans compartment drains north-east to the Zwartkrans, Danielsrust and Kromdraai Eyes (Bredenkamp *et al.*, 1986) (**Figure** 2). Because of the compartmentalisation and the heterogeneity of the karst aquifers, only a poor relationship between groundwater levels and topography exists. While surface water basins are generally controlled by topography, karst groundwater basins are controlled by subsurface drainage systems connecting recharge areas to springs e.g. Zwartkrans and Kromdraai Eyes. In karst aquifers large spatial and temporal variations in the chemistry of natural waters can be observed because of the rapid movement of water through discrete fractures or solution conduits, (ASTM, 1995). Therefore, the opportunity for naturally occurring breakdown of contaminants, filtration by soils and adsorption onto mineral grains and dilution that may prevent detrimental impacts to groundwater is limited.

Elevated levels of sulphate, nitrate, sodium and potassium can be used to indicate the degree and extent of mining and sewage-related pollution in the area. However, there is a significant lack of groundwater chemistry data in the COH WHS and where chemical data are available (Directorate Geohydrology – DWAF), only a few boreholes have continuous annual groundwater chemical data. It is important to note that applicable monitoring points will depend on the conceptual model of the area under investigation. Alternative monitoring points such as springs, cave streams and seeps are often more appropriate in karst terrains. These natural discharge points intercept flow from a larger area than a monitoring borehole. However, there is a general lack of these natural features in the study area. Therefore, the extent to which the groundwater monitoring stations adequately represent response to the aquifer to many controlling factors has to be evaluated with a view to determining if and where additional monitoring points have to be established.

6.5 Management Issues and Strategy

Karst aquifers have complex and original characteristics, which make them very different from other aquifers. Due to the heterogeneity of karst aquifers, methods used successfully for porous aquifers like pumping tests and distributed models show typically limited success in karst aquifers. The commonly proposed methodology is an integrated approach where the karst hydrologists use a variety of methods to explore and study karst aquifers, in order to describe their functioning and their structure.

These methods include:

- Characterisation of the structure by geological and morphological analyses (EPA, 1989; ASTM, 1995);
- Delineation of the karst system by means of geological mapping, tracing tests and water balance;
- Characterisation of their lump functioning;
- by using spring hydrographs and time series analyses (Kresic, 1997),
- by using hydrogeochemical and isotope methods for analysing natural tracing (Hötzl and Werner, 1992; Karst Research Institute, 1997),
- Characterisation of their local functioning;
- by artificial tracing tests (Field, 2002),
- by pumping tests (Van Tonder *et al.*, 2002).

In response to promulgation of the National Water Act (Act No 36 of 1998), tools and methods had to be developed to facilitate the use and protection of groundwater resources in South Africa. This is reflected in the subsequent development of Groundwater Resource Directed Measures (GRDM), which consists of three important aspects, namely: classification; the reserve; and resource quality objectives (Hugo *et al*., 2004). Adopting these GRDM principles provides a sequential process to ensure that groundwater resources are protected, and to ensure sustainable management and development in the future. Different levels of GRDM determination are recognised, with each expected a greater level of confidence in the results. A comprehensive GRDM is recommended for the study area. Therefore, extensive field studies and data collection by specialists are required. The duration of the study typically takes one hydrological year per water resource. However, the duration of the study depends on the ability to delineate the complex groundwater resource units in karst aquifers.

Classification of the water resource requires the assimilation of the scarce available information as well as the acquisition of additional data with regard to the water usage and water contamination. Since the recharge mechanisms as well as the surface/groundwater interactions of karst aquifers are unique, special emphasis should be given in a GRDM study to the reserve quantification. A combination of models employing water balance, chemical and isotopic analyses are recommended to assess the reserve. The COH WHS can act in this regard as a study area to develop guidelines for reserve quantifications in South African karst terrains. Furthermore, vulnerability and risk mapping with specific regard to karst aquifers is the recommended planning and decision-making tool to differentiate between areas that need protection from potential harmful activities, and areas where such activities would constitute a minor threat to the natural resources of the COH WHS. The basic premise underlying the concept of aquifer vulnerability is the variation of groundwater recharge mechanisms, which provides a direct link to a reserve determination of the area. The European approach to vulnerability, hazard and risk mapping for karst aquifers (Zwahlen, 2003) provides a good starting point, but should obviously be adapted to the specific South African conditions. Although, vulnerability maps are scientifically based planning and decision making tools, it is important to note that vulnerability maps are only part of a recommended comprehensive GRDM study of the area.

6.6 Conclusion and Recommendations

The dolomites of the Chuniespoort Group, which underlie the Cradle of Humankind World Heritage Site, are the only readily available water resource for many towns, rural areas and farms in the region. These dolomites are also a vital component of the water resources needed for the expanding demand of the urban complexes in Gauteng and Rustenburg; hence it is considered as one of the most important aquifers in South Africa (Barnard 2000). In addition, the Cradle of Humankind is deemed a World Heritage Site. Its vast treasure chest of fossilised remains of past life forms, particularly hominids (humans, their ancestors and relatives) found in the karst caves of the COH WHS, ensured its status and is therefore protected. Despite its importance and ongoing exploitation, the complex hydrogeology of this compartmentalised karst aquifer was not yet systematically investigated nor is it understood. Recent detailed mapping by A.A. Jamison (in preparation) identified for example not only compartmentalisation of the dolomites by near vertical dykes and silicified faults but also by thrust planes and refolded folds. It is obvious that we cannot achieve a sustainable balance between utilisation and protection of the water resource unless we have at least a conceptual understanding of the aquifer including its interaction with surface water resources.

Improved understanding and accuracy of the following factors is necessary for the sustainable management and development of the groundwater resources of the COH WHS: 1) delineation of the groundwater resource units within the area forming hydrogeological entities, 2) the natural drainage of both ground- and surface water of the total area, 3) the natural flow of the springs, 4) the role of bounding dykes, faults and Formation contacts on the groundwater flow and 5) water sampling of boreholes, springs and rainfall for chemical analysis. In this context it is important to recognise that not all human activities are equally significant or detrimental to the environment. The challenge to custodians, managers, scientists and stakeholders is to identify the most sensitive areas and accurately predict the significance of changing land use or other impacts in these terrains.

REFERENCES

ASTM (American Society for Testing and Materials) (1995) Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured-Rock Aquifers, ASTM Designation D5717-95, ASTM, West Conshohocken, PA.

ANDREOLI MAG (1988) The discovery of a strange and hidden African orogeny: the Transvaal fold belt, 4th Annual Conference, Tectonics Division, G.S.S.A.

BAKALOWICZ M (2005) Karst groundwater: A challenge for new resources, Hydrogeological Journal 13, pp. 148-160.

BARNARD H (1997) Geohydrological investigation of the catchment of Maloney's eye, Unpublished MSc Dissertation, University of the Free State, Bloemfontein, RSA.

BARNARD HC (2000) An Explanation of the 1:500 000 General Hydrogeological Map, Department of Water Affairs and Forestry, Pretoria.

BEEKMAN HE, GIESKE A and SELAOLO ET (1996) GRES: Groundwater Recharge Studies in Botswana 1987-1996, Botswana Journal of Earth Science 3, pp. 1-17.

BREDENKAMP DB, VAN DER WESTHUIZEN C, WIEGMANNS FE and KUHN CM (1986) Groundwater supply potential of dolomite compartments west of Krugersdorp, Technical Report Gh3440, Directorate Geohydrology, DWAF.

BREDENKAMP DB (1995) Dolomitic Groundwater Resources of the Republic of South Africa, Technical Report Gh3857, Directorate Geohydrology, DWAF.

BREDENKAMP DB, BOTHA LJ, VAN TONDER GJ and VAN RENSBURG HJ (1995) Manual on quantitative estimation of groundwater recharge and aquifer storativity, Water Research Commission Report No. TT 73/95, WRC, Pretoria.

BREDENKAMP DB and VAN WYK E (2000) Groundwater Monitoring: A critical evaluation of groundwater monitoring in water resources evaluation and management, Water Research Commission Report No. 838/1/00 WRC, Pretoria.

BREDENKAMP DB (2005) Simulation of Thermonuclear 14C in springs and its hydrological interpretation, Biennal Groundwater Conference 2005, CSIR Conference Center, Pretoria. Not in the text

BRINK ABA and PARTRIDGE TC (1965) Transvaal karst: Some considerations of development and morphology, with special reference to sinkholes and subsidences on the Far West Rand, South African Geographical Journal 47, pp. 11-34.

BUMBY AJ, ERIKSSON PG and VAN DER MERWE R (1998) Compressive deformation in the floor rocks to the Bushveld Complex (South Africa): Evidence from the Rustenburg Fault Zone, Journal of African Earth Science 27, pp. 307-330.

CLENDENNIN CW (1989) Tectonic Influence on the Evolution of the Early Proterozoic Transvaal Sea, Southern Africa, Unpublished PhD Thesis, Wits University.

COURTNAGE PM, GIBSON RL, CHARLESWORTH EG, and ANDREOLI MAG (1995) Post-Transvaal deformation between the Johannesburg dome and the Bushveld Complex, Centennial Geocongress G.S.S.A, Extended Abstracts, 1, pp. 287-290.

DE KOCK WP (1964) The geology and economic significance of the West Wits line In: Geology of some ore deposits in southern Africa, Geol. Soc. S. Afr., pp. 323-386.

DWAF (Department of Water Affairs and Forestry) (1992) Hydrology of the Upper Crocodile River Sub-System, Report No. PA200/00/1492, 1 and 2, DWAF, Pretoria.

DU PLESSIS CP and CLENDENNIN CW (1988) The Bobbejaanwater Fault System south of Thabazimbi, Western Transvaal, S.A.J.G. 91 (1), pp. 1-138.

ENSLIN JF and KRIEL JP (1967) The assessment and possible use of the dolomitic groundwater resources of the Far West Rand, Transvaal, International Conf. Water Peace, Washington.

EPA (Environmental Protection Agency) (1989) Groundwater Monitoring in Karst Terrains: Recommended Protocols and Implicit Assumptions, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada.

FIELD M (2002) The QTRACER2 program for tracer-breakthrough curve analysis for tracer tests in karstic aquifers and other hydrologic systems, EPA/600/R-02/001, National Center for Environmental Assessment, US EPA, Washington, DC.

FLEISHER JNE (1981) The Geohydrology of the dolomite aquifers of the Malmani sub-group in the south-western Transvaal, Republic of South Africa, Technical Report Gh3169, Directorate Geohydrology, DWAF.

FOSTER MBJ (1984) Steenkoppies and Zwartkrans dolomite compartments – Preliminary Geological Report, Technical Report Gh3346, Directorate Geohydrology, DWAF.

GOVERNMENT GAZETTE (1998) National Water Act, Government Gazette 398, No. 19182, Government Printer, Pretoria.

GUNN J (1986) Modeling of conduit flow dominated karst aquifers In: Karst Water Resources (Gunay, G and Johnson AI eds.), IAHS, Wallingford, UK., Publication 161: pp. 587-596.

HARLEY M and CHARLESWORTH EG (1992) Thrust-controlled gold mineralization at the Elandshoogte Mine, Sabie-Pilgrim's Rest Goldfield, South Africa, Mineralium Deposita 27, pp. 122-128.

HARTZER FJ (1989 in the text it is 1987) Stratigraphy, structure, and tectonic evolution of the Crocodile River Fragment, S. Afr. J. Geol. 92 (2), pp. 110-124.

HÖTZL H and WERNER A (eds.) (1992) Tracer Hydrology, Balkema, Rotterdam.

HUGO A, WENTZEL J, PARSONS R, CONRAD J, DENNIS I, GODFREY L, HOBBS P and VAN ZYL P (2004) Groundwater Resource Directed Measures Training Manual, FetWater Initiative, Water Research Commission and Department of Water Affairs and Forestry, Pretoria.

KARST COMMISSION, INTERNATIONAL ASSOCIATION OF HYDROGEOLOGISTS (1999) Karst Groundwater. http://www.karst-hydrogeology.de/iah-karst.html.

JAMISON AA (2001) Status Quo Report, Cradle of Humankind State of Environment, IECMP, DACEL, Gauteng, Wits University.

JAMISON AA, VAN NIEKERK EJ and VILJOEN MJ (2004) Bedding-parallel, shear and sinistral wrench faulting influencing location and formation of caves in the Cradle of Humankind, Gauteng, South Africa. Extended Abstracts Geocongress 2004, GSSA.

JACKSON JA (ed.) (1997) Glossary of Geology, 4th ed., American Geological Institute. Not in the text and supposed to be Karst Commission, International Association of Hydrogeologists (1999)

KARST RESEARCH INSTITUTE (1997) Karst Hydrogeological Investigations in South-Western Slovenia, Association of Tracer Hydrology, Ljubljana, Slovenia.

KINZELBACH W, AESCHBACH W, ALBERICH C, GONI IB, BEYERLE U, BRUNNER P, CHIANG WH, RUEEDI J and ZOELLMANN K (2002) A Survey of Methods for Groundwater Recharge in Arid and Semi-arid regions, Early Warning and Assessment Report Series, UNEP/DEWA/RS.02-2, United Nations Environment Programme, Nairobi, Kenya.

KING LC (1963) The South African Scenery, Oliver & Boyd, Edinburgh, U.K, 308 pp.

KIRALY L (2003) Karstification and Groundwater Flow, Speleogenesis and Evolution of Karst Aquifers 1 (3), pp. 2-26.

KRESIC N (1997) Quantative solutions in hydrogeology and groundwater monitoring, Lewis Publishers, Florida. pp. 269-302.

KUHN CM (1986) Geohydrological investigation of the Western and Central Steenkoppies Compartment, Technical Report Gh3446, Directorate Geohydrology, DWAF.

MARKER ME (1972) Karst landform analysis as evidence for climatic change in Transvaal, South African Geographical Journal 54, pp. 152-162.

MARKER ME (1980) A systems model for karst development with relevance for Southern Africa, South African Geographical Journal 62, 151-163.

MARTINI JEJ and KAVALIERIS I (1976) The karst of the Transvaal (South Africa), International Journal of Speleology 8, pp. 229-251.

MARTINI JEJ, WIPPLINGER PE, MOEN HFG and KEYSER A (2003) Contribution to the Speleology of Sterkfontein Cave, Gauteng Province, South Africa, International Journal of Speleology 32, pp. 43-69.

MOORE AE and LARKIN PA (2001) Drainage evolution in south-central Africa since the break-up of Gondwana, South African Journal of Geology 104 (1), pp. 47-68.

OBBES AM (1995) The structure, stratigraphy and sedimentology of the Black Reef-Malmani-Rooihoogte succession of the Transvaal Supergroup southwest of Pretoria, Unpublished MSc. Dissertation, Rand Afrikaans University, 135 pp.

PARTRIDGE TC and MAIDE RR (1987) Geomorphic evolution of southern Africa since the Mesozoic, South African Journal of Geology 90 (2), pp. 179-208.

PINAULT JL, BAKALOWICZ M, PLAGNES V and AQUILINA L (2001) Inverse modeling of the hydrological and the hydrochemical behavior of hydrosystems: characterization of karst system functioning, Water Resource Research 37, pp. 2191-2204.

SCANLON BR, MACE RE, BARRETT ME and SMITH BD (2003) Can we simulate regional groundwater flow in a karst system using equivalent porous media models? Case study, Barton Springs Edwards Aquifer, Journal of Hydrology 276, pp. 137-158.

SOUTH AFRICAN COMMITTEE FOR STRATIGRAPHY (SACS) (1980) Stratigraphy of South Africa, Part 1, Government Printer, Pretoria.

SWEETING MM (1973) Karst landforms and limestone, South African Geographical Journal 55, pp. 81-88. Not in the text

VAN TONDER G, BARDENHAGEN I, RIEMANN K, VAN BOSCH J, DZANGA P and YONGXIN X (2002) Manual on pumping test analysis in fractured rock aquifers, Report No. 1116/1/02, Water Research Commission, Pretoria.

VEGTER JR (1995) An explanation of a set of national groundwater maps, Report No. TT 74/95, Water Research Commission, Pretoria.

WILKINS CB, ERIKSSON PG and VAN SCHALKWYK A (1987) Two generations of karst-fill sedimentary rocks within Chuniespoort Group dolomites south of Pretoria, South African Journal of Geology 90 (2), pp. 155-167.

WELLINGTON JH (1941) Stages in the process of river superposition in the southern Transvaal, S. Afr. J. Sci. 37, pp. 78-96.

WOLMARANS JF (1986) Some engineering-geological and hydrological aspects of mining on the West Wits Line In: Mineral Deposits of southern Africa, Geol. Soc. S. Afr. pp. 701-796.

WOOD WW and SANFORD WE (1995) Chemical and isotopic methods for quantifying ground water recharge in a regional, semi-arid environment, Ground Water 33, pp. 458-468.

XU Y and BEEKMAN HE (eds.) (2003) Groundwater Recharge Estimation in Southern Africa, UNESCO IHP Series No. 64, UNESCO, Cape Town.

ZWAHLEN F (ed.) (2003) Vulnerability and risk mapping for the protection of carbonate (karst) aquifers, Final Report COST Action 620, European Commission, Directorate-General for Research, EUR 20912: Luxemburg.

ISSUE PAPER 7 THE USES OF CAVES AND KARST IN THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

P. Kenyon and R. Ellis

ABSTRACT

The caves and karst of the area known as the Cradle of Humankind World Heritage Site (COH WHS) northwest of Johannesburg, South Africa, are considered to be under threat from a wide variety of issues. One particular challenge to the sustainable utilisation of the area is the development of tourist activities. The pending development of the Mogale's Gate Tourist Centre will dramatically increase the human impact on the COH WHS, as visitors seek to utilise the current facilities as well as new developments that may arise. The issue lies around the sustainability of any tourist activity balanced against the need for economic growth. In particular, the impact of human activity on the cave systems of the COH WHS is seen to be a major threat. This paper describes the current human activity in the COH WHS, and provides a short description of the effects such activities have on the karst and sensitive cave environments. The gaps in knowledge about the caves and karst are highlighted and possible areas for further investigation as well as management needs are proposed.

The essential problem is the fragility of the caves, due to the low energy level of cave ecology (meaning that there is no large scale natural addition of energy to the caves) coupled with the increasing interest in caving in the area. There has been an increase in caving club activity, as well as an increase in commercial activity, which can be detrimental to the wellbeing of the cave. The attempts to gate caves to prevent damage has had mixed results. Other issues include the removal of rock, flora and fauna from the area on an uncontrolled basis. A significant area of concern is the apparent lack of coordination between the various interested and affected parties, with many groups being involved, but with limited communication between them.

The recommendations for the way forward include the development of legislation designed to:

- Address the issue of caves and karst specifically;
- Develop an education programme targeted at the residents to reduce the environmental impact;
- Secure the assistance of residents and train a dedicated group tasked with monitoring the environmental status of the area.

7.1 Introduction

The Cradle of Humankind World Heritage site is known for its beauty and unique features. The beauty ranges from the physical aspects of the weathered sedimentary rock features, known as karst, to the caves, with their palaeontological and archaeological wealth. Encompassing a large area of some 47 000 hectares and under threat from the very range of activities that make it such an appealing area, the COH WHS needs the protection and support of a wide range of role players.

This paper seeks to look at a few of those activities and stakeholders, with specific reference to the impact of tourism on the caves of the COH WHS. The problems caused by human traffic within cave systems, the removal of karst and cave formations, the tourist infrastructure within the COH WHS, and a range of surface activities affecting the karst and cave will be discussed. The sustainability of utilising karst and caves for tourism and recreational purposes, as well as the procedures required for the protection of these resources will be investigated.

There are many books and articles that cover the geology of South Africa and the Gauteng region in particular, however the literature on the caves is less prolific. Some of the South African publications on caves and karst that are useful to this topic include the following:

The book - *Caves of the Northern Cape, South Africa: A base line study* (Irish and Marais, 2002) is an attempt to establish a list of some of the lesser known caves of the Northern Cape karst region in order to establish their current condition. The study included climatological aspects, subjective CO_2 levels and biological content. The authors comment on the low level of fauna present in the region, linking it to the fact that the public has free access to the caves. In contrast, where the Griekwastad Publicity Organisation has sought expert opinion and resulting from it, allowed only limited free access, the caves are in better condition. The importance of a healthy bat population to sustain the fauna of the caves is stressed. Though not a part of the publication, a similar statement can be made about the COH WHS, where many of the caves in this area are easily accessed, with only the commercial caves offering any degree of protection. This lack of protection has allowed the caves to be degraded.

The Bulletin of the South African Spelaeological Association dedicated a whole issue to the management problems of Cango Caves (Craven, 1994). The conclusion was that uncontrolled human activity had led to the degradation of the Cango Caves. Another factor contributing to the degradation of the cave was that revenue generated through tourism was never reinvested to improve management of the caves. An appropriate cave management procedure has now been developed to ensure that further degradation does not take place. In contrast, ownership of caves at the COH WHS is in the hands of private individuals or is controlled by academic institutions due to the palaeontological and archaeological significance of the caves.

An excellent description of the Sterkfontein Cave is supplied by Martini *et al.*, (2003). This covers the history and geology of the cave in relation to the fossil finds in great depth and readability, but does not extend to describe the management of the cave. Any useful book on the general subject of caves should cover the cave and karst geological basics, cave formation, biology, history, science, ecology and cave tourist management issues. *Caves – Processes, Development, Management* is such a book (Gillieson, 1996). The ranges of human effects that he describes include deforestation, agriculture, urbanisation, mining, tourism, military and water issues. The subject of "carrying capacity" and the limitations of this concept are also discussed.

A search of the Internet will yield many references to caves and karst. Many of these references are specific to tourist caves or scientific interest positions. Many speleological interest groups publish journals or bulletins and these groups frequently will select a specific cave region and discuss the effects (usually adverse) that can be noted over time. Typical of these are The National Speleological Society (NSS) in the United States that published an issue on cave conservation in the National Speleological Society Newsletter in March 2005. The article covered some historical aspects of cave-related issues, as well as events at specific caves and karst areas. Reference is made to the use of the USA Federal Caves Conservancy Act and how it is driving NSS Cave Conservation Task Forces, which focus on local level conservation issues. Most cave interest societies will have some level of written code of conduct, ranging from basic good caving practice, to extensive researched documents that can be used to draft legislation for the protection of the caves (Box 7.1). Very little is published that refers to the economic implications of caves other than in relation to the surface activities such as forestry. This may be a useful area for future research in the light of the growing awareness of so called "green economics" and "ecotourism".

A review of the literature available on the COH WHS shows a focus on the palaeontological and archaeological features of the area and more recently the historical aspects of the region (Hilton-Barber and Berger, 2000 in the reference list it is Hilton-Barber and Berger, 2002). Even a brief internet search will find many links to tourist activities in the COH WHS other than the world famous Sterkfontein Caves and the palaeontological and archaeological aspects of the area. The range of tourist attractions includes game viewing, restaurants, hiking, fishing, horse riding, go-karting, cave tours, caving adventures, accommodation, and conference facilities. If the geographical area adjacent to the karst is included, outside the COH WHS, extending as far as the Hennops River area, then further tourist attractions include hot air ballooning, 4 x 4 trails, and canoeing, in addition to the activities found within the COH WHS. Most are marketed under the focus of the "Crocodile Ramble" which is an artist/craft route in the area. These tourist attractions, as well as the further development of such facilities as the Mogale's Gate Centre, are emphasising the question of the sustainability of the COH WHS.

Box 7.1:

South African Caving Groups and Related Organisations

CERAC – The Cave Exploration Rescue and Adventure Club (Member club of SASA)
Mr N Ringdahl Chairman (Hon. Chairman)
PO Box 3532
Middelburg
Mpumalanga, South Africa

CPSS – The Cape Peninsular Spelaeological Society (Member club of SASA)
Mr A Bucher (Hon. Chairman)
PO Box 4812
Cape Town, 8000

CROSA – The Cave Research Organisation of South Africa
Mr M Buchanan

SASA – The South African Spelaeological Association.
SASA is a long standing association of member caving clubs. The Committee of SASA rotates amongst the committees of the various associated clubs, namely SEC, CERAC, CPSS and PP.

Potch Potholers (Member club of SASA)
PO Box 795
Parys, 9585

SEC – The Speleological Exploration Club (Member club of SASA)
Mr Hardey Hugo (Hon. Chair)
PO Box 157
Modderfontien, 1654, South Africa.

Wild Cave Adventures - A commercial caving company.
Mr N. Norquoy 011 956 6197

7.2 The Problem of Sustainability within the COH WHS

The term sustainable development is a core concept for policy development in South Africa (Department of Environment and Tourism, 2003). The South African National Environment Act defines sustainable development as "the integration of social, economic and environmental factors into planning, implementation and decision making so as to ensure that development serves present and future generations". It is this link between development and environmental impact that is at the core of the issues for the COH WHS. If we neglect one, we will neglect the other.

The current range of activity within the COH WHS can be categorised in broad terms as:

- Tourist Residential: activities such as hotel or guesthouse-related facilities including restaurants.
- Tourist or Commercial Land-Based: activities such as game farming, chicken farming, horse breeding and related activities, cattle and fish farming, crop and subsistence farming, grass cultivation and orchards.
- Tourist Specific: activities such as show caves, adventure caving, archaeological tours, go-karting, quad biking, fishing, hiking and horse riding.
- Assorted Economic: activities such as petrol stations, truck repair shops, brick yards, and local builder's yards, as well as craft type activities such as candle making.

The question posed is whether these activities are degrading the karst and, where applicable, the caves, or whether they are sustainable, and if so, can they be expanded upon. Before this question can be answered, there is a need to review the level of knowledge of the existing situation not just in the COH WHS but wherever the study of karst and caves has been undertaken. In exploring the current situation, reference should be made to the extensive amount of karst and cave conservation that exists in other areas. The fragility and degradation of karst areas as well as the frustration felt by those trying to protect such areas are common aspects of karst and cave-related work all over the world.

The caves of the COH WHS are mainly "low energy caves", which means they have no large scale natural addition of energy to the caves in the form of streams flowing into the caves, heat from the surroundings and biomass from outside. Added to this problem is the principle that there is no such thing as carrying capacity for a cave – every visitor has an impact and the impacts are cumulative. Where both people and animals enter the caves, the resulting effects are particularly visible.

Karst and cave systems are important for their ability to store water and ability to act as "natural laboratories", holding information which ranges from evolutional evidence, palaeo-climatic evidence, and social history to geological interpretation. The caves of the COH WHS can be described as low energy caves. This is due to the nature of their formation, as they typically have a single entrance with minimal air flow, fragile crystals and a sensitive bat population. The caves of the COH WHS also lie along fault lines with many suggesting solution by groundwater along fissures connected to the fault systems in the region.

Karst and caves are sensitive structures and the largest factor leading to their degradation is human activity. For example, the carving of graffiti in caves has a long history, with several caves in South Africa claiming signatures going back nearly 100 years. Rietpan and Grobler's Caves are such examples, with the more recent graffiti not even having the historical significance to support its presence. Careless behaviour or even deliberate damage will easily destroy a cave formation (speleothem). Some caves, such as Sterkfontein Cave and Wonder Cave, are more or less stable at the current visitation levels. This is because their area is large enough to provide a certain degree of protection. Where such impacts have already occurred, procedures are now in place to keep visitors away from formations. There is however a strong need for more structures to channel visitors away from the walls of the caves, while an increase in the guide to visitor ratio is needed to prevent visitors from touching the cave structures.

Responsible cavers are adequately equipped and behave sensitively upon entering and moving through a cave. The areas of impact are likely to be polishing of the rock, changes to the humidity and temperature, compaction of the floor sediments, inadvertent dirtying of the rock or white formations and disturbing cave-dwelling animals. Even with the best of intentions, if great care is not exercised, caves soon lose the pristine appearance they had on discovery. Large groups of careless tourists on the other hand leave litter, touch anything, raise the temperature, noise and humidity levels and achieve nothing more than occupying some time in the cave.

These non-specialist visitors are the greatest threat to the COH WHS caves. A majority of the caves have no great attraction to the non-specialist visitor, as they are simply small caverns or sack-like caves. Those that are of interest tend to be spectacularly decorated and large in volume, such as Wonder Cave, or have extensive passageways of varying size. It is believed that some caves can sustain a degree of regular visitation due to the already dirty appearance, lack of water passageways, robust rock structure and few, if any, sensitive formations that can be accessed by visitors. Caves such as the Westminster System and Scrambler's, both on easily accessible land, are being overused. Caves such as Grobler's or Nico's II which are not easily accessible, should remain in a minimally visited state, with access only granted to special interest groups, to prevent further degradation.

Agricultural activity in the COH WHS has a significant impact on the water table and water quality. Whilst not as drastic or as publicised as the recent acid mine drainage issue (Fourie, 2005), agriculture overuse of groundwater is a long standing area of concern for residents in the valley. There is direct evidence from the Cango Valley near Oudtshoorn of the negative impact of certain agricultural practices, where the disastrous effects of silt runoff have damaged and obscured speleothems in Stroomwater Cave (Butcher, 2005). The level of silage, pesticide or fertiliser use is uncertain but the nature of karst areas is such that any runoff will inevitably end up in the aquifer. Further research into this issue is essential. A human-related activity, which may be adding to the problem, is the dumping of household waste in sinkholes and caves located on private land. The decomposition water runoff from the waste will be carried into the water table via the fault lines which the caves follow. There is evidence that the faecal bacteria count in some subterranean lakes is higher than might be anticipated (Tasaki, 2005). Large quantities of household waste, building rubble and animal carcasses are found in many sinkholes and caves close to houses and on farms. The potential for waste oil, pathogens and metal ion contamination is high. This is an area of great concern and in need of remedial action. The removal of the waste and education of the landowners, as well as finding an alternative to local dumping, is required.

Whilst no evidence of large scale gathering of karst rock formation for commercial purposes can be seen in the COH WHS, it is definitely occurring. This is apparent due to the popularity of "Pelindaba" rock in garden centres across Gauteng and in many karst districts, such as those near Ohrigstad in Mpumalanga, where rocks are offered for sale at the road side. There is a concern that as more people travel through the COH WHS area, the informal or even formal sale of the karst may take place. With the growing public awareness with regard to the COH WHS and the fossils and geology of the area, the potential for sale of speleothem and stromatolite formations is of even greater concern. The geological significance of these rock structures is poorly acknowledged in the public mind but as the area develops and the tourists become more educated this could rapidly change and the interest in owning a piece of such rock could increase.

A part of the history of the COH WHS which does not seem to be well documented is the mining of calcite from most of the caves in the area and the impact this has had on the current structure of the caves, although references are made in some literature to this mining activity and its consequences (e.g. Hilton-Barber and Berger, 2000 in the reference list it is 2002). The karst in many areas adjacent to caves has been obscured by rock spills following the excavation of the cave. The impact of archaeological digging activities on cave entrances as well as the disposal of the excavated material also deserve further investigation and research.

7.3 Commercial Activity Relating to the Caves of the COH WHS

The public perception of the caves in the COH WHS has a strong inclination towards the palaeontological and archaeological sciences. Whilst historically many of the caves of the COH WHS have been mined for commercial use of the calcite, this aspect of the history of the caves is frequently ignored as authors move toward describing the palaeontological and archaeological finds. The study of speleothems in climate comparisons and the significance of some of the fossil remains of the COH WHS are succinctly documented in Human Beginnings in South Africa (Deacon and Deacon, 1999) and The Field Guide to the Cradle of Humankind (Hilton-Barber and Berger, 2000 in the reference list it is 2002). These aspects are the driving force behind the commercial implication of Sterkfontein Cave and the soon to be Mogale's Gate facility, whilst the scenic beauty of Wonder Cave is seen as its key commercial aspect. These two caves, and the remaining archaeological and palaeontological caves, are generally well protected against casual access, as well as the implications of commercial activity. For the remaining caves, little access control, other than landowner vigilance, is in place, and there is much anecdotal evidence of caves being used without the landowner's knowledge. Two of the caving clubs have attempted to gate caves in accordance with international standards, which allow for the movement of bats. However, despite being solidly constructed, some of these gates have subsequently been smashed open by people determined to gain access (Hugo and Ellis, 2005).

The existing cave legislation, being Section 99 of the Gauteng Nature Conservation Ordinance, contains no reference to permits being required for the construction of any gate to prevent access to a cave, but merely states that any such structure should not be tampered with. The development of such gating permits should include the appropriate reasoning for the gate, as well as required standards for gate construction. To the author's knowledge, there are six gates on wild caves in the COH WHS (Box 7.2). The success of the gates is felt to be more associated with a lack of knowledge of the cave's location or the reluctance of the landowner to allow access, rather than the strength of the gate.

Box 7.2:

Known Gated Caves in Gauteng, North West, Mpumalanga and Limpopo Provinces

Wild Caves

1. Boon's Cave (North West) – Built by landowner, the gate is very large and of sturdy construction. Locked by landowner.
2. Grobler's I Cave (Gauteng) – An internal gate closing off a particularly pretty area, built by CROSA.
3. Grobler's II Cave (also known as Bobby Fulton's Cave) (Gauteng) – Two gates, one of which is deep in the cave and has been broken open, the other at the entrance is now left open due to commercial activity. The entrance gate was built as a joint CROSA/SASA project while the internal gate was built by SASA.
4. Jock's Cave (Limpopo) – Situated in the Abel Erasmus Pass and gated by CROSA. The gate is currently in good condition.
5. Knocking Shop (Gauteng) – The original steel gate erected by SEC has since been replaced with an alternative concrete entrance by the landowner.
6. Kleinfontein Cave (National Monument) (North West) – On Goldfields property. The gate is in good condition but is not locked.
7. Aladdin's Cave (Gauteng) – Sealed gate on a cave intercepted during quarrying in Sterkfontein Quarry.
8. Virtual Reality (also known as Adriaan's Cave) (Gauteng) – Gate built by SEC and since broken open.
9. Yom Tov (Gauteng) – Built by CROSA. Currently in good condition.
10. Cold Air Cave (Limpopo) – Built by CROSA. Currently not being used.
11. Chuniespoort Cave (also known as Donkerkloof Cave) – Robust gate at entrance built by provincial authorities. Currently stands open.
12. Wolkberg Cave – gated by provincial authorities.

Commercial Caves:

1. Sterkfontein Cave (Gauteng) – gated by authorities.
2. Wonder Cave (Gauteng) – gated by owners.
3. Echo Cave (Mpumalanga) – gated by owners.
4. Sudwala Cave (Mpumalanga) – gated by owners.
5. Cave of Man (Mpumalanga) – gated by owners.
6. Wonderwerk Cave (North West) – gated by owners.
7. Eye of Kuruman (North West) – gated by authorities.

Different types of caves are used for different types of activities, i.e. caves with archaeological or palaeontological significance, show caves and wild caves. Wild caves are defined as caves in which no long-term structures have been added to aid regular tourist activity. The use of wild caves can further be divided into the activities of commercial ventures and those of the caving clubs. There has been an increase in the extent of people entering the caves during the last 3 - 4 years (Hugo and Ellis, 2005; Norquoy, 2005). The caving clubs active in the COH WHS are South African Spelaeological Association (SASA) member clubs such as the Speleological Exploration Club (SEC) and the Cave Exploration Rescue and Adventure Club (CERAC) and the non-member clubs such as the Cave Research Organisation of South Africa (CROSA). Membership of the SASA clubs has been stable or has slightly increased during this period and the resulting activity has spread over a number of caves, including those outside the COH WHS. The main increase in numbers entering caves has come from commercial ventures, which use caves situated on municipal land and on private land with or without some form of agreement from the land owners (Norquoy, 2005). Whilst this has led to one cave (Bats' Cave) being significantly cleaned up, it has also led to evidence of over use in other caves, such as Grobler's Cave (aka Bobby Fulton's Cave) (Buchanan, 2005).

There are perhaps three commercial groups regularly practicing abseils into caves and or exploration of caves (Roberts, 2005). The most active of these companies utilises four caves in the COH WHS. Of these four, one is a well known bat roost, (Scrambler's Cave), one has areas of outstanding beauty, biological significance and fragility (Grobler's Cave II, also known as Koelenhof or Bobby Fulton's Cave), the third (identified by the operators as Crystal Cave) is used only for abseiling the entrance and the fourth (Bats' Cave) could be considered a suitable adventure cave, provided sufficient measurement of any impact is carried out and certain areas are placed off-limits. It has to be said the largest commercial operator has made significant efforts to clean up caves which have been abused by the public. From the price list issued by this company and based on personal interviews it can be seen that commercial adventure caving in the COH WHS is profitable but not on a significant basis (Roberts, 2005; Norquoy, 2005). The cost ranges from R55 to R160 per head in groups of 8, depending on the cave and activities offered. If an average charge of R100 per head is used, and it is based on about 70 visitors per month, then it can be seen as a low profit margin business when items such as public liability insurance are taken into account. SASA-affiliated clubs do not charge for any visitor attendance, but a minor (R10 - R20) donation for the use of equipment is accepted. However such clubs charge an annual membership fee and do not offer services to the general public but rather to the potential caving club member.

SASA-affiliated caving clubs apply an internally accepted standard of one caver to each 3 or 4 visitors, and a minimum of two competent cavers and no visitors on many cave visits. Elsewhere in South Africa, adventure caving trips have been offered where a single guide was responsible for as many as 30 visitors moving through a long and difficult route*. In the COH WHS the limiting factor to commercial adventure caving will be the fact that only one cave is suitable for this type of intensive activity. The reasons why the remaining caves are not suitable for intensive utilisation include the presence of roosting bats, histoplasmosis, fragility of the speleothems, biological or palaeontological importance and limited size or attraction of the cave. Given the need for liability insurance, advertising, the limited suitability of the caves and the time invested by the operator, commercial adventure caving is felt not to be sustainable and is already showing an impact on the remaining three caves being utilised.

It is difficult to estimate the numbers of such commercial activities, as most commercial ventures are currently scheduled on an ad hoc basis; however it would be reasonable to say a 100 percent increase in traffic through the wild caves has taken place over the last ten years from both commercial and caving club activity. It is estimated that caving clubs are visiting wild caves with about 20 to 30 visitors per month, and are utilising an average of 15 separate caves spread over a distance of 100 km within the COH WHS. The adventure caving commercial activity allows between 70-100 visitors to three or four caves within the COH WHS per month (Norquoy, 2005). The impact of such activity on the bat population, especially during their winter hibernation, will be significant.

The two main tourist caves in the COH WHS - Sterkfontein Cave and Wonder Cave -receive significant numbers of visitors. Sterkfontein Cave currently receives around 80 000 visitors per year whilst Wonder Cave is visited by 40 000 or more people per annum (Drunk, 2005; Smith, 2005). The income generated by these two commercial caves is not known. Sterkfontein Cave contributes some 7.5 percent of their income to a benefit fund for the local community. Staff and maintenance costs account for the rest of their income. Wonder Cave has a small passenger lift to lower the visitors into this spectacular cave and this adds to the maintenance cost (Drunk, 2005; Smith, 2005). Wonder Cave keeps records of the temperature, humidity and water droplet counts. Both systems are to undergo extensive replacement of the internal structures. Managers of both caves agree that the most important issue of concern is the control of large numbers of visitors, which are likely to leave some form of impact on the cave such as graffiti or damage to fragile formations.

The opportunity for adventure caving exists at Sterkfontein Cave due to its greater size, but this would lead to additional degradation of what is a comparatively restricted portion of the cave. Such activity at Wonder Cave is unlikely, due to the manager's fear for potential degradation and also due to the relatively restricted area behind the main chamber. Neither cave has seen any evidence of histoplasmosis, but the manager of Wonder Cave keeps good contacts with the medical fraternity. The lack of histoplasmosis is probably due to the environmental conditions within the caves, where the humidity is higher than known histoplasmosis caves, air circulation is greater, and movement is restricted

* P Kenyon attended an adventure trip to the crystal section of the Sudwala Caves organised on a regular basis by Sudwala Cave management. This trip was June 1995, the current standards of such trips are not known, however CERAC organised a cave rescue practice in this portion of the cave due to concerns over the difficulties of extracting a patient from this area of the cave.

to "dust-free" walkways, with no crawling in the dusty areas taking place (Smith, 2005).

An illegal but ongoing commercial aspect of the COH WHS is the removal of rocks, flora and fauna. There have been reports of trees being uprooted and removed and rocks being loaded by the trailer-full, as well as the kerb side sale of monkeys and tortoises. These activities have been reported to GDACE (Roberts, 2005), but are likely to continue. The implications that these activities may have for the caves are that acceptance of such illegal activities will directly affect the physical resources of the area. If such activities are tolerated on a low level, then the supply will grow to meet the demand.

7.4 Proposed Actions Regarding the Sustainability of the COH WHS Karst and Caves

The following is a brief description of some of the more critical factors that influence the sustainability and use of the COH WHS. It is not intended to be exhaustive, but instead tries to focus on the more immediate problems. Nor is it extensively detailed, as these issues are suggested as being suitable for further study. The topics are divided between surface and subsurface events and where possible, a recommendation on future research or implementation has been made.

7.4.1 Surface Activities

7.4.1.1 CATTLE FARMING

The cattle farming being carried out in the COH WHS appears to be over intensive. The degree of degradation of the land and the runoff of the cattle waste and mud is extensive. The measurable effects of this on the environment and the water resources of the COH WHS need more investigation and documentation. Specialised agricultural knowledge will be required to confirm the actuality of over-use by cattle farmers and the implications of its continuation.

7.4.1.2 REMOVAL OF ROCK FORMATIONS AND FLORA IN GENERAL

The attractive weathered appearance of so called "Pelindaba rock" has led to a significant level of removal in areas where casual access to the karst is possible. No large scale rock sales are evident, as they are in other karst areas, but the collection of the rocks may have been done on a more individual basis. Residents in the area repeatedly mention confrontations with collectors of Pelindaba rock. Mineral collectors have been observed in the area, mainly associated with old quarries and lime works. The breaking off and collection of speleothem is minimal and is felt to be more associated with the "torch and takkie brigade" (casual cave visitors) rather than serious collectors. The situation however needs to be monitored closely to prevent a similar situation to that occurring at Jock's Cave in the Mpumalanga Province where the cave formations were smashed off en masse and sold at the roadside (Hugo and Ellis, 2005; Roberts, 2005). A possible way forward would be to compile a review of the sale of such rocks to confirm where they are being harvested. Since it would be easier to prevent the sale rather than the harvesting of the rocks, authorities such as GDACE and Blue IQ projects should apply pressure on such legal and illegal dealers to ensure that crystals, speleothems and fossils (including stromatolites) of the COH WHS are not being harvested or sold.

7.4.1.3 THE COORDINATION OF INTERESTED AND AFFECTED PARTIES (IAP)

A significant factor in the sustainability of the COH WHS will be the ability of the IAP to work towards a common goal. There is a need to involve the landowners and local stakeholders in a coordinated way which currently does not seem to be the case. There are numerous anecdotal comments by local residents being uncertain as to what is happening within the COH WHS (Hugo and Ellis, 2005; Roberts, 2005; Norquoy, 2005). The development of a Cave and Karst Management Authority comprising cavers, scientists, management experts, IAP such as landowners and those with an interest in tourist activities should be considered, or where it may currently exist, better coordination and open activity is required. The sensitivities associated with achieving a balance between land, water and air as it impacts on a karst landscape in relation to sustainable tourism and cave conservation of the COH WHS should be the focus of the management committee. This is one of the major impediments to sustainability of the area and the degradation of the caves. It is recognised that this will not be an easy task given the varying agendas, history of interaction, lack of clarity of responsibility, lack of resources and quite often, the lack of interest amongst the many role players in the area. It is however critical that a consensus be achieved between all the bodies playing a role in the future of the COH WHS.

7.4.1.4 LEGISLATION, POLICING AND VERIFICATION

A common problem related to illegal activities in karst areas is the inability to implement and enforce any legislation. No matter how extensive or suitable the paperwork is, it is only as good as the ability to either enforce it, or have it adopted by the communities with access to the karst and caves. Fencing-off the area is often impractical and where successful, is often associated with the exclusion of certain IAP. A far better solution is to have the legislation and operating practices adopted by those with an interest in the area, and have them managed by a suitable group, which is prepared to take accountability and responsibility for the caves and karst. Such a group should include scientists, cavers, and management experts, as well as landowners and associated interested and affected parties. This will create enforcement mechanisms that any management authority can use when education has failed. Unfortunately there is no single legislative format which one can learn from and apply locally when studying and comparing international legislation. However, a review is required and a framework of cave and karst conservation legislation needs to be built. Proposals have been developed by such groups as CROSA and SASA and these need to be considered.

7.4.1.5 TOURIST GUIDES

The level of training of tourist guides is important to the sustainability of the karst and caves. The less a guide appears to know or care about the area, the less important the subject will appear to the tourists. The standard of tour guides on the COH WHS varies from those having little knowledge and being inarticulate, to professional geologists and specialists in palaeontology and archaeology. There is a need to train and establish standards for tour guides, even for those leading more popular tours such as those offered at Sterkfontein Caves.

7.4.1.6 PALAEONTOLOGICAL AND ARCHAEOLOGICAL EXCAVATIONS

An area that has not been investigated is the impact of excavations of what is often the entrance to caves for palaeontological and archaeological research. The effects on the cave atmosphere as the entrances are opened up, as well as the effects of extensive excavation, the disposal of the diggings and the associated effect of frequent occupation of the vicinity are all areas worth investigating.

7.4.2 Subsurface effects

7.4.2.1 CASUAL USE OF THE CAVES BY VISITORS

A typical situation regarding wild caves is that landowners permit visitors to access caves on their property without supervision. Education is the answer to such issues. Many caves are showing signs of past entries by the so called "torch and takkie brigade". These people leave behind litter, such as string and batteries, and show no respect for the cave or its natural inhabitants. Likewise, they show no respect for their own safety or the landowner's rights. Vigilance by the local residents combined with communication by the caving clubs is felt to be the most appropriate method of dealing with such issues. It is felt that improved education of the general public would be of help in dealing with this problem, but education of the landowners would be of far more value. An interesting and useful exercise may be to install concealed infrared counters at the entrance of some of the more easily accessible caves to monitor such traffic. This would allow for the impact on certain caves to be compared to an accurate figure of how many people visited the cave.

7.4.2.2 RADON GAS

Radon gas diffuses into the water and surface layers following the radioactive decay of uranium and thorium, which is found naturally in rocks. The radon will decay further into radioactive elements, or so-called daughter products, with associated α-radiation. The α-radiation is associated with detrimental health issues such as lung cancer. The radon concentration is determined by the initial concentration of uranium and thorium. The typical working levels (WL) acceptable in the United Kingdom are 0.05 WL for radon gas in a domestic situation (Gillieson, 1996 p. 249). When this level is exceeded, government action is required. Research done by Gamble (1981) indicated a low but variable level of exposure risk in caves of Gauteng and Mpumalanga of between 0.003 and 0.62 WL. This was a baseline study and more extensive measurement of seasonal variation and the effects of position and frequency of exposure within a cave are proposed.

7.4.2.3 HISTOPLASMA CAPSULATUM

The so called "Cave Disease" is typically an infection of the lungs by a fungal spore Histoplasma capsulatum found naturally in certain caves found in the high altitude northern areas of South Africa. The spores lie in the dusty detritus and guano deposits and are inhaled as a person travelling through the cave disturbs the dust. The fungus germinates and grows in the warm, moist lung tissue. The incubation period is normally 2 weeks and the infection period can extend to 3 or 4 weeks. The severity of the symptoms varies, from being non-symptomatic on the one hand, to severe lung infection and calcification of lung tissue. The efficacy of treatment with an anti-fungal substance versus simply enduring the infection for a few weeks is the subject of some debate, but treatment is expensive. Some South African specific studies have been undertaken, such as the early work carried out in the late 1950s and 1960s (Murray, 1957; Wolpowitz and Van Eeden, 1963; Kaye and Murray, 1964). More recently, a few South African based medical practitioners took a specialised interest and published articles on the subject (Branfield, 2002; Craven, 2003).

There are a number of caves in the COH WHS which are notorious as being "histo" caves, whilst caves not suspected of carrying the spores can occasionally lead to infection. It is currently impossible to declare a cave Histoplasma capsulatum free and the generally accepted philosophy is to approach all caves within the region as potentially having Histoplasma capsulatum. If an individual's immune system is weakened, then that individual is increasingly at risk from serious side effects of Histoplasmosis. It is recommended that if a person is first visiting a known "histo" cave and they have never caved before, that they should minimise their stay underground, because the length of exposure is considered proportional to the severity of the infection. It is recommended that children under 12 years of age do not enter caves with a known history of Histoplasma capsulatum.

7.4.2.4 LIGHTING AND LAMPENFLORA

Lampenflora are the biological growths which occur in caves as a result of a permanently installed lighting system. The development of Lampenflora is proportional to the level of heat, wavelength of light radiation and proximity to a rock surface. Such flora and fauna can be inhibited by the use of low energy lights and narrow wavelength lights (Gillieson, 1996). They are not seen as a significant issue in the COH WHS caves but little measurement has as of yet been carried out.

The effect of surface lighting is less documented. There is a loss of rural character associated with intensive street lighting, and subsequently some suburbs of Johannesburg restrict such lighting. The effect of street lighting on bat populations is uncertain, and some specialists comment that the attraction of insects to such lighting may change the hunting patterns of certain bats. This issue is worth investigating further (Arlettaz *et al.*, 2000; Taylor, 2005).

7.4.2.5 USE OF SINKHOLES AND CAVES AS DUMPSITES

This is a frequent and lamentable situation in the COH WHS and elsewhere where caves are found. Some landowners have made efforts to remove easily extractable items, such as old fences, tins, and general refuse. However, many caves and karst depressions contain many years' household refuse, dead animals, cars, drums, washing machines and associated material. This is not a case of casual dumping by careless tourists, but is a deliberate waste disposal method by local residents. Improved access to waste disposal sites and collection will help, as well as education on the implications of such dumping. A common practice that also occurs is the burning of the material that has been dumped in the sinkholes and cave entrances. The environmental implications of this practice are considerable. It is suggested that the local municipalities place greater emphasis on waste collection in the area. Possible means to clean up such sites, would be to launch campaigns whereby labour is supplied to assist the land owners in cleaning out the caves and sinkholes.

7.4.2.6 ENVIRONMENTAL IMPACT STUDIES OF CAVES AND THE LOW ENERGY DESCRIPTION OF A CAVE

The equilibrium of any ecosystem such as a cave will be driven by the exchange of energy within the cave (Gillieson, 1996; Cigna and Forti, 1988). This energy can be an ecological pyramid driven by bats and their guano, as well as an inflow and outflow of air or water, and even the thermal pulse through the rock as seasons change. Since the COH WHS caves can mainly be seen as virtually closed environments, or "sack caves", with little flow of air and water, with declining bat populations, the impact of any variable on the energy balance can be significant in proportion to the absolute value of the initial effect. It is inevitable that the flow of visitors within a cave will impact upon the cave and the return to equilibrium could take a long time. The smaller the cave and lower the energy balance, the greater the impact. It is important then to establish key indicators of the caves' "health". These can be structured into an impact study and recommendations made on the basis of the results. Such a study can then be used to indicate the much abused term "carrying capacity" of the cave or perhaps more appropriately "the limits of acceptable change". It would not be necessary to carry out such a study for all the COH WHS caves, but to select perhaps 6-8 caves and focus on simple key parameters. A short two page checklist would enable three groups of two cavers to quickly survey at least two to three caves in a day.

It is suggested that the caving organisations, such as SASA and CROSA, and local interest groups, in agreement with a management authority and specialists such as GDACE, Blue IQ Projects and Wits University, discuss with specific landowners a checklist of regularly monitored parameters. Caves such as Westminster, Grobler's, Bats', Scrambler's, Knocking Shop, Nico's I, II, III, and IV, Yom Tov, Lincoln and Bolt's would then be visited on a quarterly basis to establish a baseline of current conditions. The above list is based on the criteria of:

- Easily accessed caves with known frequent visitors and minimal protection.
- Less easily accessed caves.
- Caves of specific scientific or aesthetic value.

The parameters considered easiest to measure and encompassing the greatest impact would be the temperature inside and outside the cave, humidity, CO_2 content, water table, subsurface water quality and levels, and droplet counts.

Other parameters would include, where applicable, Lampenflora, as well as visitor numbers by means of hidden counters, dust levels on certain speleothems, and other such measurements.

The key aspect is that the measurement has to be relevant and easily carried out. Once this has been established the degradation proportional to the number of visitors can be determined. Certain cave entrances and sinkholes should be cleaned out as soon as possible.

It is recommended that the following be considered as sustainable ways of protecting the caves:

- Harden the environment in commercial caves by installing tracks and routes; This is only applicable to regular tourist caves;
- Reduce the awareness and demand for cave adventures and rather replace it with an emphasis on cave ecology and respect;
- Provide alternative activities such as in other tourist facilities;
- Restrict access to caves by gating, using the appropriate conservation standards. Raise public and landowner awareness and education.

7.4.2.7 COMMERCIAL ADVENTURE CAVING

This activity is presently limited to a few operators who use it as a marketing tool advertising caving as part of a package of activities ranging from team building, abseiling and adventure caving. It is by nature difficult to monitor those groups who offer commercial cave trips whilst acting outside the legitimate arena of publicly declaring such activities. Given the size of the COH WHS and the cooperation between the main commercial caver and cave clubs such as SEC, any additional activity is soon noted but assigning responsibility is not easily done.

On the positive side, the commercial use of Bats' Cave has led to a significant improvement in its appearance, as the commercial user of this municipal location has voluntarily cleaned up and to a significant degree, protected the cave from abuse. Bats' Cave is sufficiently large enough, with enough entrances to be considered a medium energy cave. The impacts of these commercial activities are the permanent fixtures left behind to aid the climbing of muddy walls, the compaction of mud floors as the water table recedes in certain attractive caves, and other general physically visible impacts. The effects, such as increased temperature, altered humidity (a significant destroyer of speleothems), and bat population inhibition, are not measured, but will be present in the cave. Consequently, the activities of these commercial adventure caving organisations need to be investigated further and if necessary their activities restricted to specific venues.

What is needed is a code of conduct that is followed and enforced by legislation/ monitoring, as well as a limit on the further development of such activities, a focus on the use of Bats' Cave in particular and the implementation of a cave monitoring system. An example of the type of control worthy of consideration is the effect of tour busses or private cars parking close to the cave entrance. The inward flow of automobile gasses can be seen to contribute 200 liters of CO_2 per liter petrol and no parking should be permitted close to the cave entrance.

7.5 Best Practices Worldwide

At present there is little legislative policy designed to specifically protect the caves and karst of South Africa. Whilst generic protection is covered by the National Environmental Management Act and associated legislation, and while the existing Nature Conservation Ordinance of 1983 (Ordinance No 12 of 1983) specifically describes cave conservation for Gauteng, the depth of such legislation is limited and the implementation is particularly difficult. There is a great deal of controversy on best management practices for tourist attractions such as the world famous Cango Caves, where the impact of tourism is felt by the caving bodies to have been to the detriment of the caves. At this stage, best management practices for the commercial and wild caves of COH WHS still need to be debated. Consequently there is an opportunity to draft legislation which will specifically address the unique needs of the COH WHS karst and caves. Such proposals should recognise the large body of documentation on cave and karst management, such as the IUCN Handbook on Karst and Caves (Watson *et al.*, 1997). The issue of the social and environmental aspects of cave use should be part of such legislation. It is important to have qualitative management objectives measured against robust indicators. A Recreational Opportunity Spectrum (ROS) can be established and then measured against the Limits of Acceptable Change (LAC) (Cigna and Forti, 1988).

A study of the cave and karst literature generally leads to similar comments on the importance of such areas and ideas on how to protect them. The starting point would be the formation of a management authority responsible for the area or even individual caves. The objectives of such a body should be to evaluate the current situation, develop legislative policy, implement or coordinate research and existing data, monitor ongoing activities and recommend action that the body itself or a legislative body such as GDACE would implement. There should be a strong scientific representation on such a body, given the range of scientific issues surrounding the caves of the COH WHS. These include the spelaeological, palaeontological, archaeological, biological, hydrological and social aspects.

The IUCN has published guidelines for the protection of caves and karst (Watson *et al.*, 1997). These guidelines recommend that the protection of such areas as the COH WHS should take the form of a variety of management plans focused on the desired outcome. It is a maxim of quality control systems that if one cannot measure something, then one cannot control it. A cascading series of measurements is then the starting point as described earlier. The first step is to establish the area details such as size, watercourses, population and commercial activity.

7.6 Recommendations on Cave and Karst Management

The sustainability of the karst and cave area is dependent on the interaction of the soil, water, vegetation, animal activity and how this balance is upset by human activity. Any upset of the natural balance will have some degree of impact on the cave systems. The removal of surface vegetation by harvesting or fire for example, may not have an obvious effect on a cave, however, significant levels of carbon dioxide respiration takes place through vegetation roots. The seepage of carbon dioxide into a cave system has major effects on the atmosphere within the cave and the changes in mineral solution rates. The following proposals are aimed at long term study and achieving a short term or immediate impact.

7.7 Proposed Actions

- Following a holistic approach, the measurement of the karst catchment area, the potential impact that any proposed activity may have on the area should be considered. It should be recognised that, second only to human entrance, any activity which significantly impacts on the flow or content of the surface water, will have the quickest impact on the caves.
- Focus on specific immediate activities which may be of concern, such as excessive mining of clay, high visitation levels in caves, non-regulated building activities, and so forth.
- Human visitations have the greatest impact on the caves. Certain caves should be immediately identified as being reserved for scientific or spelaeological interest alone and not for general access. Efforts to enroll the landowners in preventing unauthorised access should be undertaken. Where appropriate, gates may be erected, but landowner cooperation and vigilance is the best protection.
- Caves, which can withstand a greater degree of human traffic should be identified and used for more frequent caving trips. Such caves may well be outside the COH WHS. The management principle should not be that caving is a prohibited activity but that it is simply carried out with a degree of control by the authorities and by the IAP. Commercial caves outside the areas such as Rietpan Cave could be promoted (subject to study) instead of allowing a more sensitive cave to be developed simply because it is within the COH WHS.
- The available technical expertise should be directed to establish the karst boundaries, develop a plan of the water cycle, develop management plans of the area, coordinate the IAP, develop management plans for specific focus on key cave sites, train people to educate and interact with the landowners.

7.8 Specific Recommendations

It is recommended that the following matters be developed sooner rather than later:

- Legislation which will specifically address the protection of karst and cave areas. Such legislation will not be easy to enforce but must be defined as the option of last resort when such areas are threatened.
- A formalised education process designed to assist landowners in preventing abuse of the caves and karst should be distributed. This could be started by distributing copies of the IUCN guidelines and the Caving Code of Conduct of SASA (Box 7.3) to local landowners. The education of landowners in the importance of good practices for managing karst and cave will be the primary method of protecting the caves and karst of the COH WHS and other areas. The need to develop strong landowner interest and awareness is seen as the strongest sustainable option. Such awareness would be underscored by the legislative requirements.
- The development of a group which oversees the local implementation of such best practices, similar to those applied in other countries. Such a group would need the input of local landowners, caving groups such as SASA and CROSA, authorities such as Blue IQ Projects, and other bodies having influence in the area. Such a group would use the best operating practices as researched amongst the various karst and cave bodies.

The following should be implemented:

- Removal of general waste from the caves and sinkholes;
- Study of the effects of cattle farming and the subsequent run-off effluent;
- Study of the radon gas levels in caves;
- Measurement of the impacts of urbanisation and cave visitation on the bat population
- A limit to the expansion of spelaeological interest groups and commercial caving. Such a limit should be specified in a voluntary code of conduct regarding access and utilisation of the caves, subject to an "acceptable change limit" evaluation for the individual caves being utilised. No additional commercial activity would be acceptable until such evaluations had been undertaken. It will be necessary to establish a list of caves which are under immediate threat and to then voluntarily agree to minimise activity to an agreed reduction, for example 50 percent of current visitation, subject to the outcome of a cave impact study. An outright ban or rigorous permit system will simply perpetuate the lack of cooperation that has been seen historically.

Box 7.3:

The SASA Caving Code of Conduct

Members of this Section should at all times adhere to the following during each and every visit to a cave or caving area, irrespective of whether the trip is an official club trip or not. The Executive of this Section shall be answerable for the conduct of each member regarding all the aspects of this Code of Conduct, morally if not legally.

1. LANDOWNER RELATIONS

1.1 The Landowner's permission must always be obtained before traversing property or visiting a cave.

1.2 The Landowner's property and possessions must at all times be respected and protected.

1.3 Wherever possible, Landowners should be informed of work being undertaken, and be involved in the conservation of their caves.

1.4 Wherever practical the best Landowner and Caver relationships should be maintained at all times.

2. CONDUCT OF MEETS

2.1. Parties should not visit a cave unless someone on the surface has been informed of the cave location, of the number of members in the party, and their anticipated return time.

2.2. Caving parties should have a Leader capable of handling the conditions related to the cave to be visited.

2.3. A 2/3 ratio of experienced to in-experienced members should be maintained in accordance with the cave conditions and the number in the party.

2.4. The highest possible standard of safety must be maintained throughout each caving meet.

2.5. Meet Leaders have a personal responsibility for the conduct and safety of all party members.

2.6. The maximum possible instruction in the procedures and science of speleology shall be provided for all new members wherever practical.

3. CONSERVATION

3.1. The absolute minimum possible damage is to be caused to cave formations, growths, items of geological, archaeological, palaeontological or biological significance.

3.2. No item taken into a cave by a party is to be left in that cave unless Committee approval has been obtained for a specific purpose.

3.3. The cave environment and ecological systems are to be subjected to the minimum possible disruption.

3.4. Nothing, whether living or inanimate, should be removed from a cave unless Committee approval has been obtained for a specific purpose

3.5. Wherever possible members shall remove from a cave any foreign matter found during a meet, except items clearly serving some specific purpose.

3.6. Cave locations may not be supplied to persons whose bona fides have not been verified.

3.7. The Executive of this Section will, where necessary, negotiate with Landowners for some measure of control of access to a cave for conservation purposes.

3.8. Cavers should at all times actively promote and encourage cave conservation both amongst themselves and non-caving parties.

3.9. On the surface, members will respect and adhere to general conservation principles and ideals with equal force.

Box 7.3: Continued

4. SCIENTIFIC PROJECTS

4.1. Detailed records to the best of all members' abilities will be kept of all activities. These records will be made available for the furtherance of any scientific aim or project, but not to the detriment of caves or caving.

4.2. All possible assistance should be rendered to any person or group in the furtherance of a scientific or educational aim or project.

4.3. The Executive of the Section shall actively encourage and assist members in initiating and/or participating in projects of a scientific and/or educational nature.

5. OTHER CAVING BODIES

5.1. Wherever possible, assistance shall be given to other caving bodies in the furtherance of their aims and objectives.

5.2. The rights of other caving bodies shall not be infringed upon by the members and Executive of this Section.

5.3. Inter-club cooperation and freedom of movement shall be encouraged by the Executive and members.

5.4. Similarly, cooperation and friendship should be encouraged with other organisations of a similar, but not necessarily, of a caving nature in this and other countries.

5.5. Matters of contention shall be dealt with fairly, honestly and timeously between the Section Executive and the bodies concerned.

The Executive of this Section affirms that the above principles shall at all times form the activities of this group.

7.9 Conclusion

It is clear that human interference could be seen as being the main threat to the caves of the COH WHS. The interior of the caves of the COH WHS are in the most part low energy systems with minimal water influx and can hence can be seen as non-renewable systems. Any changes will be permanent ones. The human impact on caves can be measured from the level of abrasion or polishing on the rock, trampling of mud surfaces, damage to formations, changes in humidity, changes in temperature, disposal of waste material, alteration of light levels, construction of walkways or other alien constructs and disturbance of life forms. Few of these impacts are being measured at present.

The coordinated assessment of the caves and karst of the COH WHS is still lacking. There does not seem to be a framework to get the many IAP to adopt a unified systematic approach. Instead, many individual groups exist with significant ignorance of the actions of the others. The existing lack of cooperation is also paralysing any effective action. In the interim, a focused approach for specific issues or locations should be followed. A good start may be to take the cave known as Bats' Cave which is rapidly being commercialised without control, and address the implications of this activity. A management plan could be drawn up that would involve the municipal landowner, the commercial cavers, the spelaeological groups, scientific representation and GDACE. This might serve as a focus to establish agreed norms of behaviour and cooperation.

The caves and karst of the COH WHS are at a critical point relating to their continued existence. The opportunities to conserve the best such examples in the area has probably passed, with the next best option now being to protect what remains if it is to be appreciated by future generations. It is essential that a coordinated approach should be adopted as soon as possible in measuring the impact on the caves and karst, supporting the rehabilitation procedures as well as in the conservation of what remains.

REFERENCES

ARLETTAZ R, GODAT S and MEYER H (2000) Competition for food by expanding pipistrelle bat populations (Pipistrellus pipistrellus) might contribute to the decline of lesser horseshoe bats (Rhinolophus hipposideros), Biological Conservation 93, pp. 55-60.

BRANFIELD A (2002) Guidelines for the outpatient treatment of acute symptomatic pulmonary histoplasmosis in cavers, South African Journal of Sports Medicine 15 (2), pp. 27-28.

BUCHANAN M (2005) Personal interview with Mr Mike Buchanan of CROSA.

BUTCHER A (2005) Comments made by CPPS members on Stroomwater Cave were confirmed with Mr A. Butcher CPPS Chairman in June 2005.

CIGNA AA and FORTI P (1988) The environmental impact assessment of a tourist cave, Cave Tourism: International Union of Speleology, Commission for Cave Protection and Cave Tourism, Proceedings of the International Symposium at 170th Anniversary of Postojnska Jama, November 10-12 1988.

ISSUE PAPER 8 PERCEPTIONS, BEHAVIOURAL CHANGE AND EDUCATION AROUND KARST

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ABSTRACT

Due to the unique features of karst it is important that visitors to and residents within the COH WHS should be informed about the sensitive nature of carbonate rock, groundwater and the associated ecology. The majority of the households in the COH WHS does not have municipal services such as piped water or sewage and refuse removal. Many thousands of people use French drains while abstracting groundwater for drinking purposes and irrigation on the same property. The need for education and behavioural change is further stressed by the fact that this region is home to one of the world's most prized deposits of hominin fossils. The area is also home to a unique ecology housing many cave-dependent species, some of which are very vulnerable to disturbance. An environmental education programme should be designed to promote a better understanding of karst and to change peoples' perceptions and attitude towards karst environments. This will also provide a more inclusive environment in which the public can be involved and participate in the conservation of the karst system.

8.1 Introduction

South Africa is famous for its very old and extensive karst system, dominated by dolomite deposits, which covers a vast area stretching from North West Province, through Gauteng into Mpumalanga and the Limpopo Provinces. This karst system also coincides with the most densely populated and most extensively mined area in South Africa. Human activities such as farming, various industries and tourism, that have a negative impact on karst and karst ecology, are also prevalent in this region.

Karst environments are complex and dynamic systems, which form an interface between surface and groundwater. The aquifers and solution cavities, which are predominant features of karst, make these environments extremely vulnerable to pollution and degradation. The threat of pollution and degradation is more serious than just the danger it poses for humans extracting and using the groundwater for irrigation and consumption. The situation is exacerbated by the fact that the karst system also houses delicate ecosystems containing unique faunal assemblages, which include some vulnerable species.

This conflict of interests has led to the formation of the Karst Working Group. Under the auspices of the IUCN (South Africa Office), the group will address matters relating to karst ecology and the management of the karst system in the

Cradle of Humankind World Heritage Site (COH WHS). The greatest contributing factor to the negative anthropogenic impact to the karst system is ignorance from the side of the landowners, tenants and visitors to the COH WHS on the one hand, but also from the managers of the mines, industries and farms in the province and the governing bodies that have to monitor and regulate these impacts.

8.2 Problem Statement

Unfortunately many people living in the dolomite-rich area of the COH WHS are under the impression that there is an unlimited supply of fresh water in the karst. It is a common misconception that faeces will be broken down by bacteria in the soil and filtered out by the substrate before it reaches the water table. Similarly it is believed that faeces-containing water could be flushed downstream and that the ecosystem will neutralise the negative effect to such a degree that people can utilise the water downstream for drinking purposes. The frequency with which caves and sinkholes are used as rubbish dumps also proves that there are less conservation-minded people in the community. Few people in the COH WHS have considered that by removing the indigenous flora from their property, failing to eradicate alien plants from their property, using insecticides on their crops and flowers, and giving tourists free rein to explore caves on their property, they are threatening the survival of the cave-dwelling bats in the area.

In order to manage the karst system in this region adequately, an environmental education programme should be designed to promote a better understanding of karst and to change peoples' perceptions and attitude towards karst environments. This will also provide a more inclusive environment in which the public can be involved and participate in the conservation of the karst system. This will be in line with the mission of the Cave and Karst Task Force of the IUCN (International Union for Conservation of Nature and Natural Resources, 2006).

The Environment Conservation Act, 1989 (Act 73 of 1989), National Water Act (Republic of South Africa, 1998), the Mineral and Petroleum Resources Development Act (Republic of South Africa, 2002), the National Environment Management: Protected Areas Act (Republic of South Africa, 2003) and the National Environment Management: Biodiversity Act (Republic of South Africa, 2004) provide a legal framework in which conservation of the karst system can be enforced. It will be far less expensive and more sustainable however, if the public sector participates voluntarily in karst system and karst ecology conservation, rather than to leave the responsibility solely in the hands of the government. To ensure public participation, knowledge of the karst system and ecology, as well as a common conservation goal, must first be established. Enforcement of legislation would then only become necessary where education failed.

8.3 Discussion

The threats to the karst system and karst ecology at the COH WHS include pollution, which emanates from mines, industry, agriculture, and municipal and household activities. Habitat loss due to the mismanagement of water in the catchment area, agricultural practices, dolomite mining and urbanisation, also lead to the degradation of the karst system and threatens karst ecology (Durand, 2007, 2008).

Present legislation provides a legal framework within which the impacts on karst systems and karst ecology can be monitored and measures can be taken against transgressors. These laws and regulations cover the aspects, which impact karst, karst ecology and human health (geology and mining, pollution, biodiversity, agriculture, water quality and sanitation). It is clear however that since the negative impacts on karst systems and karst ecology still continue, legislation alone is not sufficient.

In most of the cases these impacts can be minimised if people were better informed and their attitude towards karst and karst ecology changed. Mogale City Local Municipality (2002a), Department of Public Works (2003) and the Water Research Commission (2003) have drawn up guidelines for pollution control, the erection of buildings, the placement of package plants, water quality conservation and sanitation in karstic regions.

In order to effectively address the degradation of the karst system, one has to identify the different impacts that various groups have on it. Clearly industrial waste and mining effluent issues outside the COH WHS need a different educational approach than household sanitation and borehole issues inside the COH WHS. Using this method, one can view the threats to the karst system and ecology of the COH WHS as coming from two main sources: those from within the COH WHS and the area directly adjacent to it, and those from the larger geographical area in which the COH WHS is situated and especially the catchment feeding into the surface water and groundwater of the karst system (Durand, 2008).

8.3.1 The impact on the karst system and karst ecology inside the COH WHS that can be addressed through education

Most of the threats to the karst system and karst ecology emanating from inside and adjacent to the COH WHS come from pollution generated by household and farming activities. Habitat loss on the surface, within the cave environment and the degradation of groundwater quality, are caused by dolomite mining, farming and urban development. The inhabitants of the COH WHS would benefit from environmental educational programmes addressing these issues.

8.3.1.1 HOUSEHOLD IMPACTS ON THE KARST ENVIRONMENT IN THE COH WHS

Landowners and residents within the COH WHS will benefit from educational programmes which deal with construction on dolomites, farming, sanitation and water quality, as many misconceptions exist regarding karst systems, groundwater and ecology.

There are approximately 700 farms or smallholdings within the COH WHS. There is neither municipal water supply nor sewage systems in the dolomitic area of the COH WHS. The majority of the households within the COH WHS are therefore dependent on the water from the Bloubankspruit and groundwater for drinking, sanitation and other household purposes and irrigation. The majority of households in the dolomitic area within the COH WHS also have French drains (soak-aways) for the homestead and pit latrines for the farm labourers. Most households in the dolomitic area of the COH WHS have a rubbish dump on the property since there are no municipal waste removal services (Durand 2007).

The karstic nature of the core area of the COH WHS makes it impractical to service the area with a gravitational sewage system. A conventional sewer line would require several pump stations in the undulating landscape of the COH WHS, which would make it prohibitively costly. In addition, there would be the problem of backflow and clogging during a power failure. This situation has lead to the uneasy acceptance of the fact that the majority of the households within the karst region must take care of their own sewage disposal.

There are several DWAF boreholes in and around the COH WHS where water quality is monitored regularly. If point source pollution can be traced to soak-aways, pit latrines and septic tanks, the landowner will legally be compelled to rectify the problem. There are also municipal regulations for the distance between boreholes and septic tanks, French drains and pit latrines. Unfortunately this is only a compromise, because the groundwater will inevitably be contaminated with faecal coliforms, faecal streptococci, *Salmonella* and *Clostridium*. Faecal coliforms and *Clostridium* were found in the groundwater in Sterkfontein and Koelenhof Caves in 2005 (Van Tonder *et al*., 2005).

The Department of Public Works strongly advises against the construction of septic tanks, French drains or pit latrines, as well as the use of boreholes for water abstraction in dolomitic areas (Department of Public Works, 2003). The Department of Public Works also recommends that conservancy tanks with low flush volumes be used where sewer connections are not available. Pit latrines may be used in low risk areas as long as they are situated as far as possible away from permanent structures and water supplies, are relocated annually, and are constructed to avoid ingress of storm water. It is further advised that for pit latrines, the use of holding tanks with chemical digestion should be considered. The pollution of water resources must be considered if the water is to be used for consumption. Although the best practice alternatives to French drains, septic tanks and pit latrines are package plants and vacuum tanks, these do not occur in the dolomitic region of the COH WHS.

According to people interviewed, it appears that most households have at least one rubbish dump on the property, and that the rubbish is regularly burned. Although none of the respondents admitted to dumping rubbish or carcasses down sinkholes or caves, it is a common occurrence in the COH WHS. This illegal practice has many ramifications, from soil and groundwater pollution, to habitat loss (Durand 2007).

8.3.1.2 FARMING ACTIVITIES WITHIN AND ADJACENT TO THE COH WHS THAT IMPACT ON THE KARST ENVIRONMENT

The farming activities within and adjacent to the COH WHS include agriculture, horticulture and animal husbandry. Vegetables and grain are commonly cultivated in the COH WHS and there are extensive horticultural concerns just outside the COH WHS. The accumulation of agrochemicals, such as fertiliser and insecticides, has a major effect on surface water, groundwater and soil, and inevitably leads to habitat loss and the extinction of organisms (Erasmus *et al.*, 2007, Durand, 2007).

Piggeries, chicken batteries, trout farms, dairy farms and feedlots are examples of farming practices in the core area of the COH WHS. Effluent from these farms is flushed directly into the rivers in the COH WHS (Van Staden, 2003). It is important to take note of the fact that a dairy farm, piggery, feedlot or trout farm produces far more sewage than an average household would. If the subdivision under two hectares in the COH WHS is not allowed by the municipality inter alia because of the negative impacts of the sewage on the environment, animal husbandry should also be curbed in the region.

The use of insecticides in and around the COH WHS is in direct conflict with the attempt to protect the insectivorous bats of the region. Alternatives to insecticides and fertilisers should be investigated. Workshops should be held to explain the advantages of sustainable farming to the farming community. Organic farms are becoming more commonplace in South Africa. Compost should replace fertiliser and biological control should phase out insecticides.

Over-abstraction of groundwater has a detrimental effect on two habitats – the groundwater and the surface area. The abstraction of large quantities of water has a negative effect on karst systems and karst ecology. Dolines and sinkholes form frequently when too much water is abstracted and the roof of the underground cavity caves in. The mobilisation and subsequent deposition of salts lead to salinisation of the soil and it becomes useless to human and animal alike. A drop in the water table may cause a cave to dry out, which in turn would be detrimental to humidity-dependent bats and aquatic organisms, such as amphipods, flatworms and micro-organisms (Durand, 2008).

The results of farming, such as the clearance of the natural vegetation, the planting of alien species, ploughing, and the compaction of surfaces, all contribute to changes in run-off patterns and permeability of the surface, which impacts negatively on the recharge of the aquifers in the COH WHS. The introduction of alien plants through farming and gardening contributes to the alien plant invasion of surface water bodies, which also has a negative impact on drainage patterns and the disruption of the ecology and habitat loss. This in turn has a detrimental effect on the fauna dependent on those habitats (Van Staden, 2003). In addition, alien plants often use more water than indigenous flora, which further impacts on the groundwater.

It is necessary to sensitise farmers in the COH WHS to the negative ecological impact of their orthodox farming practices. It is also imperative that alternatives be found for these practices and that the farming community is involved in the clearing of alien vegetation and clean-up operations on their farms, including the caves and riparian zones around the rivers on their properties.

8.3.2 The impact on the karst system and karst ecology from the larger geographical area outside the COH WHS that can be addressed through education

The main threats to the karst system and karst ecology are pollution, habitat loss and the mismanagement of the water catchment on which the karst system of the COH WHS is dependent. Pollution emanating from the gold and uranium mines in Gauteng and North West Province is the main threat to the whole water catchment area, including the groundwater and karst system. Other major contributors to pollution in the province which threaten the groundwater and karst system are effluents from industries, agricultural chemicals and landfills. Habitat loss is mostly caused by urbanisation and agricultural activities in the provinces within which the COH WHS is situated (Durand, 2007).

The chances of changing the perceptions of multi-national corporations, mining houses and industries through normal environmental educational programmes are unfortunately relatively small. The most practical approach to minimise or halt the negative impacts on the catchment area that supplies the karst would be through constant and consistent application of legislation. This implies that government departments, such as the Department of Environmental Affairs and Tourism, the Gauteng Department of Agriculture, Conservation and Environment, and the Mogale City Local Municipality, will be tasked with the monitoring of emissions and effluent, the environmental studies, and the issuing of warnings, warrants and fines. Mines and industries are legally forced to comply with certain health and environmental regulations (Van Eeden *et al.*, 2009). The Mogale City Local Municipality has a comprehensive monitoring and billing programme in place based on the "Polluter Pays" principle. The fines served to industries and businesses are based on the pollution emissions from their facilities. Mines, industry and developers must comply with national legislation, such as The Environmental Conservation Act, 1989 (Act 73 of 1989), the National Environmental Management Act (Act 107 of 1998), and local by-laws. Mines must also comply with Environmental Management Programme Reports (EMPRs). It seems however that this option places industries and mines in an opposing role to the conservation and health regulating bodies, and will not likely contribute to a spirit of voluntary cooperation and proactive participation in conservation.

High-level interaction between environmental officers of government departments (both national and local), and the managers of industries and environmental officers of mining houses may convince these businesses of the benefits of environmental economics. According to this approach, companies would make less profit over a shorter period, but since resources will last longer, it is possible to make profit over a longer period. Not only will this approach be more environmentally sustainable but it will also contribute to a more stable socio-economic situation over the long-term. If approached correctly, industry and mining may make ideal business partners for sponsoring environmental education programmes, clean-ups and conservation.

It is also necessary for governing bodies to weigh the short-term benefits of allowing people to continue with actions that have a negative impact on the environment and through inaction by not prosecuting transgressors, against the long-term advantages of conserving natural resources. In the introduction to the Mogale City Local Government State of the Environment Report (2003a) it is stated that: "The State of Environment Report has been compiled to assist the Gauteng Provincial Government, specifically the Gauteng Department of Agriculture, Conservation and Environment and other decision-makers to make informed decisions about our environment. The Gauteng Provincial Government will use the information presented in this report to assist in achieving sustainable development." The Department of Agriculture, Conservation and Environment states that its responsibilities are carried out in terms of 13 major national laws which include: Environment Conservation Act, 1989 (Republic of South Africa, Act 73 of 1989), the National Environment Management Biodiversity Act (Republic of South Africa, Act 10 of 2004), the National Environment Management: Protected Areas Act (Republic of South Africa, Act 57 of 2003), the National Water Act (Republic of South Africa, Act 36 of 1998), and the World Heritage Convention Act (Republic of South Africa, Act 49 of1999).

Even though the national acts and municipal regulations conform to international best practice, and whereas there is not one conflicting regulation amongst the acts and by-laws regulating conservation, there are many practices in and around the COH WHS that are in conflict with the aims of these acts. An example is the discharge from the Percy Stewart Water Care Works into a tributary of the Bloubankspruit that runs through the dolomitic region of the COH WHS. The sludge of the Flip Human and the Percy Steward Water Care Works is disposed of by irrigating instant lawn farms, which impact negatively on the surface and groundwater in the karst system (Mogale City Local Municipality, 2003a). The fact that orthodox farming practices are allowed in the ecologically sensitive karst region of the COH WHS is in direct conflict with conservation principles. The prevalence of animal husbandry, French drains and pit latrines in the COH WHS contradict the municipal by-laws and government guidelines (Republic of South Africa, 2002) prohibiting the building of French drains and pit latrines near water resources.

An alternative indirect approach, by means of which environmental education may play a positive role on the curbing of negative industrial, farming and mining environmental impacts, is to raise the environmental awareness of the general public. It would also be to the benefit of the public to know what their rights are concerning a healthy environment. Although these rights are spelled out and are firmly entrenched in the Constitution of the Republic of South Africa (Republic of South Africa, 1996, Section 24), the public is generally unaware of these rights or their implications. The public also does not know which governing bodies to approach to complain about certain practices that impinge on their rights to a healthy environment. Workshops to explain the public's environmental rights and an introduction to the different governmental and municipal departments' functions would benefit the community, and ultimately contribute to the conservation of the karst system and karst ecology.

8.4 Response required

It is imperative that the conservation and sanitation awareness of the inhabitants of the COH WHS be increased. It is also important that the inhabitants of the COH WHS be involved in decision-making and management of the area.

From interviews done with land owners and tenants in the area it seems as if they feel excluded from the decision-making process with regard to developments in the COH WHS. The majority of respondents are even unaware of which government department is responsible for developments in the Cradle of Humankind, although the Gauteng Department of Agriculture, Conservation, Environment and Land Affairs has held several public participation meetings in the area.

Although adequate and laudable legislation exists to regulate the actions of people that may have an impact on the natural resources within the COH WHS, the majority of respondents are unaware of municipal regulations about subdivision, sanitation and water quality. Some of the respondents are under the impression that they will be able to develop tourist facilities on their properties. Other respondents want to subdivide their properties, not realising that it will be against the Mogale City Local Municipality regulations to have more than two dwellings on a one hectare plot and that subdivision of a plot equal to or less than two hectares is not allowed in an area where piped water and sewerage are not available.

Legislature often includes a clause that states that the public should be educated or that public awareness should be promoted. The World Heritage Convention Act (Act 49 of 1999) states for instance, "that community well-being and empowerment must be promoted through cultural and natural heritage education, the raising of cultural and natural heritage awareness, the sharing of knowledge and experience and other appropriate means". Similarly, the Mogale City Local Municipality (2003b) aims to "disseminate information about sanitation and wastewater management".

The Mogale City State of the Environment Report (2003a) includes a "What can you do?" section in each chapter. Some of the items that are important to the COH WHS and specifically the karst systems, groundwater and karst ecology, include the following advice on the conservation of water:

- Harvest storm water on your property and use it for irrigation purposes. Ensure that there are soft permeable surfaces on the property.
- Plant indigenous species which do not require large volumes of water in the garden.
- Only flush the toilet if necessary (place a brick in the cistern and save water).
- Install 2-system flush toilets.

- Rather have a quick shower than a deep bath - it uses less water.
- Use water from the kitchen/bathroom to water the garden.

On the conservation of rivers and wetlands:

- Conserve the existing natural water resources (e.g. the wetlands and rivers) by supporting wetland/river clean-ups as well as initiating and taking part in rehabilitation/management programmes in your area.
- Take part in the Working for Water (WfW) and Land Care Programmes, which eradicate alien vegetation from water resources.
- Conserve the natural water systems in your community.

On nature conservation in general:

- Take part in the establishment of secondary industries, which are linked to the eradication of alien vegetation (e.g. furniture making woodlots). This supports the principle of sustainable development.
- Support local reserves and conservation areas.
- Plant indigenous trees in your garden.
- Familiarise yourself with regard to the Red Data species in your area and take part in the protection of these species and their habitats.
- Be aware of alien invasive species and assist your local authority in removing these species.

On environmental education:

- Take part in environmental education programmes.
- Local schools should assist in managing reserves administered by the MCLM.
- Attend education programmes regarding river and wetland conservation.

On nature conservation legislation and public participation:

- Report unlawful discharge of effluent by industry, business and/or the mining sector to the local health department.
- Owners of land on ridges can protect their properties through formal legislation.
- Communities can form conservancies to protect and manage ridges in their neighbourhoods. The public should play a watchdog role by objecting to development proposals on ridges, bringing insensitive development proposals to the attention of local media and requesting that their local councils implement the policy fully (Urban Green File, 7(4), Sept/Oct 2002).

The Department of Public Works (2003) has published extensive guidelines for the development of infrastructure on dolomites. The guidelines include a list of practices that should be avoided when designing infrastructure on dolomitic land, as well as stipulations on the designs and materials used for construction.

The World Heritage Convention Act (Act 49 of1999) states, ".. that community well-being and empowerment must be promoted through cultural and natural heritage education, the raising of cultural and natural heritage awareness, the sharing of knowledge and experience and other appropriate means".

It is clear therefore that the regulatory bodies that govern the karst system, groundwater, surface water, karst ecology and biodiversity within the COH WHS, unanimously agree on the importance of public education and participation in the conservation of these natural resources. The challenge however is to identify the most effective channels and forums for the dissemination of information, communication with the public and the involvement of the public.

Alternative avenues of communication and involvement of the inhabitants should be explored. The majority of interviewed respondents were in favour of a web site and flyers or booklets informing them on karst and karst ecology, rather than workshops or government directives. It is proposed that a web site is set up to inform inhabitants and operators in the COH WHS regarding:

- The conservation of karst and karst ecology,
- The acts and directives governing the conservation of natural resources within a karstic area,
- Guidelines on rehabilitation of the ecology within the COH WHS,
- Guidelines to sanitation and health,
- Guidelines to sustainable farming on dolomite,
- Guidelines on construction on dolomite.

The poorer section of the community who do not have access to the Internet may be reached by means of flyers and booklets. Taking into consideration that about 40% of the adult population of South Africa is illiterate, workshops may be held to reach this part of the community. It is crucial to communicate with the farm labourers within the COH WHS, since they are mostly permanent residents, and the owners are often absent.

Workshops will have the added benefit of providing a venue where booklets and flyers with information on karst systems, groundwater, karst ecology, sanitation, conservation, etc. can be distributed. The community forum can also be used as a communication organ by developers and consultants to reach the landowners and residents of the COHWS to inform them about public meetings where developments planned for the region in and around the COH WHS will be discussed.

The schools within and in the vicinity of the COH WHS should present information on karst systems and ecology, sanitation, health, construction and farming. Conservation, ecology and health issues feature strongly in the current curricula for both primary and secondary schools. It is suggested that karst ecology and conservation should be referred to specifically by schools in and around Mogale City Local Municipality as part of their teaching programme.

It would also be useful if a community forum was established where residents and workers in the COH WHS could communicate with one another and decision makers, and participate in the conservation of karst and karst ecology. This would be an ideal vehicle to inform residents and to address their fears and apprehension about conservation and development. It is even possible to arrange community days, lectures, educational tours, river clean-up outings, eradication of alien species, and fundraising events by means of such a forum. Money generated in this way can be utilised to fund clean-up operations, tree planting days, alien species eradication programmes, educational workshops and publications. The community forum could also act as a fundraising body and approach sponsors for the funding of environmental education and conservation projects.

This community forum will also benefit from working closely with other interested and affected parties that have an interest in the COH WHS, but are not necessarily residents of the COH WHS. Some of these organisations that could be approached include:

- Gauteng and Northern Regions Bat Interest Group (GNORBIG)
- South African Society for Amateur Palaeontologists
- Spelaeological societies
- Hiking clubs
- Tree and succulent societies
- Bird and wildlife societies

In order to keep the activities of this community forum democratic and transparent and to steer clear from overt or covert political or economic manipulation, it is important to select organisations to cooperate with which have the conservation of natural resources at heart. Membership of these organisations should also be open to any member of the public that subscribes to their respective constitutions. The exchange of ideas that will occur when residents of the COH WHS join these organisations will contribute to the increase of subject knowledge in the area and ultimately contribute to the conservation of the natural resources of the area. Interaction with these groups will assist residents in making decisions about conservation and tourism, rehabilitation of disturbed areas on their farms, and on sustainable development. Cooperation with these societies will also be far more cost effective than the hiring of consultants.

Government departments, local government and parastatals, such as Nature Conservation, Department of Public Works, the Department of Health, Mogale City Local Municipality, Water Research Commission and Council for Geoscience, should also be involved in educational programmes in the COH WHS. A community forum could invite researchers from these bodies to present workshops or lectures on matters of importance in the COH WHS. Cooperation of the government and parastatals with the community forum will also be beneficial in that a new and direct channel of communication will be opened through which legislative directives can be passed on to the community. This approach will give the residents the opportunity to discuss the directives from the government and other decision makers. It will also make the process more transparent and inclusive and will lessen the suspicion and animosity among residents.

8.5 Regulatory response required

It is clear that there is adequate legislation to protect the soil and water quality and biodiversity, as well as to insure the health of the inhabitants of the COH WHS and to control the farming, industrial and mining activities within and outside the COH WHS. The areas that could be added or referred to specifically in future augmentations or addition of legislation could include the classification and use of caves, and the protection of karst ecology.

According to the Integrated Development Plan of the Mogale City Local Municipality (2002a), environmental stability, which includes resource protection, ecological conservation and pollution prevention, is one of its key priorities. The municipality therefore protects the natural resources of the region, such as the fauna and flora, as well as land and water, by promoting and upholding sustainable development principles. Protection of these natural resources is achieved through development and implementation of environmental programmes such as the promotion of environmental awareness, parks development, waste management, species protection and water conservation. Relevant legislative mechanisms and various decision support tools such as the State of Environment Report (Mogale City Local Municipality, 2003a) and the Environmental Management Framework (Mogale City Local Municipality, 2003b) are also utilised.

The problem lies firstly with the prioritisation of legislation: i.e. do property rights outweigh the Biodiversity Act? Should people be allowed to use pesticides in an area that is occupied by Red Data species? Should land that could be rehabilitated be cleared for farming if it has a high agricultural potential? Should animal husbandry be allowed in a karstic area where the majority of people depend on groundwater for human consumption? Do the rights of the mining companies responsible for the toxic effluents entering the COH WHS outweigh the rights of the inhabitants to clean water? Virtually every household in the dolomitic area of the COH WHS has French drains and pit latrines and depends on boreholes for water although it is against Department of Public Works and Mogale City regulations. On the other hand, Mogale City releases the wastewater of the Percy Stewart Water Care Works into a tributary of the Bloubankspruit, the main water supply to several households within the COH WHS.

The second problem is that the enforcement of legislation is difficult, if not impossible in some cases. One of the major obstructions to the enforcement of legislation pertaining to environmental health is that environmental health officers depend on the Department of Justice to penalise offenders. Environmental health offences take second priority to the other crimes with which the Department of Justice is bogged down. The success rate for the prosecution of offenders is therefore relatively low (Mogale City Local Municipality, 2002c).

This conflict of interests on top of the ineffective enforcement of legislation is a matter of serious concern and should be resolved at the highest level. The COH WHS has the potential to become a showcase of South African natural resource conservation. The World Heritage Status of the Cradle of Humankind should not be taken for granted. It is an honour that has to be earned and maintained. It has happened before that the World Heritage Status has been withdrawn due to the degradation of a site.

8.6 Research required

An inventory should be compiled of waterborne diseases threatening the people and animals living in the COH WHS. Continuous monitoring and research should be done on water quality and pollution in the area. Alternative ecology-friendly farming methods should be tested in the COH WHS.

8.7 Monitoring required

- It is necessary to ascertain exactly how many pit latrines, French drains, septic tanks and boreholes are present in the karstic region of the COH WHS.
- Microbial analyses of the water from boreholes used for human consumption should be done on a regular basis.
- The water of the rivers in the COH WHS must be monitored downstream from piggeries, chicken batteries, trout farms, dairy farms and feedlots.
- Waste disposal in sinkholes and caves in the COH WHS should be monitored.
- Water from the DWAF boreholes should constantly be tested for agrochemicals and mine and industrial effluents.
- Removal of exotic plants and animals from the COH WHS.

REFERENCES

Department of Public Works (2003) Published Report PW344, Appropriate development of infrastructure on dolomites: Guidelines for Consultants.

DURAND JF (2007) Challenges associated with living in karst environments such as the historical Cradle of Humankind World Heritage Site. New Contree **54,** pp.75-98.

DURAND JF (2008) Die karst-ekologie van Suid-Afrika met spesiale verwysing na die Wieg vn die Mensdom Wêrelderfenisgebied. Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie **24** (4) pp. 5-16.

ERASMUS B, DURAND JF and NEL A (2007) Die gebruik van Amfipoda (Sternophysinx filaris) vanaf die Sterkfonteingrotte as bioindikatore om die effek van landboukundige chemikalieë op karst-ekologie te bepaal. Die Suid-Afrikaanse Tydskrif vir Natuurwetenskap en Tegnologie, **27** (1), p. 70.

International Union for Conservation of Nature and Natural Resources (2006) Conserving Biodiversity – Cave and Karst Task Force.

http://www.Karst education\IUCN - World Commission on Protected Areas.htm

Mogale City Local Municipality (2002a) Integrated Development Plan 2002-2006.

Mogale City Local Municipality (2002b) Waste Water Sector Plan for the Integrated Development Plan, Directorate: Technical Services.

Mogale City Local Municipality (2002c) Mogale City Local Municipality Integrated Health Sector Plan for the Integrated Development Plan, Mogale City Local Municipality, 2002-2006.

Mogale City Local Municipality (2003) State of the Environment Report, Mogale City Local Municipality.

Republic of South Africa (1986) Constitution of the Republic of South Africa, Act 108 of 1986.

Republic of South Africa (1989) Environment Conservation Act, Act 73 of 1989.

Republic of South Africa (1998) National Water Act, Act 36 of 1998.

Republic of South Africa (1999) World Heritage Convention Act, Act 49 of 1999.

Republic of South Africa (2000) Department of Water Affairs and Forestry (DWAF), Policy and Strategy for Groundwater Quality Management in South Africa of 2000.

Republic of South Africa (2002) Mineral and Petroleum Resources Development Act, Act 28 of 2002.

Republic of South Africa (2003) National Environment Management: Protected Areas Act, Act 57 of 2003.

Republic of South Africa (2004) National Environment Management: Biodiversity Act, Act 10 of 2004.

Urban Green File, **7** (4), Sept/Oct, 2002 http://www.urbangreen.co.za/

VAN EEDEN ES, LIEFFERINK M and DURAND JF (2009) Legal issues concerning mine closure and social responsibility on the West Rand. TD: The Journal of Interdisciplinary Research in Southern Africa **5** (1), pp. 51-71

VAN STADEN S (2003) A case study on the use of habitat assessments and biological indices for the management of recreational stream fisheries, Unpublished MSc Dissertation, Rand Afrikaans University, Johannesburg.

VAN TONDER S, DURAND JF and TAYLOR S (2005) Aspects of the general histology of the gastrointestinal tract, and the use of microbiology and molecular techniques in determining the GIT contents of cave dwelling amphipods, Proceedings of the 15th Entomological Congress of the Entomological Society of Southern Africa, Rhodes University, Grahamstown, pp. 88-89.

Water Research Commission (2003) Sanitation research strategy, Water Research Commission of South Africa.

ISSUE PAPER 9 THE IMPACTS OF MINING ON THE WATER RESOURCES AND WATER-BASED ECOSYSTEMS OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

W.G. Krige and M. Van Biljon

ABSTRACT

This paper was produced on request by the IUCN South Africa Karst Working Group. It deals with the impact of mining on the Cradle of Humankind World Heritage Site.

The paper starts off by describing the surface water catchment of the Cradle and shows that, although this catchment extends beyond the boundaries of the Cradle, this extended catchment is extremely important in relation to the gold mining industry and its impact on the Cradle. The paper then proceeds to describe the formation of the dolomitic aquifers and also gives a synopsis of the geology of the Cradle and its catchment relating to the mining industry that would be established within this area.

The minerals found within the Cradle are subsequently briefly described in terms of the regional geology. Potentially the largest impacter on the Cradle, gold mining in the Witwatersrand reefs in the catchment of the Cradle, is described in detail and the impact which this industry has had on the Cradle is discussed.

The most important of the mining impacts, the decanting of polluted mine water into the catchment of the Cradle, is subsequently discussed in detail, initially by listing the sequence of events that lead to the polluted water being released into the Cradle and then by listing the potential impacts of this water on the Cradle, its karst and its residents.

This paper attempts to be as objective as possible on a highly controversial subject and attempts to put all the facts on the table. The paper disproves the statements made by the press that the acid mine water will flood the Sterkfontein Caves.

9.1 Introduction

During the month of August 2002, an event took place that would have a far-reaching impact on the Cradle of Humankind World Heritage Site (COH WHS). This event was the first decanting of water from the flooded gold mines of Krugersdorp and Randfontein, collectively referred to as the Western Basin Mine Void (**Figure** 9.1). This water flowed through the Krugersdorp Game Reserve and entered the dolomitic aquifers of the COH WHS. Although predicted by specialists as early as

1996, the magnitude of the event still caught most people, mining houses and authorities by surprise.

The decanting of polluted mine water was the final stage in a sequence of events which took approximately 115 years to complete. The process started back in 1887. Approximately a year after the discovery of gold on the Witwatersrand, the gold-bearing reefs of the Western Basin were discovered and have been mined ever since. During this mining process, water was pumped from the mine workings into the dolomitic aquifers of the Cradle to enable deeper mining to take place. This pumping continued until around 1998, when a final decision was made to stop the last pumping operations and to allow the mine void created during the previous 110 years, to flood.

Figure 9.1: The first water to decant from the flooded mine void occurred from a borehole sunk into a dolomitic inlier which, in turn, is linked to flooded mine workings. This borehole is next to the Tweelopiespruit (photo: G. Krige, 28 August, 2002).

For the next four years the mine void gradually flooded, the mines' ownership changed and the predictions of 1996 were all but forgotten until 2002, when the water in the mine void finally reached the surface and started to decant into the Tweelopiespruit, upstream from the Krugersdorp Game Reserve.

Although this event made headlines all over the press and local TV channels, it represented not the only impact that mining has had on the COH WHS. Mining has been carrying on for thousands of years within and around the area, albeit on a smaller scale. As far back as 2 000 years ago, the first Iron Age miners found that there was an adequate supply of iron ore in the landscape and sufficient trees to burn in order to work the raw iron into weapons and tools (Hilton-Barber and Berger, 2002). The mineral worth of the region reached its climax with the discovery of gold on the Witwatersrand in 1886. Between these times, however, the COH WHS had been mined extensively for a variety of minerals. The following sections will summarise the events of human mining activities in the COH WHS.

9.2 The Surface Water Catchment of the Cradle of Humankind

Mining activities that impact on the COH WHS have a wider distribution than the mines within the site itself. For this reason, a brief description of the COH WHS surface water catchment will be presented.

Figure 9.2 shows the boundaries of the COH WHS and includes the boundaries of the surface water catchment of the Zwartkrans and North dolomitic compartments. Apart from rainwater falling on the portion of the catchment of the Zwartkrans compartment located outside the COH WHS boundaries (to its southwest), no other surface or groundwater, from natural origins, enters the COH WHS from areas outside the boundaries of the COH WHS. Water originating from the Vaal River does, however, enter the COWHS via the Percy Stewart and Randfontein Sewage Plants (27.46 Mℓ/day). This is not considered natural water, as it did not originate in this particular catchment.

The COH WHS northwestern boundary follows the watershed created by the Witwatersberg Ridge. Rainwater falling within the COH WHS along this ridge (on its southern slope) is drained out of the COH WHS via the Hekpoortspruit, the Doringspruit, the Skeerpoort River and the Leeuspruit, which flows into the Hartbeespoort Dam at Oberon. Rainwater falling on the other side (the northern side) of the watershed drains away from the COH WHS.

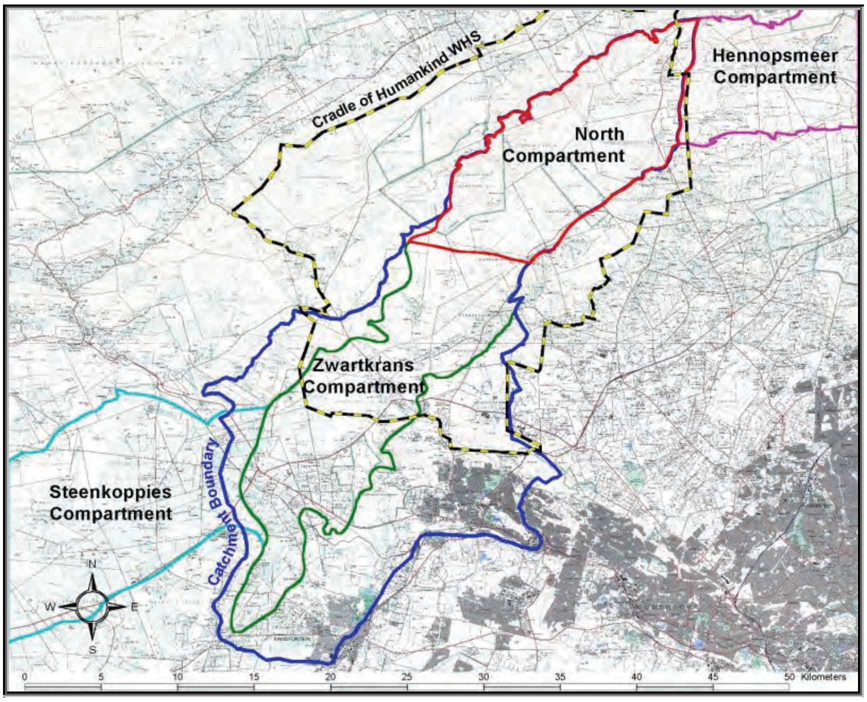


Figure 9.2: Portions of topocadastral maps 2527DC, 2527DD, 2627BA and 2627BB showing the boundaries of the Cradle of Humankind World Heritage Site, the dolomitic groundwater compartments and the catchment of the Zwartkrans and North Compartments. (The boundaries of the dolomitic compartments were digitised from the 1:250 000 SA Geological Series maps.)

Along the eastern boundary of the COH WHS, water flows eastwards, i.e. out of the site towards the Crocodile River. In fact, the Crocodile River forms part of the boundary of the COH WHS for a distance of about 3.5 km. As is the case with the northwestern boundary, no rainwater enters the COH WHS from its eastern border.

The Hekpoortspruit forms the northern sub-portion of the western boundary of the COH WHS. Rainwater drains towards this stream, thus also leaving the COH WHS where this stream cuts through the Witwatersberg. There is only a very small catchment portion (approximately 4 km^2) of the headwaters of the Skeerpoort River that falls outside the COH WHS. This section locates immediately to the north of the point where the catchment boundary of the Zwartkrans Compartment (blue line, **Figure** 9.2) crosses the boundary of the COH WHS (yellow and black line, **Figure** 9.2). The situation is different along the southern and southwestern boundary of the COH WHS, however. The Zwartkrans Compartment extends well beyond the COH WHS boundaries to the southwest, while the surface water catchment extends even further as indicated in **Figure** 9.2 (blue line). It can be concluded therefore that apart from its southern and southwestern boundary, the COH WHS does not receive any natural surface or groundwater from outside its boundaries.

The southern and southwestern catchment of the Zwartkrans Compartment increases the surface catchment area of the COH WHS (47 000 km^2) by an additional 24 845 km^2, i.e. 52.9%. This area is significant, not only for its size, but also for the fact that it contains a highly populated area and the gold mines of the Witwatersrand reefs. There are three streams draining this particular catchment area; the Rietspruit which drains Randfontein and its surrounding area and also receives sewage effluent from their sewage plant, the Tweelopiespruit which drains the mining area around the Millsite area (and which also receives the water decanting from the Western Basin Mine Void) and the Blougatspruit which drains almost the entire (Old) Krugersdorp area from the industrial area of Factoria all the way to the Percy Stewart Sewage Plant on the border of the COH WHS. After the confluence of these streams, the watercourse continues through the Cradle as the Bloubankspruit.

Unless under extremely high rainfall conditions (approximately once in 5 years), neither the Tweelopiespruit nor the Rietspruit flows where they enter the COH WHS. Instead, all the water in these streams recharges into the Zwartkrans groundwater compartment. At least some of the water from the Blougatspruit manages to get across the dolomitic compartment up to the Danielsrust Eye, where a dyke forces the groundwater to daylight in the Bloubankspruit in the form of an eye.

As part of the EIA process as directed by the Department of Water Affairs and Forestry for the gold mines responsible for the mine water decanting from the Western Basin Mine Void into the COH WHS, a study was done in which a water and salt balance was done for the Zwartkrans Compartment (Krige, 2006). From flow measurement studies done between October and December 2005, the following statistics are available for the three streams. These values represent the dry-weather flow created by human activities and do not include the normal seepage occurring from natural processes:

Blougatspruit:

Flow in stream upstream from Percy Stewart Sewage Plant originating from human origins: 2.4 Mℓ/day

Percy Stewart Sewage Effluent: 19.3 Mℓ/day

Total: 21.7 Mℓ/day

Flow measured at the small bridge across the Bloubankspruit between the Sterkfontein and Zwartkrans Caves: 8.18 Mℓ/day

Streambed loss after flowing over 5.86 km of dolomite: 13.57Mℓ/day

This amounts to a streambed loss of 2.3 Mℓ/km/day.

Tweelopiespruit:

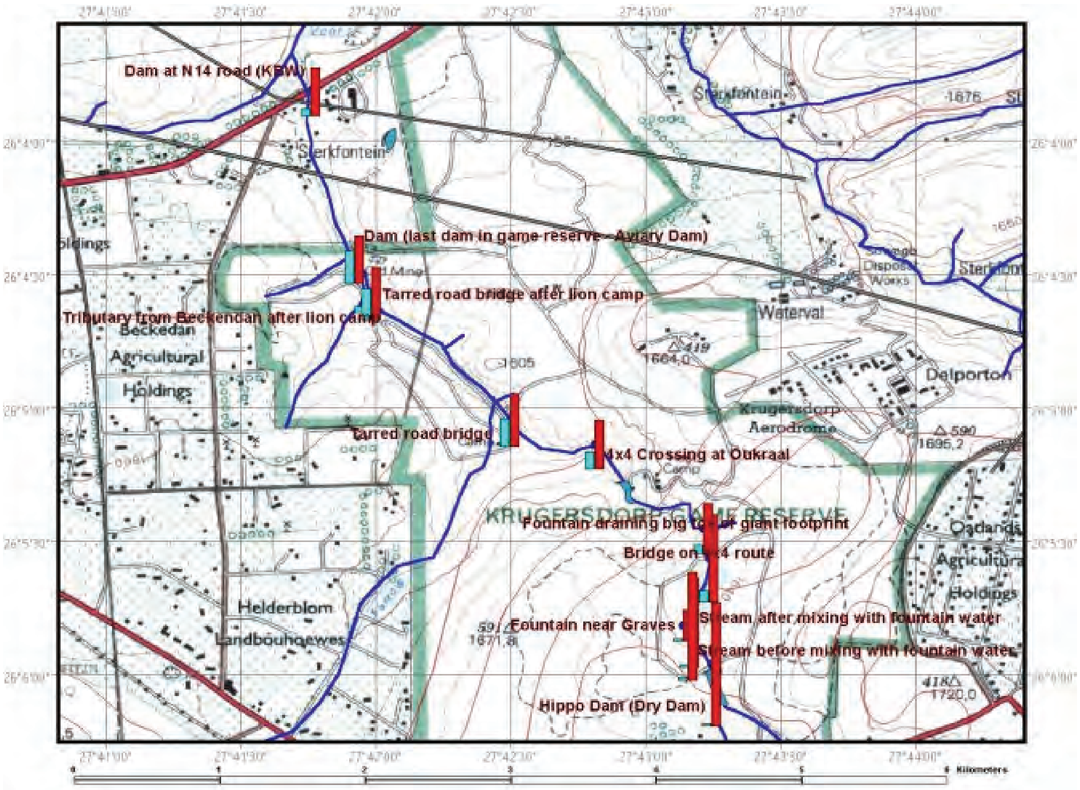
All surface water from the decant point was pumped and treated by the mining companies at the time of the study. However, it is suspected that at least some of the water decanting from the mine is bypassing the pumping operations sub-surface in the dolomitic inlier and is daylighting at the first dam in the Krugersdorp Game Reserve, from an area of seepage downstream from the dam as well as from a spring immediately downstream from the dam. The total flow represented by this seepage was measured at a 4x4 track crossing a short distance downstream from this point. This flow was measured at 1.47 Mℓ/day.

Rietspruit:

The only significant human-made flow in the Rietspruit is the sewage effluent from the Randfontein Sewage Works. This flow is 8.16 Mℓ/day.

It can be seen from **Figure** 9.3 that the flow rate in the Tweelopiespruit is initially low in the upper reaches of the stream, while the Electrical Conductivity (EC) is very high. This is due to the very poor quality mine water decanting into this stream. As the stream progresses through the Krugersdorp Game Reserve, more and more water from relatively uncontaminated dolomitic sources is added to the stream and the EC is reduced. This is due to the gaining part of the stream where significant volumes of dolomitic water enters the stream. However, the fact that the EC is still in the low 90s mS/m when the water reaches the KBW Dam, shows that, in spite of the relatively small flow from the mine void decant point, the impact of this water is significant.

Under normal circumstances, a stream originating at the continental watershed should contain very clean water. This was probably the case with the Tweelopiespruit before mining activities started in the area in 1887. A continuous stream of uncontaminated water would probably decant from the dolomitic inlier from which the mine void water is currently decanting. This stream would become progressively larger up to the point where the water recharges into the Zwartkrans Compartment in the vicinity of the Rietfontein fault, shown in **Figure** 9.3 as two grey lines



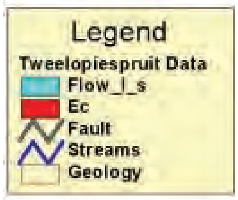


Figure 9.3: A section of the Tweelopiespruit through the Krugersdorp Game Reserve showing the relationship between the Electrical Conductivity (EC) and the flow rate of the stream. In general, the high EC immediately downstream from the mine water decant point indicates a strong influence from the water decanting from the mine. As the stream progresses downstream, an ever-increasing amount of unpolluted groundwater enters the stream and dilutes the dissolved salts in the stream. This occurs up to the last dam in the reserve, after which the stream crosses the Rietfontein Fault where a substantial amount of water disappears back to groundwater (Krige, 2006).

9.3 Urbanisation as a Direct Result of Gold Mining

This aspect is covered in detail in the following Issue Paper and will be discussed briefly in this section. Historically, towns and cities developed around streams or rivers as the stream supplied almost all of the human needs i.e., it provided a drinking water source, a means of transport, irrigation water for crops and for watering livestock while also providing a means of disposing of waste products.

The development of the Witwatersrand metropolitan area was not driven by natural circumstances but by the discovery of gold. Instead of developing alongside a river, the Johannesburg metropolitan area was developed along the reef outcrop on the watershed between two catchments. This happened to be the furthest place you could get from a river. The nearest reliable and sustainable water sources to the Witwatersrand were the Orange (Gariep) and Vaal Rivers, the nearest being some 60 km to the south. The metropolitan area that subsequently developed around the gold mining industry had to import water from these sources. The cost of returning the treated wastewater back to the rivers of origin, however, excluded this practice in the Witwatersrand and treated wastewater would be discharged into other catchments, including those of the COH WHS. Examples are the Percy Stewart and the Randfontein Sewage Plants, which discharge essentially Vaal River water directly into the COH WHS.

Apart from this, the wastewater and other waste products produced by the gold mining industry and the associated industries that supplied the metropolitan area also impacted – and are still impacting – on the COH WHS. It is therefore as an indirect consequence of mining of gold on the Witwatersrand that the COH WHS is now feeling the pressures associated with the nearby metropolitan area.

9.4 Regional Geological Setting

A discussion of the mining in and around the COH WHS will be incomplete without proper reference to the geology in which the minerals are found. The following is a brief description of the regional geology with special reference to the gold occurrences, which potentially are the largest impacters on the COH WHS. A detailed description of the geology in the COH WHS is contained in Issue Paper 6 (Holland *et al.*, 2007 not in the reference list).

The regional surface geology is briefly discussed with reference to **Figure** 9.4. The geology is described in chronological order, from the oldest to the youngest formations.

9.4.1 Archaean Basement Granite

The geological basement in the study area consists of Archaean rocks, known as the Kaapvaal Craton. Most of the craton is composed of what is broadly referred to as granite. The granites are in fact a complex suite, not only are there true granites but there are granodiorites and quartz-diorites, as well as some more basic rocks. The Halfway House granite that outcrops in the northwest of the study area is representative of the Archaean Basement and consists of gneiss, granite and granodiorite.

A number of unmetamorphosed sequences were deposited on the Kaapvaal Craton and range in age from 3 000 to 1 750 million years (Truswell, 1977). They have accumulated in basins and from oldest to youngest are the Pongola, Witwatersrand, Ventersdorp, Transvaal and Waterberg. With the exception of the Pongola and Waterberg, all other basins are present in the study area.

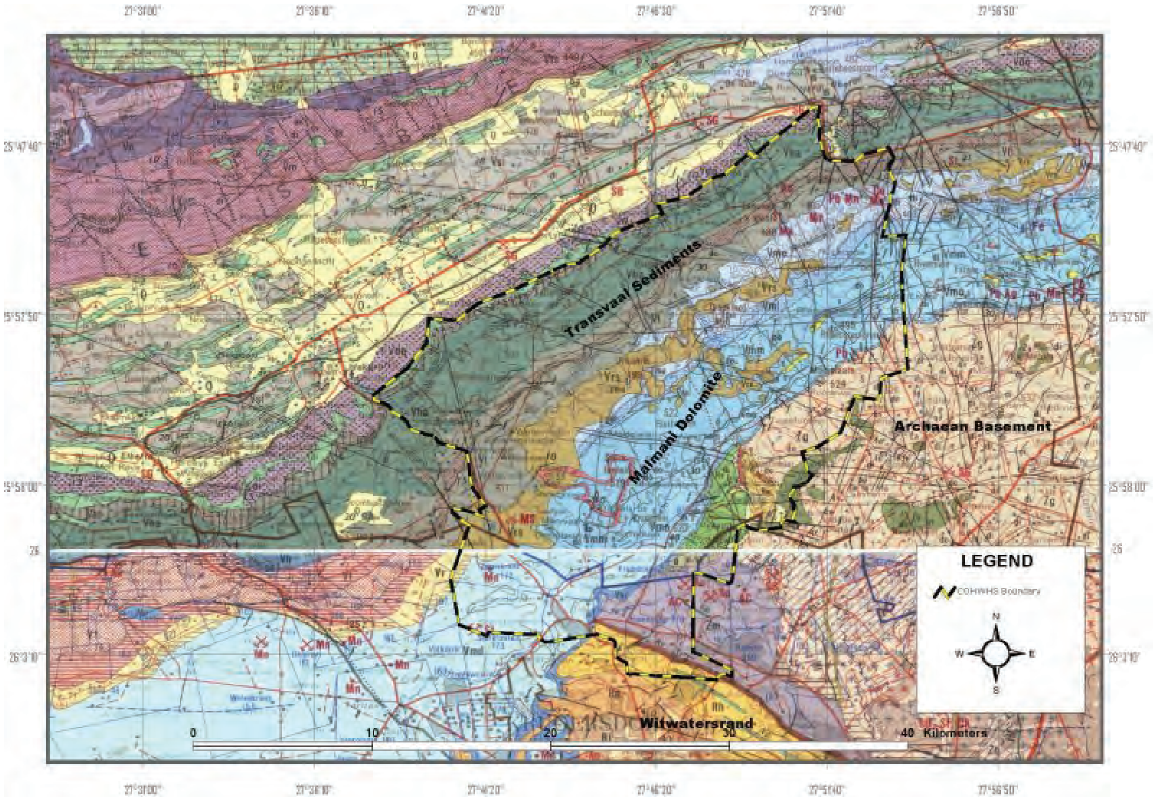


Figure 9.4: Regional geology of the study area. (Maps copied from the 1:250 000 SA Geological Series Maps)

9.4.2 Witwatersrand Supergroup

The Dominium Group, Witwatersrand Supergroup and Ventersdorp Supergroup constitute a volcano-sedimentary sequence that is well known for its fossil gold placers (Tankard *et al*., 1982). Since gold-bearing conglomerates were discovered near Johannesburg in 1886 the mines in Gauteng, Northwest and Free State Provinces have produced more than 55 percent of all the gold ever mined in the world (Pretorius, 1976 not in the reference list). On average, 300 000 workers developed 1 000 km of underground tunnels annually at an average depth of 1 650 m and mined 10^8 metric tons of ore to produce approximately 700 metric tons of gold annually.

The geology of the Witwatersrand Supergroup is well understood and documented as a result of extensive mining and exploratory drilling. Although only limited outcrop of the Witwatersrand Supergroup is present in the south of the Cradle, this geological unit potentially has the largest impacts on the study area in as far as mining is concerned. Impact from the gold mines is through the decanting of contaminated water that may enter the dolomite aquifer, not only threatening the underground water reservoir, but potentially could flood fossil locations such as the Sterkfontein Caves. The impact of this water on the Sterkfontein Caves is discussed later.

Truswell (1977) describes the Witwatersrand geology as follows: The Witwatersrand Basin deposited in a fluvial system some 2 800 million years ago, is a thick sedimentary sequence of shale, quartzite and conglomerate. The average dip of the strata varies between 10° and 30° South, although localised dips of up to 80° have been encountered in mine workings closer to the reef outcrop (Randfontein and Krugersdorp region). There are two main divisions, a lower predominantly argillaceous unit, known as the West Rand Group and an upper unit, composed almost entirely of quartzite and conglomerates, known as the Central Rand Group. The latter contains the economic gold deposits (reefs) that were mined extensively not only in the West Rand, but throughout the Witwatersrand Basin.

The West Rand Group is divided into three subgroups namely the Hospital Hill, Government Reef and Jeppestown. These rocks comprise mainly shale, but quartzite, banded ironstones, tillite and intercalated lava flows are also present. The rocks were subjected to low-grade metamorphism causing the shale to become more indurated and slatey. The original sandstone was recrystallised to quartzite.

The Central Rand Group is divided into the Johannesburg and Turffontein Subgroups and is composed largely of quartzite, within which there are numerous conglomerate zones. The conglomerate zones may contain any number of conglomerate bands, with individual bands interbedded with quartzite. The upper conglomerates are usually thicker with coarser fragments. An argillaceous zone known as the Booysens Shale (also known as the Kimberley Shale) separates the Johannesburg and Turffontein Subgroups. From an economic point of view the Johannesburg Subgroup is the most important gold producing unit. The formation of the gold-bearing deposits is discussed in more detail later in the paper.

9.4.3 Ventersdorp Supergroup

The younger Ventersdorp Supergroup (2 300 million years old) overlies the Witwatersrand rocks. Although acid lavas and sedimentary intercalations occur, the Ventersdorp is composed largely of andesitic lavas and related pyroclastics. The Ventersdorp Supergroup consists of the Platberg Group and the Klipriviersberg Group. The Klipriviersberg Group consists of the Alberton and Westonaria Formations. The Klipriviersberg Lava Formation constitutes the lowermost component of the Ventersdorp Supergroup and overlies various stratigraphic zones of the Witwatersrand Supergroup. Prior to the deposition of the Klipriviersberg lava the Witwatersrand gold bearing reefs were partially eroded and again deposited in what is now known as the Ventersdorp Contact Reef (VCR).

9.4.4 Transvaal Supergroup

The entire area was peneplained in post-Ventersdorp time (Lednor, 1986 not in the reference list) and it was on this surface that the Transvaal Supergroup was deposited, some 2 200 million years ago. The deposition commenced with the Kromdraai Member of the Black Reef at its base. The Black Reef has eroded the Witwatersrand outcrop areas and as a result contains zones (reef) in which gold is present. The occurrence of the gold is not as widespread as in the Witwatersrand and mainly restricted to non-persistent north-south trending channels. The Black

Reef is overlain by a dark, siliceous quartzite with occasional grits or small pebble bands. The quartzite grades into black carbonaceous shale.

Overlying the Kromdraai Member is the dolomite of the Malmani Subgroup of the Chuniespoort Group. The origin of dolomite is still a matter of some debate. According to Truswell (1977) dolomite normally represents a replacement of pre-existing calcium carbonate, but the only setting in which this has been observed is close to and above the high water mark, i.e. in a supratidal setting. However, most dolomites are not supratidal and appear to be intertidal and subtidal. During the deposition of the Transvaal Supergroup the only living organisms on earth were anaerobic bacteria i.e. bacteria that lived in the absence of oxygen. Of particular importance were a group of bacteria that acquired the ability to photosynthesise. These are collectively known as the *cyanobacteria* or blue-green bacteria (also incorrectly referred to as blue-green algae) (Pelczar, Reid and Chan 1977). During the early periods of the Transvaal deposition, the atmosphere was completely devoid of free oxygen, making it impossible for air-breathing organisms to evolve. However, over many millions of years and as a result of the photosynthetic activities of the cyanobacteria, the Earth's atmosphere was gradually converted to an oxygen-rich atmosphere.

The cyanobacteria were indirectly responsible for the precipitation of the dolomite itself. Almost all other sedimentary rock types are formed as erosion products (particles), originating somewhere outside the water body in which it is finally deposited. Dolomite on the other hand was formed as a precipitation product of a chemical reaction that took place within the water body. As a result of the photosynthetic activities of the cyanobacteria, large quantities of dissolved CO_2 were removed from the water in which they lived and consequently, the pH of the water was increased. Soluble calcium bicarbonate, $Ca(HCO_3)_2$, was converted to less soluble calcium carbonate, $CaCO_3$. Subsequent to this, some of the calcium in the mineral was replaced with magnesium, producing the mineral, dolomite, $CaMg(CO_3)_2$. The dolomite also contains lenses and layers of chert. The dense, hard and fine-grained chert tends to stand out in relief. Chert replaces carbonate material and forms in this siliceous material could accumulate only where the pH was lower than the mildly alkaline conditions under which marine carbonates formed.

The remains of these cyanobacteria are abundant in the COH WHS in the form of stromatolites. These are laminated structures that are considered to be similar to cyanobacterial mats still found today in places such as Shark Bay, Australia. According to Truswell (1977) these structures form when the sticky upper surface of the cyanobacteria trap limy mud. This trapped material forms a distinct bedding plane. The cyanobacteria then grow through the mud and the process is repeated.

The dolomites of the COH WHS, which are 1 500m thick, are known for their huge water storage potential. Storage of as much as 8.5 x 10^6 m^3/km^2 and transmissivity as high as 29 000 m^2/day have been reported (Vegter, 1984 not in the reference list) although fluctuating widely. Carbonate rocks are practically impermeable and therefore devoid of any effective primary porosity. During its geological history, however, the dolomite strata have been subjected to karstification and erosion. The potential for large-scale groundwater exploitation depends solely on the extent to which the dolomite has been leached by percolating rainfall and groundwater drainage and the degree to which it has been transformed into aquifers capable of yielding large quantities of water and sustaining high abstraction capacities. Previous studies (Bredenkamp *et al.*, 1986) indicated that significant aquifers have developed within the Cradle boundaries. The Sterkfontein Dolomite has been divided into different groundwater compartments by the later intrusion of diabase and dolerite dykes (**Figure** 9.5). The Zwartkrans groundwater compartment or aquifer may potentially be impacted upon by the decanting of poor quality mine water. This compartment also contains the Sterkfontein Caves. According to Jamieson *et al.* (2004 not in the reference list), the development of caves is largely controlled by the structural geology. Some of these geological features occur in definitive genetic relationships to existing surface watercourses and to known cave systems. WNW linear fracture zones accompanied by sinistral shear folding correlate with the distribution of bedding-parallel shear hosted gold mineralization as well as of caves and sinkholes in the dolomites. The localities of some of the better-known caves in relation to the major faults are shown on **Figure** 9.6.

The dolomites are partly overlain in the North by the Pretoria Group rocks. The Rooihoogte Formation forms the basal member of the Pretoria Group, consisting predominantly of shale and quartzite. These sediments were deposited at a time when the inland sea started to dry and these rocks represent beach and shallow water deposits. According to Carruthers (2000) the sandy deposits were leached from very pure quartz and the purity of its silica content attracted glass manufacturers to mine these formations

9.4.5 Karoo Supergroup

The Karoo Supergroup was deposited approximately 345 million years ago. It commenced with a glacial period during which most of South Africa was covered by a thick sheet of ice. This ice cap slowly moved towards the south, causing extensive erosion as a result of accumulated debris at the base. This debris was eventually deposited as the Dwyka tillite. The latter is only partially preserved in small pockets in the COH WHS. The subsequent sedimentary deposits of the Karoo Supergroup that consists of mudstone, shale and sandstone are also absent from the COH WHS.

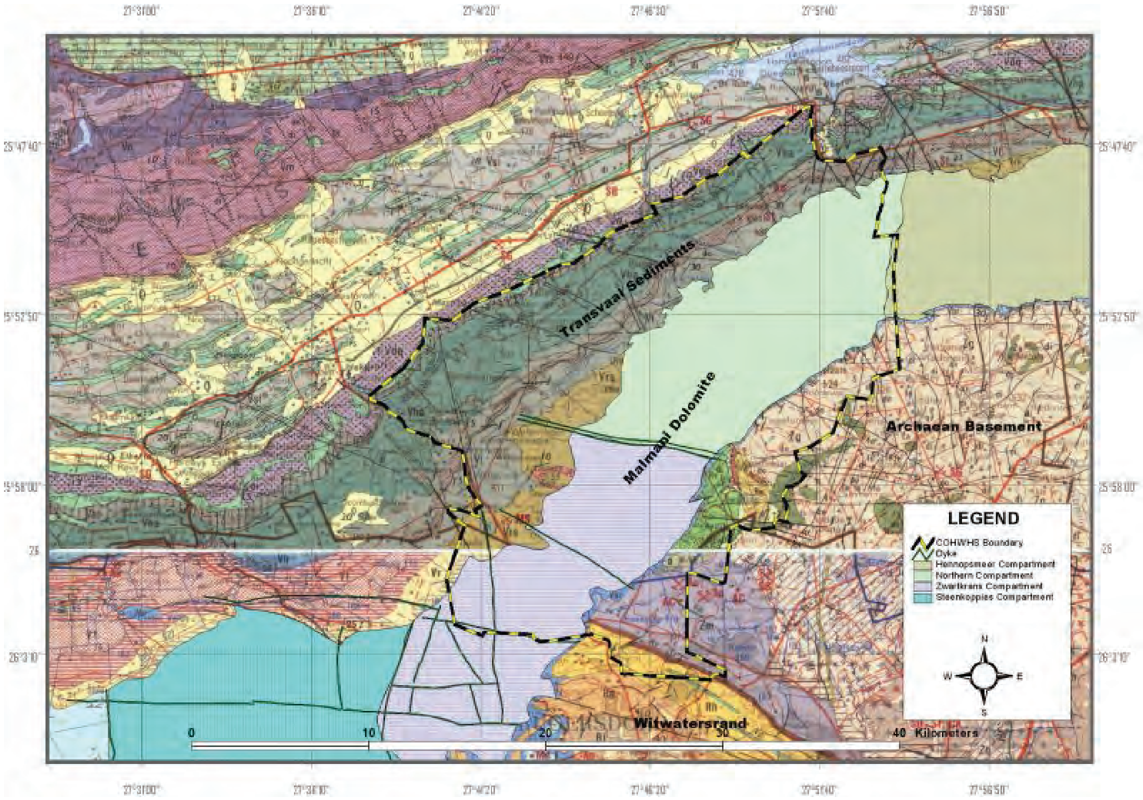


Figure 9.5: Compartmentalisation of the Sterkfontein dolomitic aquifer (map copied from the 1:250 000 SA Geological Series Maps).

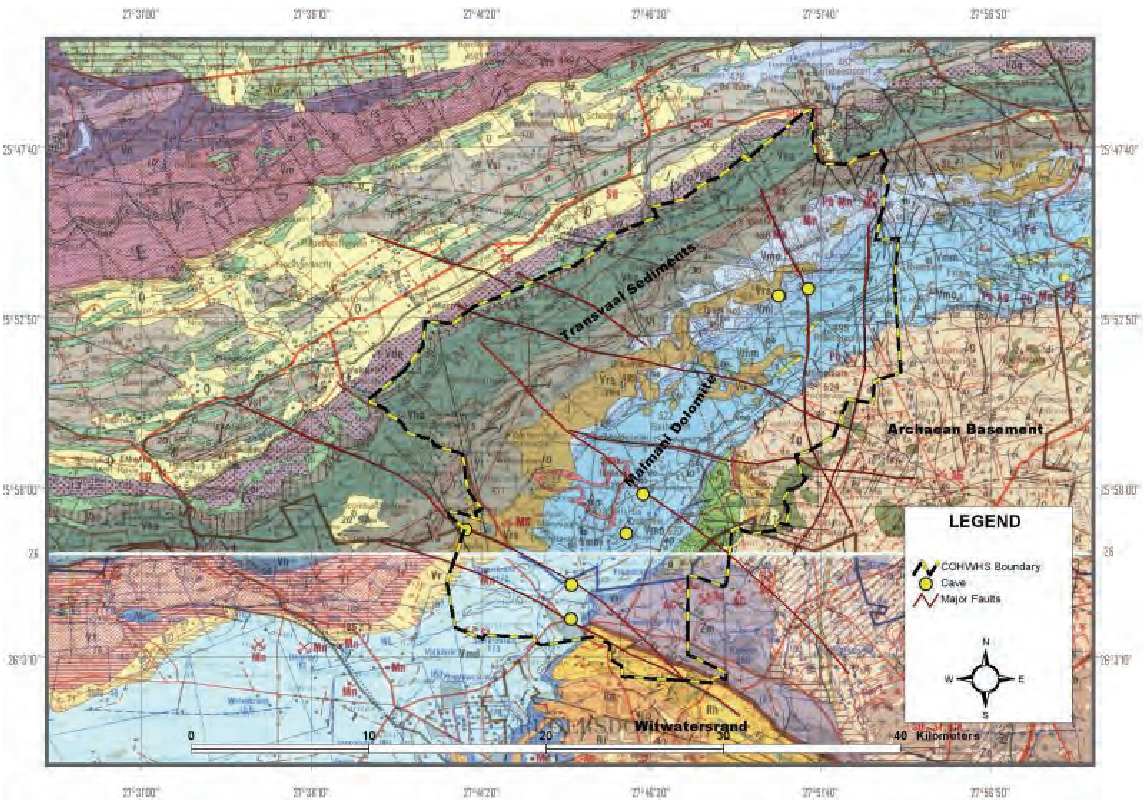


Figure 9.6: Locality of the well-known caves in relation to the regional and structural geology (from the 1:250 000 SA Geological Series Maps).

9.5 Mineral Deposits and Mineral Geology

Mineral occurrences in the Cradle are shown on **Figure** 9.7. Although seldom economically exploitable the following deposits occur:

- Manganese (Mn)
- Lead (Pb)
- Copper (Cu)
- Gold (Au)
- Silver (Ag)
- Shale, slate, banded ironstone
- Stone aggregate
- Chrysotile-Asbestos
- Clay

The minerals listed above occur in the dolomite and underlying Black Reef as well as in the Pretoria Group overlying the dolomite and excludes minerals found in the Witwatersrand strata. The dolomites had early economic and scientific significance, as caves and minerals were discovered and exploited for lead and lime during and after the Anglo-Boer Wars. Fossils began to be discovered, whilst the water resource was exploited for the increasing urban-industrial centres of Johannesburg and Pretoria. The caves within the area became a world-class resource for the study of hominid evolution with the increasing discoveries of fossil material in the cave breccias by Broom, Dart, Brain, Cooke, Tobias and Keyser. Scientific excavations of these cave breccias at Sterkfontein and other sites finally put a stop to lime working, which exploited and destroyed the lime-rich cave deposits. The caves then became available for scientific investigation.

Gold was discovered in the West Rand around 1887. Originally the mining operations were concentrated along the reef outcrop but from 1905 the small companies began to amalgamate until eventually four large mining companies were established: Randfontein Estates Gold Mining (Witwatersrand) Company, West Rand Consolidated Mines, Luipaardsvlei Estate and Gold Mining Company (**Figure** 9.8) (Coetzee, 1976 not in the reference list). Gold production reached its peak during World War II and then started to decline. The demand for Uranium after the war did, however, prolong the life of the mines. Some of the conglomerates in the Bird Reef Group are low in gold content, but contain high concentrations of uraninite. Currently all the mines have closed and only selected reworking of sand and tailings dams is taking place.

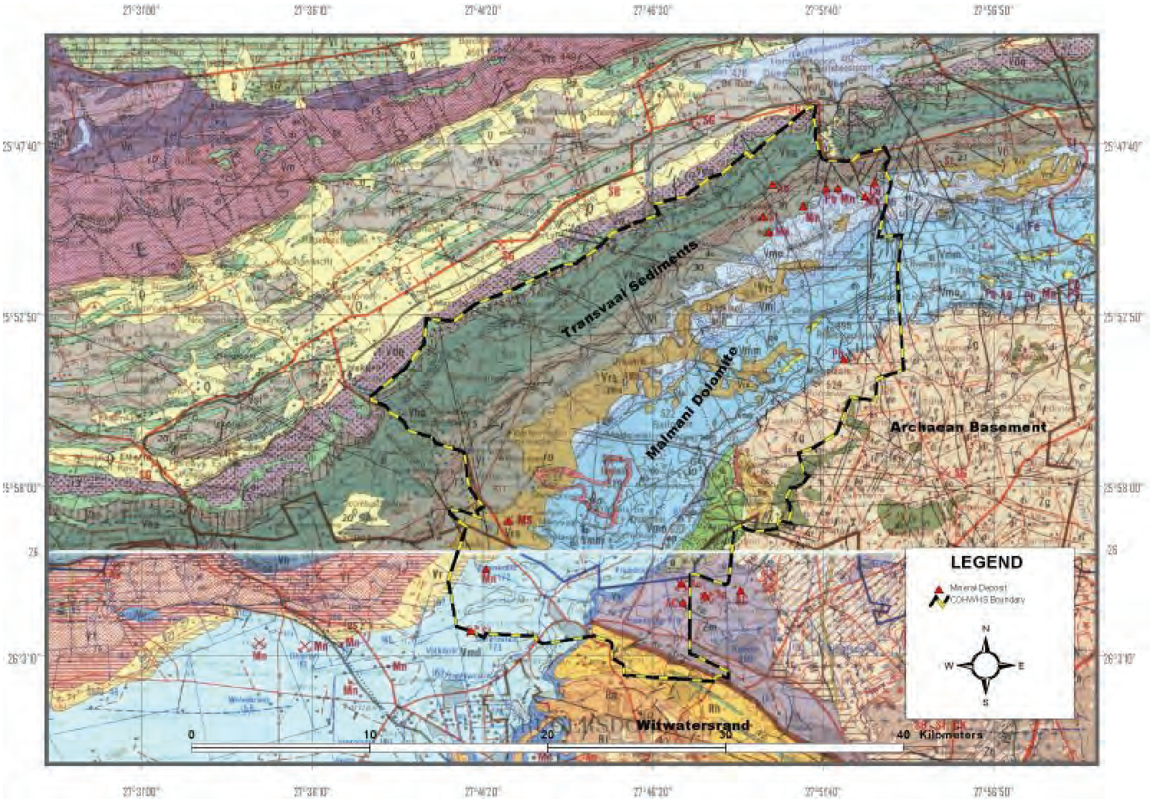


Figure 9.7: Mineral deposits within the Cradle (from the 1:250 000 SA Geological Series Maps).

The West Rand Triangle is remarkable for the number of reefs that were mined. In all, some twenty different horizons were mined for gold and uranium. The debate surrounding the origin of these gold and uranium deposits is briefly discussed in Truswell (1977). The question remains whether the gold and uranium were introduced into the conglomerates in which they occur through the percolating hydrothermal waters of magmatic origin (hydrothermal theory) or whether they were deposited with the sedimentary detritus (placer theory). Currently the most widely accepted theory is that the gold was originally detrital but in their present form it has been metamorphosed. The metamorphoses involved the recrystallisation of the gold and some very localised movement of the reconstituted material.

Although the extensively mined gold deposits of the Witwatersrand do not fall within the Cradle, its close proximity potentially has the largest impacts on the study area. This is predominantly due to the fact that the now defunct mines have been allowed to flood and this contaminated water is currently decanting from the mine. Decant occurred into the Tweelopiespruit, which is a tributary of the Blaauwbank Spruit that flows through the Cradle past the Sterkfontein Caves. The decant water is currently contained and treated by Harmony Gold Mining Ltd, but concern has been raised as to the potential for future spills. Apart from the potential impacts that contaminated water might have on the karst landscape the possible rise in water table could impact on the fossil remains.

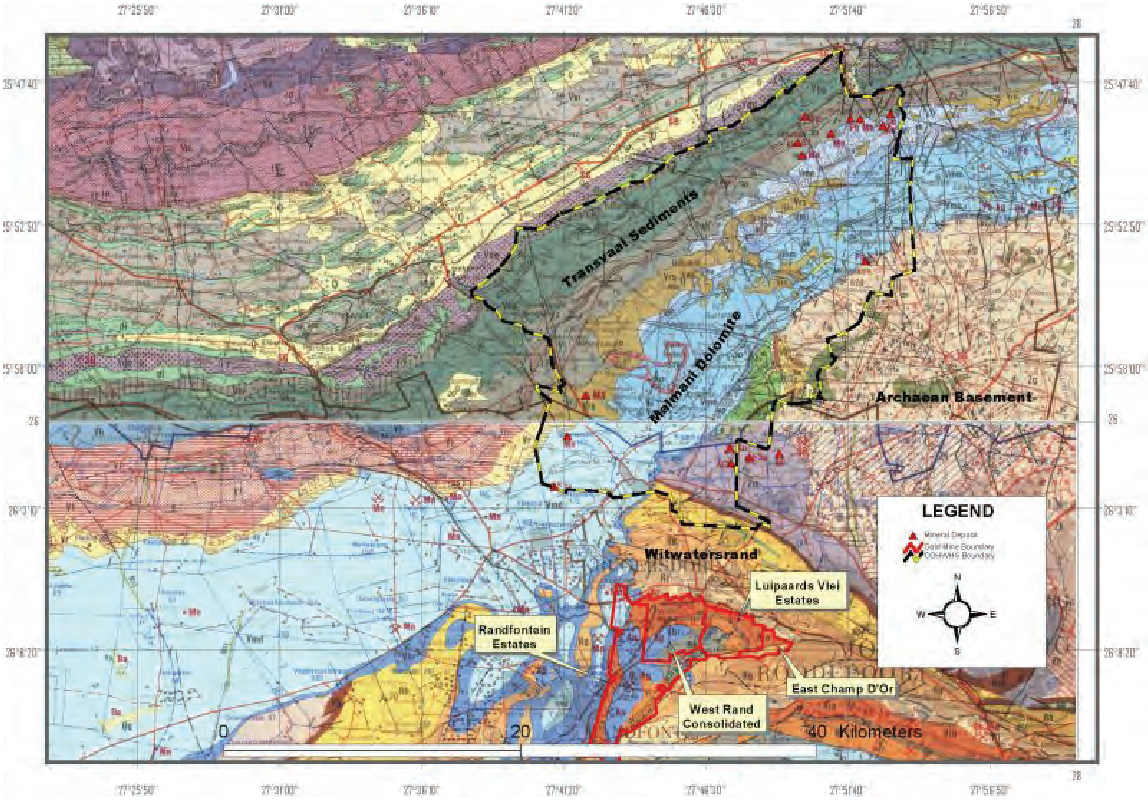


Figure 9.8: Locality of the West Rand gold mines in relation to the Cradle (from the 1:250 000 SA Geological Series Maps).

9.6 Some of the Minerals Mined Within the Cradle of Humankind or its Surface Water Catchment

9.6.1 *Gold mining – Witwatersrand reefs*

9.6.1.1 GOLD MINING HISTORY WITH REFERENCE TO WATER POLLUTION

Since a year after the discovery of gold on the Witwatersrand in 1886, the gold bearing conglomerates of the Witwatersrand Supergroup have been mined on the West Rand in the Krugersdorp, Chamdor, Witpoortjie and Randfontein areas. The gold bearing reefs outcrop along an east-west line following the railway line in the Krugersdorp area and curves progressively southwards around the axis of the West Rand Syncline towards the west until it runs almost entirely in a north-south direction in the Randfontein area. Initially the reef outcrops were mined from the surface using primitive opencast methods, but as mines got progressively deeper, opencast mining methods were replaced with shafts, initially incline shafts, following the dip of the reef (approx. 60°) and later vertical shafts designed to intersect the reefs at pre-determined depths. In addition to the Witwatersrand reefs, the Black Reef of the Transvaal Supergroup, overlying the Witwatersrand reefs and which are particularly deep in this area (deep valleys cut into the Witwatersrand Supergroup by ancient rivers that were subsequently filled in when the Transvaal Supergroup's Black Reef was being formed) in the area between

Randfontein and Krugersdorp, was mined within the catchment of the Cradle, mostly by modern opencast mining methods.

As mines became deeper, increased problems were experienced with water ingress into the underground workings of the mines (Scott 1995). This water was pumped from the mine workings into the Wonderfonteinspruit and Tweelopiespruit. According to official records obtained from the Harmony Gold Mining Co. Ltd Randfontein Operations, an average volume of 32 000 m^3 of water was pumped daily into these streams at the peak of their mining activities.

Most of this water was pumped into the Tweelopiespruit, which currently disappears into the dolomite of the Zwartkrans Compartment shortly after leaving the Krugersdorp Game Reserve. For many years this mine water discharge had been impacting on the COH WHS. This fact became evident from the study by Bredenkamp *et al.* (1986) when it was found that the water in the sub compartment of the Zwartkrans Compartment immediately downstream from the Tweelopiespruit had sulphate concentrations in the region of 150 mg/ℓ and above. High concentrations within this range are not normally expected to occur in dolomite.

More than 100 years of mining created a combined mined out void of 44 926 778 m^3 (Van Biljon and Krige, 2005). This is now referred to as the Western Basin Mine Void and refers to the combined, interlinked mined-out void created by more than 100 years of gold mining in the region by a succession of several mining companies (**Figure** 9.9).

The Western Basin Mine Void initially consisted of four major mines:

- Randfontein Estates Ltd (Now owned by Harmony Gold Mining Ltd).
- West Rand Consolidated Mines Ltd (Now owned by Durban Roodepoort Deep).
- Luipaardsvlei Estates Ltd (Now owned by Mogale Gold).
- East Champ D'Or GM Co. Ltd (now owned by First Westgold).

As the gold reserves gradually became depleted, the underground mines started closing one by one and the focus shifted more to opencast mining. During this period, the West Wits pit was created by West Witwatersrand GM Co. Ltd, owned by Durban Roodepoort Deep. This pit is by far the largest opencast pit in this region and apart from its size, it is of importance for another reason. The pit was initially constructed to mine the Black Reef of the Transvaal Supergroup. However, during the mining of Black Reef, deeper Witwatersrand reefs were also intersected and mining breached the barrier between the two reef types. Any rainwater falling into the West Wits pit or on any of the other Black Reef outcrops or pits would enter the Witwatersrand mine void via this breach.

During this time, pumping only occurred from Randfontein's Central Ventilation Shaft. This mine was now responsible for pumping the entire volume of water entering the underground workings of all its neighbouring mines. During 1998, a decision was made to stop the pumping operations altogether. Since then, the mine void has systematically been flooding and underground operations were restricted to retreat mining. Finally in September 2002 the poor quality water started to decant from a number of boreholes and an old shaft into the headwaters of the Tweelopiespruit East in the Millsite vicinity (see **Figure** 9.9 for locality).

Initially the water decanted from a dolomitic borehole sunk into a dolomitic inlier and was of a relatively good quality. However, some two weeks after the initial decant started from the borehole, the increased water pressure in the flooded mine void opened a previously unknown Black Reef incline shaft and the volume decanting from the mine void increased progressively while the quality of the decanting water decreased, as the relatively good quality dolomitic water in the dolomitic inlier from which the mine water decanted was systematically replaced by mine void water. According to the official laboratory analyses done by DD Science, a SANAS accredited analytical laboratory, on behalf of Harmony GM Co. Ltd, the sulphate concentration in the decanting water increased from around 400 mg/ℓ to well in excess of 4 000 mg/ℓ within a period of 6 months. The water quality has remained within this range (sulphate concentration >4 000 mg/ℓ) ever since.

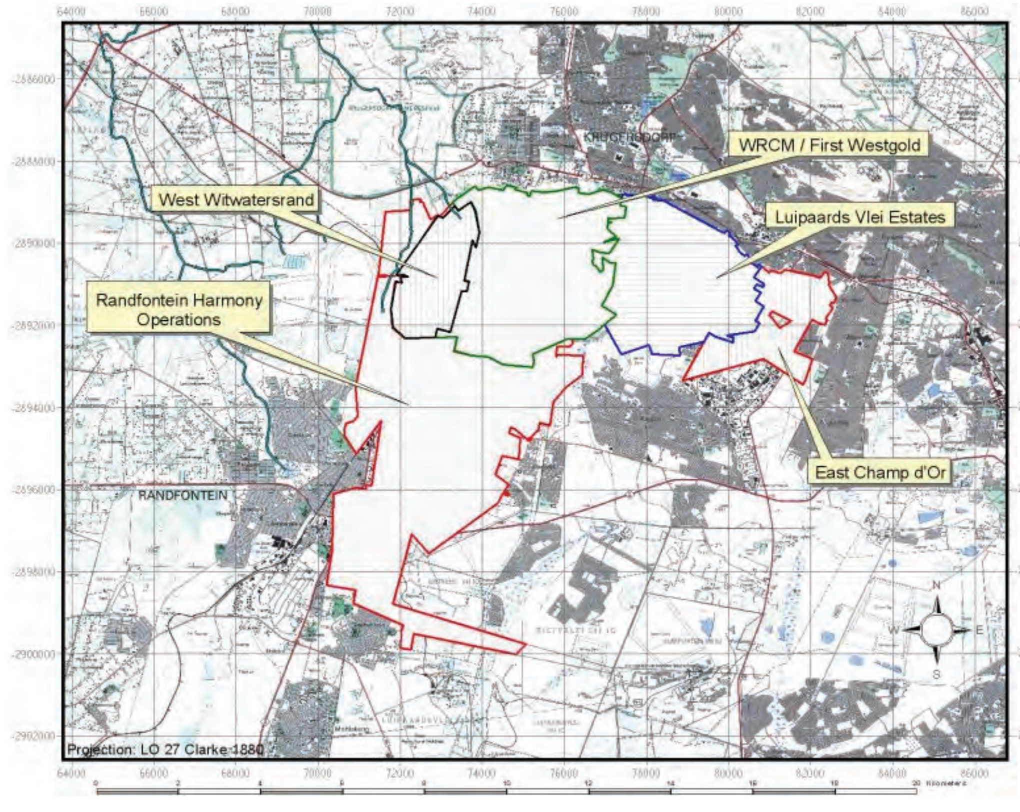


Figure 9.9: The approximate location of the Western Basin Mines in the catchment of the groundwater compartments of the Cradle. The mine boundaries were digitised using shareholders maps and surface right permits obtained from the Department for Minerals and Energy and from Harmony GM Co. Ltd and digitised on the appropriate sections of the topocadastral maps 2627BA and 2627BB.

9.6.1.2 ACID MINE DRAINAGE

A number of other minerals are found along with gold in the gold-bearing Witwatersrand and Black reefs. Of particular importance is the mineral, iron pyrite, more commonly referred to as "pyrite", for its properties to produce acid mine drainage (AMD), also sometimes referred to as "acid rock drainage" (ARD). Pyrite, with a chemical formula of FeS_2 (iron disulphide) is a sulphur-containing mineral, which, in its un-oxidised form, superficially resembles the colour and sheen of gold and for this reason is often also referred to as "fool's gold".

As long as pyrite remains buried deep underground within the rocks of the Witwatersrand and Transvaal Supergroups, it remains in a stable condition. However, when it is exposed to oxygen in the presence of water, a series of chemical reactions occur which ultimately give rise to the production of acidic water. During this process, a particular group of bacteria referred to collectively as the "sulphate oxidising bacteria" (SOB) play a role in increasing the rate at which the chemical reactions take place.

There are four chemical reactions that represent the chemistry of pyrite weathering to form AMD:

Reaction 1: $2\ FeS_2 + 7\ O_2 + 2\ H_2O = 2\ Fe^{2+} + 4\ SO_4^{2-} + 4\ H^+$

Pyrite + Oxygen + Water = Ferrous Iron + Sulphate + Acidity

The first reaction in the weathering of pyrite includes the oxidation of pyrite by oxygen. Sulphur is oxidised to sulphate and ferrous iron is released. This reaction generates two moles of acidity for each mole of pyrite oxidised.

Reaction 2: $4\ Fe^{2+} + O_2 + 4\ H^+ = 4\ Fe^{3+} + 2\ H_2O$

Ferrous Iron + Oxygen + Acidity = Ferric Iron + Water

The second reaction involves the conversion of ferrous iron to ferric iron. The conversion of ferrous iron to ferric iron consumes one mole of acidity. Certain aerobic bacteria (the SOB) increase the rate of oxidation from ferrous to ferric iron. This reaction rate is pH dependent with the reaction proceeding slowly under acidic conditions (pH 2-3) with no bacteria present and several orders of magnitude faster at pH values near 5 and in the presence of bacteria. This reaction is referred to as the "rate determining step" in the overall acid-generating sequence.

Reaction 3: $4\ Fe^{3+} + 12\ H_2O = 4\ Fe(OH)_3 + 12\ H^+$

Ferric Iron + Water = Ferric Hydroxide + Acidity

The third reaction, which may occur, is the hydrolysis of iron. Hydrolysis is a reaction which splits the water molecule. Three moles of acidity are generated as a by-product for every mole of ferric iron. Many metals are capable of undergoing hydrolysis, not just iron. The formation of ferric hydroxide precipitate (solid) is pH dependent. Solids form if the pH is above about 3.5 but below pH 3.5 little or no solids will precipitate.

Reaction 4: $FeS_2 + 14\ Fe^{3+} + 8\ H_2O = 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$

Pyrite + Ferric Iron + Water = Ferrous Iron + Sulphate + Acidity

The fourth reaction is the oxidation of additional pyrite by ferric iron. The ferric iron is generated by reactions 1 and 2. This is the cyclic and self-propagating part of the overall reaction and takes place very rapidly and continues until either ferric iron or pyrite is depleted. Note that in this reaction, iron is the oxidising agent, not oxygen. The reaction is therefore not reliant on the availability of oxygen.

All four of the above reactions can be summarised as follows:

Overall Reaction: $4\ FeS_2 + 15\ O_2 + 14\ H_2O = 4\ Fe(OH)_3 + 8\ H_2SO_4$

Pyrite + Oxygen + Water = Ferric Hydroxide + Sulphuric Acid

Overall, one mole of pyrite creates two moles of sulphuric acid. Note that only reactions 1 and 2 require the presence of oxygen. The only factor governing the rate at which reactions 3 and 4 will occur is the pH; a low pH slows the reactions down or brings it to a halt, while a higher pH increases the reaction rate.

Mining operations exposed ever-increasing underground rock surfaces containing pyrite to the effects of oxygen and water, setting the chemical reactions shown above in motion. Mining also introduced the SOB to speed up the process. Lastly, in order to protect their pumps against the corrosive properties of the acidic mine water, mining engineers increase the pH of the mine water in the mine by adding lime to the water and in so doing play directly into the hands of the SOB (refer Reactions 2 and 3). Researchers over many years and across almost all the continents have attempted to find a method of controlling the SOB in mines, to no avail. Apart from the cost, the problem is that during the mining process rock is fractured to several meters deep into the rock faces. There is no known disinfectant that can penetrate that deep into a fractured surface and the SOB continued unhindered to produce sulphuric acid.

Once water becomes acidic, it will dissolve any other metal that may be present in its environment. AMD water therefore contains high concentrations of dissolved metals in addition to its acidic properties.

During the mining era, the water pumped from the underground workings was not of such a poor quality as the current decanting water. As water was pumped immediately after it entered the mine, there was often not sufficient contact time for it to acquire excessive amounts of contaminants. The water nevertheless, had elevated sulphate concentrations, but not nearly the concentrations that are found at present in the decanting water. From personal experience gained over many years by the author's involvement with the mining industry, water pumped from the mine workings of operating mines would, on average, have sulphate concentrations ranging from 200-1200 mg/ℓ, depending on the distance it traveled through the mine workings and the time it remained in contact with the pyrite oxidation products in the mine. In contrast to this, the water decanting from the mine void since pumping operations ceased have sulphate concentrations in excess of 4 000 mg/ℓ. This occurs as a result of the rising water in the old mining tunnels mobilising contaminants, mostly sulphates, which have been produced over long periods and which have been sitting there, in some areas for over 100 years, just waiting to be mobilised again. The 15.5 Mℓ/day of water currently decanting from the decant point is of an extremely poor quality with sulphate concentrations in the thousands.

9.6.1.3 THE HISTORY OF THE DECANTING MINE WATER

During 1996, it became clear that pumping operations would cease within the foreseeable future and that a model would be required to predict whether the water would reach surface and, if it did, what its quantity and quality would be.

The mining house, JCI, undertook these predictions and, under the leadership of one of the authors of this paper (M van Biljon), a model was created which predicted that the water would, in fact, reach the surface and that this would occur in September 2002. It was anticipated that the water would be of a poor quality based on the quality the mines were pumping at the time, but the predicted quality was still significantly underestimated. It should be borne in mind that, at that time, an incident of such a magnitude had never occurred anywhere in the world and that the environmental engineering team of JCI was working in completely uncharted territory.

These predictions sparked a series of events, which culminated in the publication of two documents. The first document was called "SWaMP" (Strategic Water Management Plan for the West Rand) and put forward the predictions, the criteria on which these predictions were based and suggested a number of potential processes with which to treat the decanting water. At that stage, however, other operating mines in the Central and East Rand Basins, who were facing similar water problems, were also included in the research and a second, more thorough, study was undertaken, named "Amanzi". However, the project never came to fruition, mainly due to companies changing ownership or closing down. As a result of this, the Amanzi Project was never finalised and apparently forgotten.

The mining houses as well as the Department of Water Affairs and Forestry were caught somewhat unprepared when the water, true to the predictions of 1996, reached the surface in 2002, less than a month sooner that what was predicted six years earlier. The decant, however, occurred from a borehole and at an unknown Black Reef shaft some 400m from the predicted decant position and a few meters below the collar elevation of the shaft where the JCI team thought the water would decant from.

Initially, the water started to decant from a borehole sunk into a dolomitic inlier on the property of Harmony. This dolomite was, however, in direct hydraulic continuity with the flooded mine workings and within a few weeks the borehole could not pass the volume of water and the rising water pushed open an old incline shaft nearby. This shaft was sunk into the Black Reef and was not indicated on any of the mining plans. The water that decanted initially was effectively dolomitic water from the perched water table in the dolomitic inlier and was of a relatively good quality, compared to the quality of the water that was to come. However, as the acidic mine water slowly replaced the dolomitic water over the following months, the quality deteriorated until there was no difference between the quality of the mine water and the water decanting from the borehole. The water quality stabilised with sulphate concentrations in the region of 4 500 mg/ℓ (Ferdi Dippenaar, 2004, pers. com.).

Harmony Gold Mining Ltd took quick action shortly after the water started to decant and constructed an HDPE-lined dam and a pumping station to contain the mine water and to pump it to the Robinson Lake at the origin of the Tweelopiespruit. It soon, however, became apparent that there was too much water to contain in the Robinson Lake and that a treatment plant would have to be built to treat the water to such a quality that it could be disposed of into a public stream. Over the next two years Harmony modified an old uranium settling plant to treat the mine water. At the same time, DWAF served a Directive to all the mines responsible for creating the Western Basin Mine Void originally. Briefly, the Directive stated that the mines should come to some agreement as to a cost apportionment for the water treatment, treat the mine water to an acceptable quality and discharge it across the watershed into the upper Wonderfonteinspruit and that they should do an impact assessment on both the Tweelopiespruit and the Wonderfonteinspruit. To date, only Harmony Gold Mining Ltd has complied with the DWAF Directive.

For a period of about two and a half years untreated and partially treated water flowed through the Krugersdorp Game Reserve into the Zwartkrans dolomitic compartment. The low pH of the water (the pH of the water leaving the Hippo Pool had a range of between 2.5 to 3.5 according to weekly samples collected by the Mogale City Local Municipality), the high dissolved salt load as shown in **Figure** 9.3 and the oxygen-consuming chemical reactions taking place in the water, resulted in the destruction of the entire faunal population of the Tweelopiespruit and also caused an unconfirmed number of deaths among the animals in the game reserve. Since the beginning of 2005 Harmony has been pumping most of the water via their treatment plant to the Wonderfonteinspruit. Their facilities can, however, not contain the flow from the mine void during heavy rainstorms and significant volumes of mine water still flows down the Tweelopiespruit during such times. It is, furthermore, suspected that a significant volume of water still flows down the Tweelopiespruit through the fractured aquifer underlying this stream.

9.6.1.4 THE EFFECT OF THE MINE WATER ON THE CRADLE OF HUMANKIND

The most important effect that the mine water could have on the dolomitic aquifers of the COH WHS, is to contaminate the groundwater with the substances dissolved in the mine water. The discharge of mine water over many decades of pumping have increased the concentrations of sulphate (an indicator for gold mining-related pollution) from the expected single figures to around 150 mg/ℓ in the section of the Zwartkrans Compartment downstream from the Tweelopiespruit. There are many people living within the COH WHS that are totally reliant on this groundwater for drinking purposes, for watering of their livestock, for irrigational purposes and, as the COH WHS turns into a tourist destination, for the hospitality industry. The COH WHS was declared a World Heritage Site on the grounds that its caves (where the area's human ancestors developed), were created through the groundwater action with the dolomite. It would be somewhat ironic if this same groundwater was now not safe for people to drink due to human negligence. As part of the EIA study for the gold mines responsible for the decanting of mine water into the Zwartkrans Compartment, a number of DWAF and private boreholes were sampled in the area immediately downstream from the mine water decant point. The results of this study are presented in **Figure** 9.10.

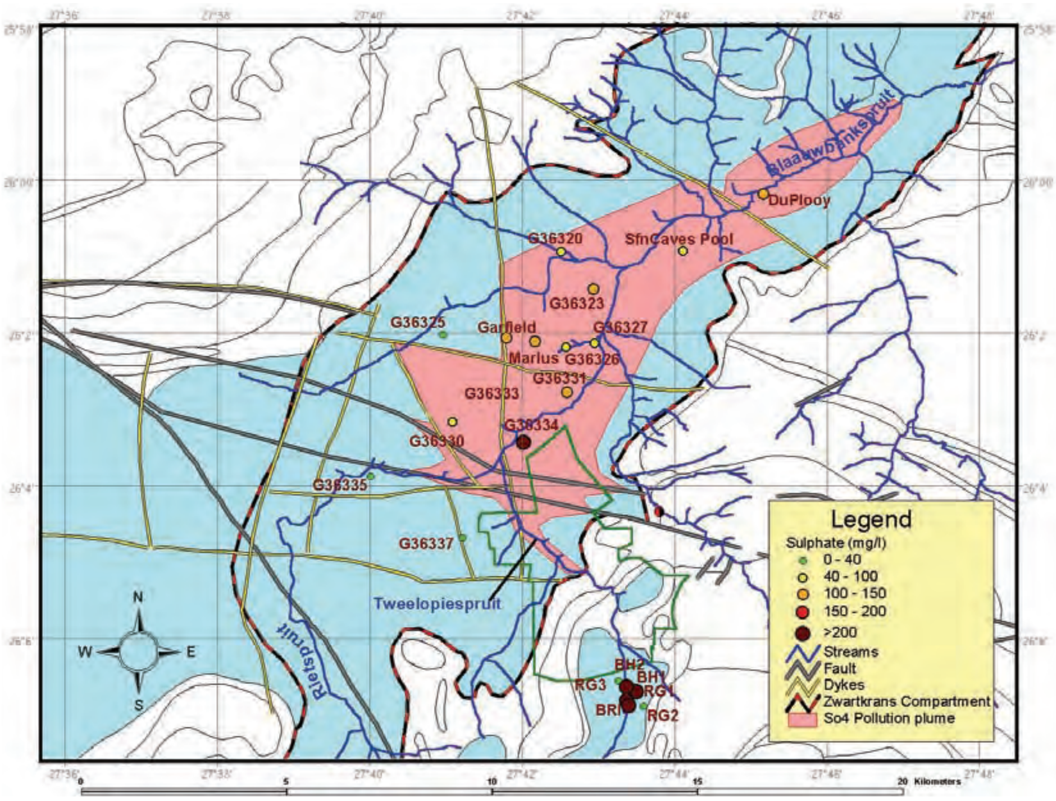


Figure 9.10: According to a study done by Krige (2006) a pollution plume of excessive concentrations of Sulphate is spreading through the Zwartkrans aquifer immediately downstream from the mine water decant point represented by the point "BRI" at the bottom of the map.

It is a well-known fact that acid will dissolve dolomite. This phenomenon is one of the processes, which created the caves in the dolomite when slightly acidic rainwater dissolved the dolomite. It is therefore not surprising that the primary impact that the mine water could have on the COH WHS is the deterioration of the water quality that may result in the chemical dissolution of the dolomite. In a worst-case scenario the acidic water (untreated mine water) can lead to ground stability problems such as sinkholes and can potentially damage the Sterkfontein Caves and all other caves at or near the water table. This dissolution process is, however, a slow process and will take many years before it may even be noticed. Another potential impact of the decanting mine water is that it can increase the groundwater levels in the aquifer. It should, however, be noted that the groundwater levels in the dolomite aquifers are controlled by the elevations of the various eyes and introducing more water into the system will therefore only lead to increased stream flow at the eyes. Preliminary findings to date indicate that the groundwater levels in the aquifers have dropped in recent years due to over-abstraction for agricultural purposes. If over-abstraction is allowed to continue unchecked, it will eventually lead to ground instability and sinkhole formation. Furthermore, the continued over-pumping of a groundwater resource could also lead to the compaction of an aquifer causing it to hold less water. The release of treated mine water is likely to be a benefit to the region rather than a negative impact provided that the water is treated to an acceptable standard which is compatible with the water in the dolomitic aquifer and provided that the volume is sufficient to replace the water abstracted by the farming industry.

A proper monitoring system is recommended to detect changes in groundwater chemistry before any major damage can be caused. Studies are currently underway to better understand the flow patterns within the dolomitic aquifers and these are necessary before qualitative statements can be made regarding the impact of the decant water (treated or untreated) on the Cradle.

To answer the most asked question relating to the decanting acid mine water, i.e. "W*hat impact will the mine water have on the structural integrity of the Sterkfontein Caves and will the caves be flooded should the water table rise?*" the following findings are relevant to the water levels in and around the Sterkfontein Caves. These findings form part of a much larger groundwater census currently being undertaken by the authors of this paper. The results are as follows:

- Regional groundwater level at the Sterkfontein Caves Borehole:

  1 436.15 mamsl

- Water level in the Bloubankspruit adjacent to the Sterkfontein Caves:

  1 445.00 mamsl

- Water level in the pool of the Sterkfontein Caves:

  1 436.114 mamsl

The water levels in the Sterkfontein Caves' pool and the nearby borehole are therefore for all intents and purposes the same. The water in the Sterkfontein Caves pool therefore forms part of the regional groundwater. At the same time, the water level in the Bloubankspruit at its nearest point to the caves was approximately 1 445 mamsl (± 1 m), i.e. some 8.9 m higher than the water level in the caves' pool.

The portion of the Bloubankspruit adjacent to the Sterkfontein Caves is a losing stream, i.e. it loses water to the groundwater environment. It can therefore be assumed that water (and whatever is dissolved in it) leaking from the streambed would enter the groundwater environment and that it could potentially have an impact on the water in the Sterkfontein Caves pool. It should, however, not be forgotten that all water decanting from the mine void enters the Zwartkrans Compartment shortly after the stream leaves the Krugersdorp Game Reserve.

There would, under normal circumstances, not be any mine void water in the Bloubankspruit in the vicinity of the Sterkfontein Caves. All the mine void water would rather be in the groundwater environment. The water in the Bloubankspruit near the Sterkfontein Caves would be made up entirely from Percy Stewart Sewage Plant effluent, some water from the town of Krugersdorp flowing down the stream and some rainwater during the rainy season.

Acidic water decanting from the mine void reacts relatively rapidly with the water in the dolomitic aquifer at the point where this water enters the Zwartkrans aquifer. This area of reaction would be in the general vicinity immediately downstream from the Krugersdorp Game Reserve. By the time the sulphate in the mine water reaches the Sterkfontein Caves, the acid-base chemical reactions would have completed and the sulphates would no longer be in the sulphuric acid form.

The Daniëlsrust Eye located on the Daniëlsrust dyke in the Bloubankspruit a relatively short distance downstream from the Sterkfontein Caves is the controlling structure that controls the elevation of the water in the Zwartkrans aquifer upstream from this dyke. Given the high transmissivity of the Zwartkrans aquifer, an increase in infiltration rate into the aquifer will result in an increase in the water flowing from this eye and will therefore have a negligible effect on the water level in the aquifer. It is unlikely that the water level in the Sterkfontein Caves' pool would show any significant increase, let alone flood the caves.

Although we cannot state it with 100 % certainty, we believed that the mine water would not have any significant detrimental effect on the structural integrity of the caves, i.e. it would not cause accelerated dissolution of the dolomitic structure. The natural process of dissolving of dolomite as a result of slightly acidic rainwater infiltrating the karst environment would, however, still continue. Theoretically, the large man-made archaeological excavation in the rocks immediately above the Sterkfontein caves could potentially pose a much greater threat to the structural integrity of the cave and should the roof of the cave eventually collapse, this excavation as well as the damage done by calcite miners coupled to natural dissolving of the dolomite would probably be the cause rather than accelerated dissolution of the dolomitic rock due to the decanting mine water.

The chemical character of the water in the caves pool does show contamination from mining origins. Surplus underground mine water has, after all, been discharged into this stream for many decades. As shown in **Figure** 9.10, the sulphate in the water samples collected from the Sterkfontein Caves pool is higher than what would normally be associated with natural dolomitic water. By the time the sulphate reaches the Sterkfontein Caves pool, however, the sulphate would already be in the calcium or magnesium sulphate form and not in a sulphuric acid form.

9.6.1.5 THE FUTURE OF THE MINE WATER

It is clear that the problem of mine water will continue to be experienced and although at the time of the writing of this paper, short-term solutions were being put into place, the medium- and long-term solutions are still under investigation. At present, Harmony has been paying the costs for all the infrastructure and treatment facilities constructed so far though it seems as if they are only responsible for approximately half of the problem (Van Biljon and Krige, 2005). The question furthermore arises as to what is going to happen with the water once Harmony closes their Randfontein Operations.

Historically, before mining commenced in the West Rand, water would decant from the same dolomitic inlier from where the mine water is now presently decanting. Historically, though, this was uncontaminated dolomitic water. Evidence of these fountains and a canal constructed from the fountains to convey water to the farmland further downstream is still visible today. Furthermore, the title deeds pertaining to portions of the farm, Sterkfontein 173 IQ, that are located in close proximity of the canal, still refer to the canal, the maintenance thereof and the water usage from the canal. However, due to the artificial lowering of the water table in the mine void, these fountains had not been flowing for a century - until 2002. The canal is now all but forgotten. The water now flowing from these fountains has however a totally different character to the pristine water that probably used to flow from them a century ago.

With regards to how long it will be before the decanting water will start to show an improvement; the following points are noted:

- The mine void has a volume of 44 926 778m^3 (Van Biljon and Krige, 2005). On average, a volume of 15.5 Mℓ/day, i.e. 15 500m^3/day, decants from the mine void. It will take 2 989.5 days, i.e. 7.9 years before this volume is replaced even once. It can safely be assumed that the basin will have to be flushed several times before any significant improvement will be noticed.
- A second question that arises is whether there will be any stratification occurring in the basin. There are two conflicting theories. Firstly, there are large ingress points such as the West Wits pit where rainwater finds direct access routes that convey it directly into the deep part of the mine void. This will continually introduce fresh water into the deep part of the mine void, creating a mixing effect and effectively preventing stratification from occurring. Secondly, stratification may actually occur. Colder, saltier water is heavier than fresh and warmer water (originating from rainwater) and may form a thermocline or halocline in some parts of the mine. This will effectively sequester a large part of the water in the mine void allowing new rainwater to move above this thermo/halocline to the decant point. This will effectively reduce the amount of water to be replaced considerably and better quality (slightly less contaminated) water could be expected within 10 to 20 years as opposed to the expected 100 or more years if stratification does not occur. Although some areas exist where stratification may not occur due to the mixing effect of "new" water entering the deeper parts of the mine void, there are areas, especially in the eastern section of the mine void in the vicinity of the East Champ d'Or Mine where there will be little or no mixing or water movement taking place. It is very likely that stratification will occur there. In the end, a combination of the two processes will occur. In the light of this, it is also

imperative to seal water ingress points such as open pits and other access points where rainwater can find direct access to deeper mine workings.

The most plausible long-term solution currently under review by the relevant role players and the authorities is to establish a water utility company that can treat and sell the water. This option will turn the current liability into an asset. The mine water can be treated to different levels of quality, which can be suitable for agricultural use, industrial use, and even drinking water quality. Agriculture is abstracting large quantities of groundwater from the dolomite aquifers and although it may be a somewhat controversial subject, it is felt that at least a portion of the water currently decanting from the Western Basin should be allowed to flow into the Zwartkrans Compartment to bring the groundwater levels back to how they were some 100 years ago. Of course, this water will have to be treated to acceptable water standards before this can occur. Historically, fountains fed both the Tweelopie- and Wonderfonteinspruit. On the other hand, the volume of the water received from the Percy Stewart sewage plant and which ingresses into the dolomite through streambed loss will probably offset the volume that is now lost to the Wonderfontein catchment from the game reserve fountains.

9.6.1.6 OTHER IMPACTS ASSOCIATED WITH THE GOLD MINING INDUSTRY

In addition to the water pollution, which has had a direct bearing on the COH WHS, there are a number of additional impacts from this industry. It has already been shown that the metropolitan area of the Witwatersrand would never have been built had it not been for the gold mining industry. The impact on the Cradle due to its close proximity to this metropolitan area is explained in detail in the Issue Paper 10 (Krige, 2007).

In mining the reefs, a mine void of 44 926 778m^3 of material was removed from the ground of the West Rand. This material was placed on the surface in the form of waste-rock dumps, sand dumps and tailings dams. Waste-rock dumps have a tendency to disappear from the environment after a while as they are crushed to produce aggregate used in the building industry. Older sand dumps often contain sufficient residual gold to make it profitable to rework them using modern technology, but they do not disappear, but are merely milled to a finer grade, processed and placed back on surface in the form of tailings dams. In modern operational mines, tailings is mixed with cement and pumped back into mined-out underground workings in an attempt to stabilise the underground environment and to reduce the volume of material that has to be stored on surface. Due to the age of the mines on the West Rand, this was never done. After all the mining and reworking operations finally come to an end on the West Rand, the only remains of the mining legacy will be the tailings dams (and of course, the decanting water). Apart from being unsightly, tailings dams have a few impacts directly related to the COH WHS.

Firstly, unprotected tailings material in the catchment of the COH WHS erodes rapidly and is transported via the streams draining into the Cradle directly into the groundwater environment of the COH WHS. The same pyrite oxidation previously described causes AMD from this source. Due to the fineness of the tailings material presenting a much-enlarged surface area from which AMD can occur, the acidification process of water percolating through a tailings dam occurs extremely rapidly. Contaminated water ends in both surface streams and groundwater.

Secondly, unprotected tailings dams can cause severe dust problems in the COH WHS. Fortunately, the wind direction is mostly from the Cradle to the mining areas and not *vice versa*. On some days, however, the wind does blow from the other direction and causes the COH WHS to become blanketed by the fine dust of the tailings dams. Apart from the nuisance factor, the dust contains many contaminants which eventually fall to the ground and which in turn become part of the surface and groundwater environments in the COH WHS.

Thirdly, tailings material contains all the contaminants associated with the gold ore. These contaminants are directly related to the AMD process and all the metals found in the rock will also be found in the water draining from a tailings dam, or in the water into which the tailings material is blown or washed. In addition to the metal contaminants (chemical), tailings material also contains radioactive metals such as uranium and radium and the radioactive radon gas, which is emitted from tailings dams on a continuous basis.

It has been shown through many failures throughout the gold fields of South Africa and at great expense that the vegetation growing on a tailings dam only grows successfully while the vegetation is kept wet through continuous irrigation. During the irrigation period, the salty phreatic water within the tailings dam is driven into the dam by the continuous application of fresh water on the outside of the dam. However, once irrigation operations cease, this contaminated water together with its salt load migrates to the outside of the dam as this outside becomes desiccated. This movement is partly due to capillary action in the interstitial voids between the grains of slimes material, but also occurs when rainwater, entering the upper surface of a tailings dam, reaches the less permeable original soil level on which the tailings dam was built. This water then moves laterally across the original ground surface towards the sides of the dam. The effect of this is that the lower 10 to 20 m of vegetation on the sided of a tailings dam dies off and is eroded away. With a gap around the base of a tailings dam, erosion from rainwater causes the higher thin layer of vegetated surface to erode downwards until soon there is no evidence that the tailings dam was ever vegetated.

A better way of containing a tailings dam is to place a layer of waste rock on the upper surface and sides of the dam. Provided the waste rock is of the correct grade and thickness, it forms a much better barrier against the effects of water and wind erosion than a layer of vegetation. This has been proven at a number of tailings dams where this method has been applied. There is only one major problem with this type of rehabilitation. Most of the waste rock was sold to crushing operations in the heydays of mining operations and has subsequently been removed in the form of aggregate used in the building industry.

As it stands, there is still no long-term solution relating to tailings dams, other than to mix it with cement and to pump it back into the mine void from which it was mined originally. All other methods, such as storage thereof in the form of tailings dams, are considered to be temporary solutions.

While on the subject of tailings dams, the high-density sludge plant which treats the decant water at Harmony produces large volumes of sludge. This sludge contains all the products originally dissolved in the water. At present it is disposed of on top of one of their tailings dams, but this facility is limited and a much larger tailings dam will have to be constructed to accommodate the solids removed from the water over the centuries to come. At present, some of the water and solids mix is irrigated onto nearby land. Although the sulphate is more-or-less sequestered in the form of gypsum in this mixture, the other contaminants are not and the build-up of these products in the soil will ultimately find their way back into the Tweelopiespruit and into the groundwater of the COH WHS, as this is the only direction in which both surface and groundwater can flow.

9.6.1.7 THE BENEFITS OF GOLD MINING TO THE CRADLE OF HUMANKIND

Probably, the most obvious benefit would be the replenishment of the groundwater. Although many see dolomitic water as an infinite source, it is, in fact, just as limited as any other inland water source. Over the last number of years, over-abstraction of groundwater in the Tarlton region has caused the groundwater table to drop. This is the most probable cause for the Maloney's Eye in the Steenkoppie Compartment, to dry up for the first time in recorded history in 2005. It has been speculated that the continued uncontrolled abstraction of groundwater in the Tarlton area could lower the water table in the Steenkoppie dolomitic compartment to such an extent that the flow direction would reverse and that water would drain from the Zwartkrans Compartment to the Steenkoppie Compartment.

It has been recorded in the Sterkfontein Caves that the water table has dropped by around 3 m over the past 20 years in spite of good rainy seasons. Adding water to a groundwater aquifer, which is being overexploited, can only be beneficial, provided that the water is of an acceptable quality.

The proximity of the gold-bearing reefs to the north of the COH WHS has seen that the geology of the area now covered by the COH WHS was surveyed better than would have been the case had there not been gold in the area. In addition, faults, dykes and other geological phenomena found underground in the mines could be traced into and across the Cradle. This knowledge can be used to the advantage of the COWHS. The lime mining industry, a direct spin-off of the gold mining industry, was responsible for the discovery of the first hominid fossils. It could, however, also be debated that this industry was also responsible for the destruction of many fossil sites.

Finally, over many decades, the gold mining industry has created wealth in an area, which would otherwise have been pretty standard. Gauteng is the wealthiest province in South Africa because of the gold mines.

9.6.1.8 GOLD MINING – BLACK REEF

Although the mining of gold from the Black Reef did not have an impact on the COH WHS such as the mining of gold in the Witwatersrand reefs, it is nevertheless worth a brief discussion.

Gold deposits are found in limited quantities and in limited areas in the Black Reef, the lowest layer of the Transvaal Supergroup. Before the Transvaal Supergroup was formed, the quartzites and conglomerates of the Witwatersrand Supergroup covering the area now occupied by the Tweelopiespruit and all the way south into the town of Randfontein, was scoured by an ancient river system also flowing northwards as the Tweelopiespruit does today. This ancient river created deep channels, which were subsequently in-filled with the Black Reef, an erosion product of the Witwatersrand Supergroup. Normally, the Black Reef is a thin layer 1-10m thick. In this particular area, however, the Black Reef, which was formed in the channels, was several tens of metres thick and due to the proximity of the Witwatersrand reefs, contained exploitable quantities of gold.

These reefs were mined using modern opencast methods as described in the preceding sections, but was also mined through small shafts and adits. Many of these mines are still visible along the eastern side of the Krugersdorp Game Reserve. More recent mining took place in the Honingklip area while a prominent tourism feature in the COH WHS is a historic Black Reef mine, the Kromdraai Mine.

Most of these mines, including the Kromdraai Mine, are now roosts for a variety of bat species. The Black Reef also contains pyrite, but as the Black Reef is below the dolomite and due to the impermeable nature of the quartzite and shale surrounding the mines, water contamination from these sources is not in the same order of magnitude as contamination from the Witwatersrand reefs.

9.5.2 Lime and other metal mining operations

Although overshadowed by the impacts of gold mining, lime mining has probably had the second greatest impact on the COH WHS. As a matter of fact, lime mining can be related directly to the gold mining industry, as the latter industry created a demand for cement used underground, for unslaked lime used in the metallurgical plants and as building material for the ever-increasing populations and industries living and operating in the Witwatersrand.

When lime is subjected to heat, the calcium carbonate [$CaCO_3$] is converted to unslaked lime [calcium oxide or CaO] and carbon dioxide [CO_2]. The unslaked lime is used in the manufacturing of cement. When unslaked lime is mixed with water, it combines with the water to form slaked lime [calcium hydroxide or [$Ca(OH)_2$]. This slaked lime is used in the metallurgical process to control the pH of the solution in which gold is dissolved and extracted.

It was found that cave speleothems were a good and very pure source of lime and extensive mining of these cave formations took place throughout the COH WHS. Many caves were completely or partially destroyed in this process and many fossil sites were also destroyed. The lime miners would break or blast out the speleothems, break them into smaller chips and burn them in lime kilns, usually in close proximity to the mining sites. The resultant unslaked lime powder produced in this process would then be sold. Remnants of the lime kilns are scattered throughout the COH WHS.

Often other metals such as lead, manganese, copper and silver were also associated with some caves and sinkholes and limited amounts of these metals were mined together with lime. Of particular interest is the fact that lead was mined during the Anglo-Boer Wars for the manufacture of ammunition. Very little of these mines are still to be seen and the residual impact would be purely of visual nature.

It is known that humans from the two Iron Ages mined the banded ironstone found immediately above the dolomite within the Pretoria Group. This ore was then processed into weapons and tools in furnaces by burning large quantities of trees. This denuded the landscape to a great extent of its trees. Hilton-Barber and Berger (2002) state that some historians speculate that the Kalahari desert, which lies several hundred kilometres to the southwest of the COH WHS was, at the time of the Iron Age, a more wooded environment than it is today, and that it was denuded by the early metalworkers, who required copious quantities of wood and charcoal to support their industry. Archaeologists assume that the heat needed to forge a single spearhead would have required the wood from two large trees and a smelting period of two weeks.

To gain access to the speleothems that were mined for the production of cement, lime miners had to enlarge the entrances to many of the caves they were mining. Apart from the visual impact created by the larger entrances and their discard dumps, the opening of cave entrances had additional negative impacts. When a cave opening is enlarged or when a closed cave is opened, oxygen is introduced into an environment previously devoid of oxygen. The effect of this is that iron and manganese in the soluble form is oxidised to the insoluble form. This, in turn has an effect on the speleothems, which are coloured dark orange or black. Furthermore, larger cave openings allow more contaminants to be washed into the underground and groundwater environments, while also allowing animals and insects to populate caves where they did not have access previously. Furthermore, introducing air into a cave results in a drying effect. The formation of speleothems is subsequently halted or severely restricted.

9.5.3 Stone aggregate, shale, slate, building brick, brick-making clay and asbestos quarries and mines

The most prominent of this group of mines is the Sterkfontein Quarry due to its locality. For many years, the quarry produced stone aggregate for the building industry and created a scar in the landscape right next to the road leading to Maropeng and the turn-off to the Sterkfontein Caves. During the lifespan of this mine, many caves were destroyed or severely damaged, perched water tables were punctured and drained and a huge pit was created, altering the hydraulic recharge rate of the underlying dolomitic aquifer, albeit on a very local scale.

On a positive note, the quarry showed to what extent certain types of speleothems provided resistance to the vibrations and shocks created by blasting, but also showed how quickly the introduction of oxygen into a previously sealed cave can alter the atmosphere and permanently discolour the cave formations due to the oxidation of dissolved metals in the water dripping from the cave roof.

The Sterkfontein Quarry has intersected many interesting geological features. It is envisaged that this quarry could be used as a geological/palaeontological education centre where students could experience the geology and fossil sites at first-hand.

To the west of the Cradle, but still within its catchment in the vicinity of Tarlton, a number of clay quarries can be found. These operations are mining the clay associated with the Rietfontein fault and using it to manufacture clay bricks. In general, these operations are small and illegal, and do not have any plan for the eventual rehabilitation of the pits created by the mine. Once finished with a portion of land, the quarry is simply abandoned. Squatters have subsequently invaded large areas of mined-out clay pits, but they face flooding problems when it rains, as clay is not a good transmitter of water. Furthermore, some of the pits are used as illegal dumping sites. Although resting on dolomite deeper down, the clay lining of an abandoned clay pit is at least a good barrier against pollution of groundwater. Thus, the impact is mostly of a visual nature.

There are some larger operating clay mines to the north of the Cradle, which mine weathered shale of the Magaliesberg, but these mines are outside the Cradle and will not be discussed in this paper.

Slate and building block quarries are found mostly in the Pretoria Group, which is located in the northern section of the Cradle. It is not known whether there are still operating slate and building block mines within the boundaries of the Cradle, but the impacts of these mines in the Cradle are generally limited to visual aspects, rather than to the water resources, as they are off the dolomite.

There is an old asbestos (chrysotile or white asbestos) mine in the Honingklip vicinity in the serpentine rocks of the Archaean System. This mine closed down before 1930 and it used to be located where the Lethamo Estates are presently.

9.6 Conclusions and Responses

The mining industry and the gold mining industry in particular, have had a profound impact on the COH WHS. Yet at the same time, a lot of knowledge has been gained, especially geological knowledge, because of the gold mining industry. Mining operations other than gold mining within or close to the COH WHS had very localised impacts and are considered being of minor concern.

Although the gold mining industry in the catchment of the COH WHS is slowly dying, as all the gold reserves have been exhausted, it has recently given the COH WHS its last, and probably most powerful blow, in the form of decanting of polluted water from the worked-out mines. This water has created one of the most testing challenges for scientists and has come at a time when there is no further income from the gold mining industry to fund the solutions to the problem. In hindsight, it may be speculated that the cost of treatment of this water for centuries to come, may very well offset all the money ever gained by the mining of the gold in the West Rand. This may, in fact, also be true for the entire

Witwatersrand's gold mines, as these mines will be facing similar problems in the near future.

Until a final solution to the decanting mine water has been implemented the following responses are recommended to minimise future impacts:

- Water is a resource in a country with an average annual rainfall well below the world average. The establishment of a water utility company that can treat and sell the mine water is currently under review. This option is regarded as the only sustainable solution to the problem and should be viewed as such by the regulatory authorities. Only if this liability can be turned into a viable economic entity will it succeed.
- There are minerals dissolved in the water and each of these "pollutants" has a use somewhere in another industry and means of extracting them in a cost-effective way must be found to turn this problem into a resource.
- Historically, some of the water that is currently decanting from the mine void flowed down the Tweelopiespruit (pre-mining) and it is therefore proper that this scenario be restored. The water must, however be of an acceptable quality. It is recommended that a needs analysis be done to determine the requirements of the downstream users, as well as current water usage and available treated decant water. Such a survey will indicate whether there is an ample supply of treated decant water to satisfy the needs of the downstream users.
- The Department of Water Affairs and Forestry should monitor the groundwater table and water quality on a regular basis. This data should be made available to a central database and used as an early warning system for any contamination and groundwater level fluctuations.
- The last, and probably the most asked, question relating to the decanting mine water is "*What impact will the acid mine water have on the structural integrity of the Sterkfontein Caves and will the caves be flooded?*" Preliminary research has confirmed that the water level in the Sterkfontein Caves' pool is at a higher elevation than the water level in the Bloubankspruit adjacent to the caves and even higher still than the regional groundwater level. The chances that the caves will be impacted directly by the water in the stream or in the groundwater aquifer are therefore fairly remote.

REFERENCES

BREDENKAMP DB, VAN DER WESTHUIZEN C, WIEGMANS FE and KUHN CM (1986) *Groundwater Supply Potential of Dolomite Compartments West of Krugersdorp*, Technical Report No. GH3440. Directorate of Geohydrology, Department of Water Affairs.

BRINK ABA (1979) *The First 2000 Million Years of Geological Time* In: Engineering Geology of Southern Africa 1, Building Publications, Pretoria Not in the text.

CARRUTHERS V (2000) *The Magaliesberg,* Protea Book House, Pretoria.

COURTNAGE PM (1995) *Post Transvaal Deformation Between the Johannesburg Dome and the Bushveld Complex*, Unpublished MSc Dissertation, University of the Witwatersrand.

DE KOCK WP (1964) The geology and economic significance of the West Wits line In: *Geology of some ore deposits in southern Africa*, Geol. Soc. S. Afr., pp. 323-386.

Department of Geology, University of Witwatersrand, Council for Geoscience and Black and Veatch (2001) *Status Quo of the Geohydrology of the COH WHS Area.*

ERIKSSON KA and TRUSWELL JF (1974) Stratotypes from the Malmani Subgroup northwest of Johannesburg, South Africa, *Transactions of the Geological Society of South Africa*.

HILTON-BARBER B and BERGER LR (2002) *The official field guide to the cradle of humankind*, Struik Publishers, Cape Town.

HOLLAND M, WITTHÜSER KT, JAMISON AA, VAN NIEKERK HJ and BREDENKAMP DB. Hydrology of the Cradle of Humankind World Heritage Site: Geology, Surface- and Groundwater. *The Karst System of the Cradle of Humankind World Heritage Site* (Durand JF ed.), Issue Paper 9, WRC Consultancy Project No. K8/624, 160-188

JAMISON AA, VAN NIEKERK EJ and VILJOEN MJ (2004). Bedding-parallel shear & sinistral wrench faulting influencing location and formation of caves in the Cradle of Humankind, Gauteng, South Africa.

KRIGE WG (1999) *An investigation into groundwater recharge derived from the upper Klip River tributaries where these cross the Main, Bird and Kimberley reef outcrops and associated shallow mine workings*, Unpublished report JCI Limited.

KRIGE WG (2006) *Hydrological/Chemical aspects of the Tweelopie-/Riet-/Blaauw-bankspruit, with specific reference to the impact water, decanting from the Western Basin Mine Void, has on this system*, Unpublished report, Harmony GM Co. Ltd.

KRIGE WG (2007) The impact of urbanisation on the water resources and water-

based ecosystems of the Cradle of Humankind World Heritage Site. *The Karst System of the Cradle of Humankind World Heritage Site* (Durand JF ed.), Issue Paper 10, WRC Consultancy Project No. K8/624, pp. 189-216.

LEDNOR M. (1986). The West Rand Goldfield. Geol. Soc. S. Afr., Johannesburg.

MARTINI JEJ and KAVALIERIS I (1976) The Karst of the Transvaal, (South Africa), *International Journal of Speleology.*

MOON BP (1972) Factors controlling the development of caves in the Sterkfontein area, *South African Geographical Journal*. Not in the text

MOON BP and MARKER ME (1969) Cave levels and erosion surfaces in the Transvaal, *South African Geographical Journal*. Not in the text

PELCZAR MJ, REID RD and CHAN ECS (1977), *Microbiology*, 4th edition, McGraw-Hill Publishers, New York.

PRETORIUS DA (1976). The nature of the Witwatersrand gold-uranium deposits. Handbook of Strata-bound and Stratiform Ore Deposits. II. Regional Studies and Specific Deposits. Wolf, K.H. (ed.). Amsterdam, Elsevier Scientific Publishing Company.

SCOTT R (1995) Flooding of the Central and East Rand Gold Mines, WRC Report No. 486/1/95. not in the text

TANKARD AJ, JACKSON MPA, ERIKSSON KA, HOBDAY DK, HUNTER DR and MINTER WEL (1982) *Crustal Evolution of Southern Africa*, Springer-Verlag, New York.

TRUSWELL JF (1977) *The Geological Evolution of South Africa*, Purnell and Sons, Cape Town.

VAN BILJON M and KRIGE WG (2005) *Cost apportionment for the treatment of contaminated water decanting from the Western Basin mine void*, Unpublished report for Harmony GM Co. Ltd.

VEGTER JR (1984) - Dolomitic water supplies with special reference to southern and western Transvaal. International conference on ground water technology, 14-17 November 1984, Johannesburg – Vol. 1, National Water Well Association.

WOLMARANS JF (1986) Some engineering-geological and hydrological aspects of mining on the West Wits Line In: *Mineral Deposits of southern Africa*, Geol. Soc. S. Afr. pp. 701-796.

ISSUE PAPER

10 THE IMPACT OF URBANISATION ON THE WATER RESOURCES AND WATER-BASED ECOSYSTEMS OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

W.G. Krige

ABSTRACT

As part of a project for the IUCN Karst Working Group, a study was conducted on the impacts of urbanisation on the water resources and the water-based ecosystems of the Cradle of Humankind World Heritage site in South Africa. This paper discusses the more important human impacts that have significant impacts on the water resources of the study area.

For the purposes of this paper, the word "urbanisation" was interpreted in its broader sense, and it included not only people living within the boundaries of the study area, but also people living or impacting on the study area, irrespective of whether these people or activities occur within or outside of the boundaries of the study area.

The physical characteristics of the catchment of the aquifers and the importance that the entire catchment has on the study area are described. The human population of the catchment is described and put into context. The body of the paper revolves around the listing of human activities within the Cradle of Humankind World Heritage Site (COH WHS) as well as in the catchment of its two important aquifers and how these activities impact on the water resources within the study area. Finally, some recommendations are made as to the mitigation of some of the impacts described in the paper.

The terms of reference for this paper were the identification of the impacts of urbanisation on the water resources and water-based ecosystems of the Cradle of Humankind. Although urbanisation may have many impacts on the environment in general, this particular paper only focuses on the impacts of urbanisation on the water resources of the COH WHS, as per the terms of reference.

In some cases it may therefore appear as if certain urban impacts were omitted from the paper. However, the author tested urban impacts against the terms of reference and removed those that did not comply. Items such as the impacts of roads on the environment, the impacts of commercialisation of caves on the karst and speleothems, the impacts of street lighting on the bat and other nocturnal animal populations and other impacts of urbanisation on non-water related aspects, were therefore not included in the paper.

10.1 The Background of Humankind's History in the Cradle of Humankind

The Sterkfontein Valley landscape comprises a number of fossil bearing cave deposits. These are considered of exceptional universal value, because they summarise the emergence and evolution of the human race over the past 3.5 million years. It is thus considered an important site for human evolutionary studies and has gained the status of The Cradle of Humankind World Heritage Site (www.cradleofhumankind.co.za).

Clues about the past have been preserved in the multitude of caves and caverns beneath the dolomitic outcrops and grassland of this area. Literally thousands of fossils have been excavated creating a puzzle for scientists to piece together in order to discover from whom or what humans evolved. Many hominid species occurred, but through the process of evolution and natural selection they became extinct (Hilton-Barber and Berger, 2002).

The Out of Africa hypothesis, which is supported by modern phylogenetic research, postulates that *Homo sapiens* developed in Africa and then migrated to other continents replacing *H. erectus* populations. Only in Africa is there evidence that modern *H. sapiens* evolved from an archaic form, which, in turn, evolved from *H. erectus* (Hilton-Barber and Berger, 2002). Surprisingly, the cultural history of the more recent past isn't always as clear as the distant past, since it has not been recorded in sufficient detail. Virtually the only source of information about the people of this area is from the diaries of early European travelers, hunters and explorers.

Considering this rich anthropological history, it is a shameful and ironic fact that the single most destructive force operating on the karst landscape is that of humans. Through urban sprawl, cities, towns and many informal settlements have claimed a lot of the natural area and this has had an immense influence on the environment. Nature simply cannot adapt to the new demands posed by humans at the rate at which changes are occurring.

The Cradle of Humankind World Heritage (COH WHS) site in South Africa has probably felt human's impact for the past years. As far back as 2 million years ago, humans' early ancestors were already manufacturing stone tools in the Cradle (Hilton-Barber and Berger, 2002). They hunted animals, harvested fruit and built their dwellings and in so doing, gradually started to alter the environment of the Cradle of Humankind to suit their needs. Around 1.5 to 1 million years ago, human's early ancestors tamed fire, probably by "stealing" fire from natural veld fires. Over the next million years or so, these ancestors flexed their mental and social superiority, slowly coming to dominate the harsh and competitive environment of the African Bushveld and slowly adapting the environment to its needs (Hilton-Barber and Berger, 2002).

Up to the end of the late Stone Age (1 000 years ago), early humans had a hunter-gatherer economy in the Cradle, which did not have such a significant impact on their environment. Around 1 000 years ago though, the hunter-gatherers were absorbed into or replaced by people from the Iron Age. To practice their metalworking skills, humans required copious amounts of fuel for their furnaces in the form of firewood. The first really significant impact was being felt in the COH WHS as humans slowly denuded the landscape of its trees. People of the late Iron Age, learnt the art of cultivating crops and also brought cattle into the COH WHS. The late Iron Age societies were very successful. Their populations increased rapidly as a result of their metalworking and farming skills, which became the foundation of the early South African economy.

The population within the COH WHS gradually increased while wars among the tribes mostly dictated which society succeeded which. According to Hilton-Barber and Berger (2002), the rise to power of the Zulu King Shaka around 1818 set off a chain reaction of violent disruptions across the subcontinent. Ironically, the consequence of Shaka's actions, namely the complete breakdown of social and political structures, made it much easier for European settlers to claim much of South Africa's interior, including the Cradle of Humankind.

Of all the human-related events, which have occurred in the COH WHS, the single most important event, which would have the most significant and far-reaching impact on the COH WHS, however, was the discovery of gold in 1886 on the nearby Witwatersrand. This brought large numbers of people into an area where, under normal circumstances, a city would never have been developed. Almost all large cities in the world developed along large rivers. The water in the river would provide all the human requirements, while also providing a means of transport, irrigation water for their crops and for watering their livestock and also providing a means of disposing their waste products.

This was not the case with the Witwatersrand, however. Instead of developing alongside a river, the Johannesburg metropolitan area was developed along the reef outcrop on the watershed between two catchments. This happens to be the furthest place you could get from a river. The nearest reliable and sustainable water sources to the Witwatersrand were the Orange (Gariep) and Vaal Rivers, the nearest being some 60 km to the south. The metropolitan area that subsequently developed around the gold mining industry had to import water from these sources. The cost of returning the treated wastewater back to the rivers of origin, however, excluded this practice in the Witwatersrand and treated wastewater was discharged into other catchments, including those of the Cradle of Humankind. Examples are the Percy Stewart and the Randfontein Sewage Plants, which discharge essentially Vaal River water directly into the Cradle. This water, being sewage effluent, had a totally different chemical character to the water found within the dolomitic aquifers of the Cradle.

Apart from this, the wastewater and other waste products produced by the gold mining industry and the associated industries that supply the demand of the metropolitan area also impacted – and are still impacting – on the Cradle.

10.2 Determining of the Boundaries for the Study

The Cradle of Humankind World Heritage Site (Cradle) comprises of an area of approximately 47 000 ha of which the largest part is underlain by rocks of the Transvaal Supergroup, made up of the more recent Pretoria Group which overlies the older Chuniespoort Group. Roughly half of the Transvaal Supergroup surface area of the Cradle (approximately 22 890 ha) consists of dolomite and chert of the Chuniespoort Group. It is within this Group that karst formation has occurred. These caves provided shelter for early hominids and their fossilised remains, in turn, gave rise to the establishment of the Cradle. Refer **Figure** 10.1 for location.

This paper will not cover the entire Cradle, but will focus in particular on the karstified dolomitic components of the area. Karstified areas contain aquifers with particularly high storativity and transmissivity values and contain some of the country's largest aquifers. The impacts by human activities within, as well as impacts from outside the boundaries of these aquifers, which may have negative impacts on the groundwater quality and available quantity will be addressed in this paper.

Groundwater flow in the karstified fraction of the Cradle more or less follows the regional surface hydrology and is predominantly from southwest to northeast (from around Randfontein, through Tarlton, towards the Hartbeespoort Dam). The main input aquifer is the Zwartkrans Compartment (Bredenkamp *et al*., 1986) with a surface area of approximately 15 398 ha. This aquifer lies partially within and partially outside the Cradle. It also contains most of the well-known caves and karst formations, including the Sterkfontein Caves, the Wonder Cave, the Kromdraai Eye, the Zwartkrans Eye and the Danielsrust Eye. Unfortunately it also has a surface catchment area reaching well beyond the boundaries of the Cradle. Within this extended catchment, human activities play an important role relating to the deterioration of groundwater quality and quantity within the karstified fraction of the Cradle.

According to Barnard (2000), water leaving the Zwartkrans Compartment at its northern boundary enters the Cradle North Compartment on the farm, Rietfontein 522 JQ, roughly 2.6 km north of Wonder Cave. A syenite dyke separates the two compartments. The North Compartment with a surface area of 12 698 ha is slightly smaller than the Zwartkrans Compartment.

While the Zwartkrans Compartment has a much larger surface catchment area than the area of the compartment itself, the North Compartment's catchment and surface areas are almost identical. This suggests that apart from the recharge that occurs via its own surface, the North compartment receives all its water from the Zwartkrans Compartment. It unfortunately also implies that if the water in the Zwartkrans Compartment is contaminated, this contamination will eventually spill over into the North Compartment. The two compartments and their mutual catchments are shown in **Figure** 10.2.

Apart from its northeastern-most tip, the boundaries of the North Compartment fall entirely within the Cradle. As can be seen in **Figure** 10.1, however, the Zwartkrans Compartment falls only partially within the Cradle and, more importantly, its catchment extends to include the towns of Randfontein and Krugersdorp. The boundaries of this study will therefore not only include the portions of dolomitic compartments falling within the Cradle, but will also include the entire catchment of the Zwartkrans Compartment as shown in **Figures** 10.1 and 10.2.

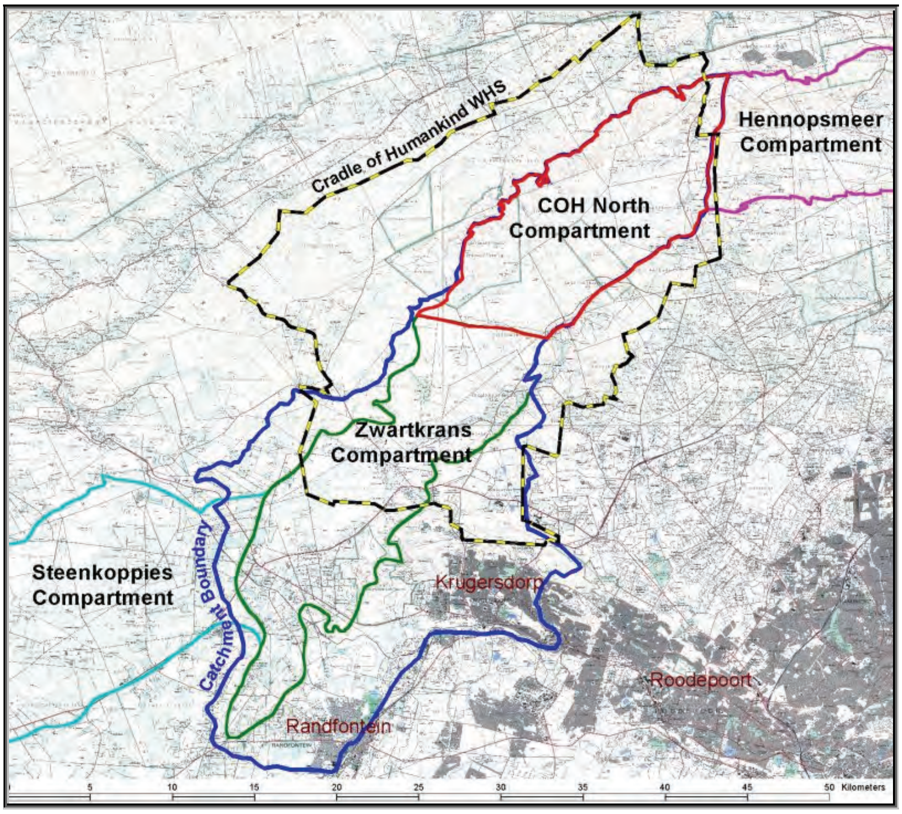


Figure 10.1: Portions of topocadastral maps 2527DC, 2527DD, 2627BA and 2627BB showing the boundaries of the Cradle of Humankind World Heritage Site, the dolomitic groundwater compartments and the catchment of the Zwartkrans and North Compartments (the boundaries of the dolomitic compartments were digitised from the 1:250000 SA Geological Series maps).

10.3 Human Activities, which Impact the Groundwater Resources in the Cradle

In spite of its World Heritage status, surprisingly little data is available relating to the population living within the Cradle and the activities that take place within this area. The only reliable source of data came from an unlikely source, the Municipal Demarcation Board. The Municipal Demarcation Board, with assistance from the Royal Norwegian Embassy, the Norwegian Agency for Development, the Norwegian Association for Local and Regional Authorities and the Norwegian Mapping Authority, compiled a CD, named SA Explorer, which includes ArcView shape files and databases containing all the data available from the 2000 municipal elections of the entire Republic of South Africa.

The groundwater compartments and their catchment fall wholly or partially within several municipal areas consisting of both local and district municipalities. Table 10.1 shows the populations of the portions that make up the catchment of the Cradle's water supply, while **Figure** 10.3 shows their actual locations.

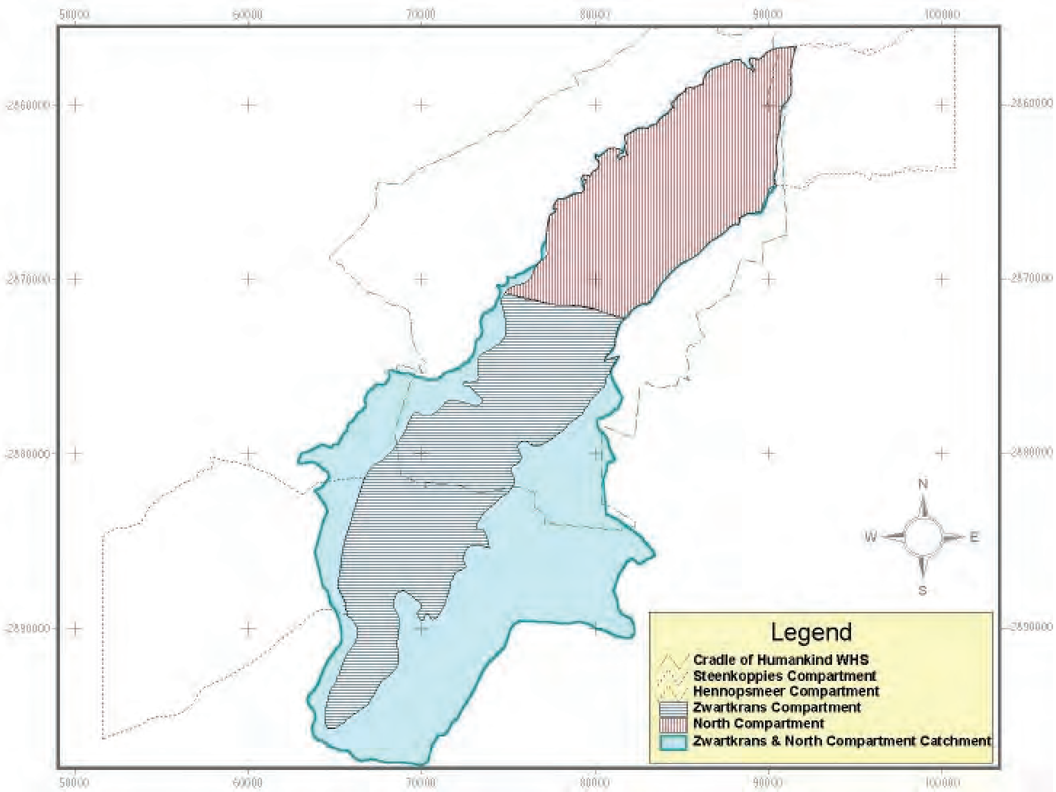


Figure 10.2: Map showing the two important dolomitic groundwater compartments of the Cradle of Humankind World Heritage Site, the Zwartkrans and North Compartments as well as their surface catchment areas (The boundaries of the dolomitic compartments were digitised from the 1:250000 SA Geological Series maps).

. To calculate the population within the catchment of the groundwater compartments of the Cradle, the portion of surface area of each ward or municipality falling within the catchment was digitised and presented as a percentage of the total surface area of that ward or municipality. The total population was then calculated by simply multiplying the population with the percentage of the municipal area that fell within the catchment of the groundwater compartments of the Cradle. The resultant populations may not necessarily be a 100% true reflection of the actual population within the area, as the population may not necessarily be spread evenly over the area occupied by the municipal area. It could well be suggested that the population of a municipal area falling partially within and partially outside the Cradle would have a less dense population within than outside the boundaries of the Cradle. Contrary to this, however, the municipal areas outside the Cradle, but still within the catchment of the two groundwater compartments of the Cradle, may show an opposite trend.

Table 10.1: The various municipal areas that fall wholly or partially within the catchment of the groundwater compartments of the Cradle of Humankind World Heritage Site (SA Explorer 2004).

	Ward	Municipal Area (km²)	Municipal Population	Area within Catchment(km²)	Percentage of total Population	Population within Catchment
Mogale City Local Municipality	14	13	5795	4.0	30.8	1783
	13	6	8429	0.7	11.7	983
	9	4	8340	1.0	25.0	2085
	21	8	8415	7.4	92.5	7784
	11	40	6343	13.5	33.8	2141
	1	5	11968	5.0	100.0	11988
	20	2	5397	2.0	100.0	5397
	24	7	6928	7.0	100.0	6928
	23	1	5886	1.0	100.0	5886
	25	1	7886	1.0	100.0	7886
	12	40	6818	40.0	100.0	6818
	19	147	6692	91.1	62.0	4147
	30	43	6515	33.2	77.2	5030
	18	430	7810	5.0	1.2	91
Randfontein	1	298	6760	20.5	6.9	464
	2	71	7201	4.3	6.0	432
	3	28	8953	24.1	86.1	7706
	4	3	4051	3.0	100.0	4051
	6	4	6810	4.0	100.0	6810
	7	5	5628	3.2	63.6	3579
	9	29	5895	15.4	52.9	3120
Other	GTDMA41	243	2291	209.8	86.3	1978
	NW372	3812	320 796	19.5	0.5	1641
				TOTAL		**98729**

From the above statistics it is estimated that 98 729 people lived within the catchment of the dolomitic aquifers of the Cradle during 2000. In the author's opinion, this may be an underestimate as there are a number of informal settlements and squatter camps that are not officially recognised and whose residents are not recorded in any population census. These settlements are mostly located outside the Cradle but still within the catchment of the Cradle.

Although this is not necessarily a large number of people considering the surface area of the catchment (47 745 ha, i.e. ± 2 people/ha), it is the activities of these people and others from areas outside the Cradle that work or operate within this area, which dictates the impacts that humans have had on the Cradle. A large part of the catchment of the groundwater compartments of the Cradle is occupied by gold mining activities. This includes the Randfontein and Krugersdorp areas. Although the Tarlton area is not densely populated, farming activities and resultant groundwater abstraction has had a huge impact on the groundwater resources of the Cradle. Likewise, although the harsh dolomitic landscape of the Cradle is not considered to be ideal grazing or arable land due to the rocky nature thereof, increasingly a high concentration of animal farming is taking place to produce fresh food for the metropolitan area of the Witwatersrand. In particular, chicken farms are increasing at an alarming rate. Farming with animals may not necessarily degrade the land, but poor management of waste products and wastewater poses a serious source of contamination to the groundwater in the aquifers of the Cradle. The alteration of land use within the catchment also alters the amount, intensity and quality of water entering the Cradle via its drainage channels and streams.

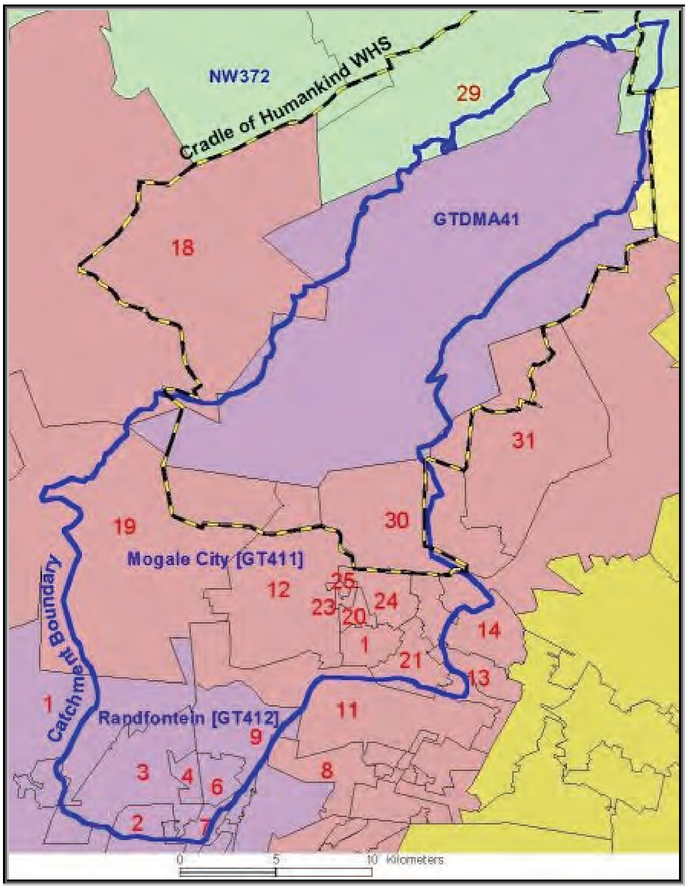


Figure 10.3: The various municipal areas that fall within the catchment of the groundwater compartments. Only the wards that fall wholly or partially in the catchment of the Cradle of Humankind World Heritage Site are numbered (from: *SA Explorer*, 2004).

Each of the impacts of human activities will be discussed briefly below:

10.3.1 Mining

This item is discussed in the previous Synopsis Paper (Krige and Van Biljon, 2007). This section will therefore be limited to a brief overview of the impacts.

The discovery of gold on the Witwatersrand probably created the single greatest impacts that humans have had on the Cradle. Not only did it create a city where there should never have been a city and caused the associated water shortages and waste disposal problems, but the mining activities themselves created immense groundwater problems for the Cradle. Large waste rock dumps and tailings dams were built within the catchment of the Cradle. Poor water management in and around these structures has created serious acid mine drainage problems.

Since 2002, an average of 15.5 Mℓ/day acid mine water has been decanting from boreholes and an abandoned Black Reef incline shaft into the Tweelopiespruit East (Van Biljon and Krige, 2005). This water flows through the Krugersdorp Game Reserve and disappears into the dolomitic aquifers of the Zwartkrans Compartment. It has yet to be understood exactly what the impact of this water will be on the Cradle in the medium and long term.

The discovery of gold also created a critical demand for cement (building industry) and lime (gold metallurgical process). Every possible source of lime was mined, most of which were located within the Cradle in the form of speleothems within the caves. Many of the pristine caves were completely or partially destroyed, the remnants and waste rock dumps of many of these lime mines still litter the hillsides of the Cradle.

Apart from being unsightly, these lime mines opened up the deeper parts of caves resulting in increased ventilation and oxygenation while also providing access for cave-dwelling animals and access routes for water and pollutants. Often, the local residents use these abandoned lime mines as domestic waste sites (see **Figure** 10.6). Ironically, it was as a result of the lime mining activities that the first hominid fossils were discovered which, in turn, lead to the eventual declaration of the Cradle.

The Tweelopiespruit West between Randfontein and Tarlton used to contain vast amounts of peat. Water from Randfontein urban area, its sewage works, and the gold mine tailings dams adjacent to the stream used to be filtered and attenuated by these peat beds before it flowed into the dolomitic aquifers of the Zwartkrans Compartment. The mining of these peat deposits has prevented this from occurring.

One large quarry exists within the Cradle, the Sterkfontein Quarry near the Sterkfontein Caves. Although this quarry is not being mined any longer, a closure certificate has not been issued by the Department of Minerals and Energy. Apart from this particular quarry, a number of clay quarries exist within the catchment of the Cradle in the Tarlton area where eroded Karoo material is mined for the brick-making industry. The Sterkfontein quarry intersected a number of previously undiscovered caves. Severe damage was caused to these caves in this process.

10.3.2 Large municipal sewage disposal works

There are two large sewage treatment facilities in the catchment of the Cradle's groundwater compartments, the Percy Stewart Sewage Works of the Mogale City Local Municipality and the Randfontein Sewage Works. The two plants together dispose a volume of 27.46 Mℓ/day of treated sewage effluent (8.16 Mℓ/day for Randfontein Sewage Works – average September 2004 to September 2005 – and 19.3 Mℓ/day for the Percy Stewart Works) (Official municipal records of Randfontein and Mogale City Local Municipalities).

Water disposed by these sewage works originates from the Vaal River. It is treated and distributed by Rand Water and is used in various ways within the towns' residential and industrial areas and is eventually disposed of as treated sewage effluent. The Randfontein Sewage Works disposes its effluent into the Tweelopiespruit West, while effluent from the Percy Stewart Sewage works is discharged into the Blougatspruit, a tributary of the Bloubankspruit, the main arterial of the Cradle. In the case of the Randfontein water, all of it disappears into the dolomitic aquifer of the Zwartkrans Compartment before even reaching Tarlton, while at least some of the effluent from the Percy Stewart Works remains in the stream on the surface. Part of this study showed low measurements of the streams transporting water into the Cradle. These measurements indicated that a volume of 13.57 Mℓ/day recharges into the Zwartkrans Compartment between the Percy Stewart Sewage Works and the small bridge across the Bloubankspruit to the Zwartkrans Cave (almost opposite Sterkfontein Caves). This amounts to a streambed loss of 2.3 Mℓ/km/day for this part of the Rietspruit/Bloubankspruit.

Sewage plants are primarily designed to remove organic matter and some plant nutrients from sewage water, while most other chemicals pass through the sewage plant unaffected. Furthermore, on average, 27.46 Ml of sewage effluent, which originates from the Vaal River, enters the Zwartkrans compartment daily. This Vaal River water has a totally different chemical character to the water found in the dolomitic groundwater aquifer of the Zwartkrans Compartment. The mixing of these two waters over a prolonged period may produce unknown results within the dolomitic aquifers.

Apart from the chemical character of the sewage effluent being vastly different from the dolomitic water, the increased volumes in the two streams are also an area of concern. Immediately downstream from Tarlton, a number of sinkholes have formed in the streambed of the Tweelopiespruit West, as a possible result of the increased flow in the stream due to the Randfontein Sewage Effluent. Furthermore, as a result of the removal of the peat beds, the reduced attenuation properties of the Tweelopiespruit West between the Randfontein Sewage Plant and Tarlton has allowed water to flow further downstream during thunderstorm events, further aiding the sinkhole forming process (see **Figure** 10.4).

The Percy Stewart Sewage Plant of Mogale City (**Figure** 10.5) was constructed on an extension of the Rietfontein Wrench Fault, an active geological fault. As a result, reservoirs and tanks cracking and leaking plague the sewage plant (Jamison, 2004). An unknown volume of untreated water enters the groundwater environment via these leaks and the fault. Furthermore, the sewage sludge produced by the plant is irrigated onto pastures of kikuyu grass in the Krugersdorp Game Reserve adjacent to the sewage plant. This is done through flood irrigation. These pastures also happen to be located directly on the Rietfontein Fault, further increasing the contamination of groundwater within this area.

10.3.3 Rural sewage and solid waste disposal

There are no municipal sewage removal services and very limited solid waste removal services available within the Cradle. Sewage and solid waste services are available in catchments outside the Cradle in the built-up areas, but large portions of land within this catchment are still without municipal sewage or refuse removal services. The three most important services having an impact on the groundwater resources of the Cradle are sewage disposal, solid waste disposal and water supply.

Figure 10.4: One of the sinkholes in the dry streambed of the Tweelopiespruit West immediately downstream from Tarlton. These sinkholes were formed due to the increased flow in the stream and also due to the removal of the peat beds in this stream (run-off attenuation properties of peat lands and associated reed beds), allowing storm water to flow further downstream before recharging into the dolomitic aquifer (photo: W.G. Krige 31/03/2002).

10.3.3.1. RURAL SEWAGE DISPOSAL

The traditional method of sewage disposal in rural areas is through a septic tank and French drain soak-away. In most parts of the country this method works well and will remain the preferred method for many years to come. However, this is not true where dolomite is concerned. Although the septic tank will work perfectly, the high transmissivity of the dolomite could lead to two problems.

Firstly, the rapid rate at which water infiltrates the thin, porous dolomitic soils together with structures such as fissures, caves, etc. in the underlying dolomite, poses a problem as the water is not retained for a sufficient period before entering the groundwater environment. At best a septic tank removes only some 40 percent of the organic load in sewage. This partially treated water is then directed into the French drain where the filtering action of sand and further bacterial actions is utilised to provide for the final “polishing” of the water. Usually, many months, even years, would pass before the water from the French drain reaches the groundwater table. By this time the water would be free from bacteria and organic matter. However this is not the case with dolomite where very little, if any, filtering occurs. Preferential pathways exist and water leaving the septic tank could be back in the groundwater environment within minutes.

Secondly, any water percolating into dolomite in the same place for prolonged periods of time will inevitably transport some of the soil with it. This, in combination with the rapid dissolving power of sewage, will sooner or later cause ground instability (sinkholes) in the immediate area around the French drain.

Figure 10.5: The Percy Stewart Sewage Plant of Mogale City discharges effluent into the Blougatspruit entering the COH WHS. Behind the sewage works is the industrial area of Delporton, while still further in the background, one of the sand dumps of the gold mines is just visible on the horizon. Every-thing in the photo falls within the catchment of the Cradle. The Rietfontein Fault has created the valley along which the Blougatspruit flows as shown in this photo to the left (east) of the sewage works (photo: W.G. Krige 05/10/2004).

There are other sewage treatment systems on the market, which utilises the same principle as the larger municipal sewage plants (activated sludge process), but these systems are considerably more costly than the septic tank/French drain systems and have only been installed in a few places in the Cradle. These systems also require a power source to produce oxygenation in the aerobic reactor section of the plant, further increasing their running costs. The advantage of such a system is that all treated sewage effluent is collected in a reservoir and is utilised somewhere else on the property, usually in the garden. In spite of their cost, this type of sewage treatment plant is the only safe alternative to the septic tank/French drain system in the Cradle.

10.3.3.2. RURAL SOLID WASTE DISPOSAL

There are very few farms where one would not find a hole in the ground where waste is disposed of. In many cases not only domestic waste, but also items such as fertiliser and insecticide containers, sometimes containing extremely toxic substances, are included in the waste. Burning of the waste does not, however, necessarily remove the toxic substances. This occurs all over the dolomite of the Cradle. In almost all the cases where there are sinkholes or caves on the farm, these convenient holes are used for the disposal of domestic and other wastes. Refer to **Figure** 10.6 for examples of these practices. Very often animals that die of unnatural causes are also disposed of into such sinkholes.

As is the case with septic tanks, and although the water table may be over 100 m from surface, contaminants could migrate extremely rapidly through the well draining dolomitic soils and could theoretically enter the groundwater environment within hours after a rainstorm.

Figure 10.6: Waste being dumped within the catchment of the Cradle of Humankind World Heritage Site. The photo on the Left was taken in the Tarlton vicinity at a large vegetable farm and processing plant, while the one on the Right shows the waste from a shop near Sterkfontein Cave being disposed of into a cave (photo left: W.G. Krige, photo right: courtesy Mike Buchanan).

10.3.4 Agriculture

The impacts of agriculture are discussed in Issue Paper 11 (Groenewald, 2007). This section only deals with the important aspects pertaining to the impacts on the water resources.

The Tarlton area has a thick layer of weathered Karoo and other alluvial material covering the area with relatively few rocks at or near surface. This, in combination with the very significant groundwater resources in the underlying dolomite, makes intensive irrigation farming a profitable proposition in these areas. Apart from Tarlton, many of the floodplains of the few perennial streams traversing the Cradle are also ploughed up and under irrigation (**Figure** 10.7 and 10.8). Apart from the destruction of the natural riverine vegetation along the streams and the general grassland biome in the Tarlton area, the over-exploitation of the underlying dolomitic aquifer poses a serious risk of ground stability (sinkhole formation), while the continuing lowering of the water table could lead to irreversible damage (compaction) of the aquifer over time.

In 2005, the Maloney's Eye in the Steenkoppie Compartment, to the west of Tarlton and bordering the Zwartkrans Compartment, dried up for the first time in recorded history. Unconfirmed reports from farmers in the Tarlton area claim that the water table in the Tarlton region had dropped by more than 10 m over the previous year. The lowering of the water table in the Tarlton area through overexploitation of groundwater is probably the cause of this perennial spring drying up.

As the Cradle is so close to the Johannesburg Metropolitan area, it supplies many of the food requirements of the metropolitan area. Many feedlot-type farms are found in the area, including chicken batteries (broilers and eggs), dairies, piggeries, etc. In all these cases, the management of waste and wastewater poses a problem to the underlying karstified dolomite and the associated aquifers.

Figure 10.7: Not only are the flood plains ploughed up, but the streambeds of non-perennial streams are converted to vegetable farms. The photo was taken on the last occasion the Rietspruit flowed (28/12/2002) immediately before its confluence with the Blougatspruit in the COH WHS (photo: W.G. Krige).

Where high-density animal farming practices are employed, water is usually used to transport the resultant wastes and manure. In larger installations, effluent treatment plants treat the wastewater and separate the solid matter from the water. The water is then irrigated onto pastures while the solids are composted. Contrary to the larger (more professional) installations, it was observed in at least a few places in the Cradle that waste is either not treated at all or only partially treated. In some cases, the untreated effluent and solids from piggeries and dairies are merely discharged into a nearby stream or allowed to seep into the ground.

Fig.10.8: The photo shows the same streambed, now converted to agricultural land (photo: W.G. Krige).

In the case of chicken batteries, water is usually not used to transport the wastes generated by chickens. Chickens are poor converters of food to meat and most of the nutrients in the chicken food pass through the digestive system of the chickens. For this reason, there is a demand for chicken manure and manure is stockpiled until a sufficiently large volume is accumulated to transport it off the property. The stockpile in itself may pose a problem in relation to groundwater pollution, but in general, chicken farming does not have the same negative impacts on the groundwater resources as dairy farms and piggeries do, as the manure is removed from the premises rather than being disposed of on the premises.

Apart from the increased water use for irrigational purposes, nurseries also pose a significant additional threat for the Cradle. In the case of properly managed nurseries, the new plants are planted in a compost or potting soil mixture purchased from an area outside the Cradle. However, in some cases, plants are planted in soil collected on the farm. This eventually leads to the stripping away of topsoil and in at least one case, the creation of a huge open quarry. Similarly, poor instant lawn farming practices slowly strips away the topsoil together with the grass. Over time, the area will become denuded of its topsoil, altering the infiltration/run-off rate of the land. This, in turn, will have negative impacts on the underlying groundwater resources.

A relatively large portion of the Cradle is divided up into smallholdings. Although the surface area of a smallholding is designed to be an economical agricultural unit, due to the rocky nature of the Karst landscape and the poor agricultural potential of the dolomitic soils of the Cradle, this is not always the case. Residents then employ other forms of income generation on these smallholdings. Often, the land is used for some industrial purpose not related to agriculture. As none of the areas covered by smallholdings are serviced with sewage or waste disposal, these small industries simply dump all their wastes, be it solid, sewage or industrial effluent into the ground resulting in potentially serious contamination of the groundwater.

10.3.5 Industries other than agriculture and mining

Three medium-sized industrial areas are located within the catchment of the Cradle. These are Factoria, Boltonia and Delporton within the Mogale City Local Municipality. Factoria is of particular importance relating to the Cradle due to the proximity of a stream it could potentially contaminate. Factoria is located in the headwaters of the Blougatspruit, where a number of springs from the surrounding Witwatersrand quartzite cause the flow in this stream to be perennial almost right from its origin. This is the reason that the Eeufees Dam in the stream is always full of water, even in winter. The Blougatspruit follows the fracture line of the Rietfontein Wrench Fault mentioned in Section 10.3.2. Some of the industries located in Factoria have the potential to contaminate the ground and surface water within the catchment of the Blougatspruit. Furthermore, a "rehabilitated" landfill site is located across the streambed immediately downstream from Factoria. Although there is a leachate pond downstream from the landfill site, this pond often overflows, while most leachate merely underflows the pond and daylights as surface water a short distance downstream from the landfill site.

The Blougatspruit is canalised through most of the town of Krugersdorp, therefore almost no natural water treatment takes place in this part of the stream. By the time the stream enters the Cradle at its confluence with the Rietspruit; it has accumulated wastes not only from Factoria, the landfill site and the run-off from the town of Krugersdorp, but has also received the effluent from the Percy Stewart Sewage Works. At this point no natural in-stream assimilation has occurred due to the rapid rate that water flows and due to the absence of vegetation in a concrete canal.

Petronet is in the process of erecting a petrochemical distillation plant at their Tarlton Depot and to increase their storage facility by an additional 12 million liters. This depot is not only located on the dolomite of the Zwartkrans Compartment but also at the point where the Rietfontein Wrench Fault crosses the Tarlton Dyke (Jamison, 2005). Although the Environmental Impact Assessment indicates otherwise, the nature of the local geological structures is cause for considerable concern as to the vulnerability of the Tarlton Site to geohydrological risk and hazard from collapsing dolomitic cavities as water is progressively withdrawn by the present heavy pumping drawdown of the aquifer by the surrounding agricultural industry.

Diesel/petrol mixtures from all the Petronet depots across the country will be transported by rail to the Tarlton depot, where it will be offloaded and then distilled to separate the diesel from the petrol. Although Petronet has a good track record relating to environmental management, this does not exclude the increased chances of spillages, while the air quality over the southeastern part of the Cradle will deteriorate significantly, in addition to the groundwater pollution potential.

10.3.6 The drilling of boreholes and the destruction of, or damage to unknown caves

Drilling of boreholes in dolomite is a hazardous operation. A number of factors associated with drilling into deep weathered dolomite (wad) increase the cost of drilling in dolomitic areas significantly. Drilling operators drilling boreholes into dolomite run the risk of losing equipment when the rods or drill hammer becomes stuck when drilling into wad. The dolomite of the Cradle is particularly well weathered and often, long before the water table is reached, wad, cavities or caves are encountered. Percussion drills make use of large volumes of compressed air to blow the rock chips and dust, broken by the hammer, out of the borehole. When a cave is encountered, the air, dust and rock chips are blown into the cave instead of out to the surface. In this case, a real danger exists when the drilling equipment may become stuck due to rock chips falling from the cave floor back down the hole when the air is stopped for a moment. The drilling operator will apply as much compressed air as the compressor can produce to prevent rock chips and dust from falling back down the hole until a firm foundation is reached onto which he can install a casing through which he will be able to drill further, albeit with a smaller hammer. This blows large volumes of air, dust and rock chips into undiscovered caves. Usually, the air and dust is contaminated with drilling grease and lubricant. Little is known about what extent this action would damage the cave. In addition, cave pools and perched water tables are punctured and drained down the borehole.

Dependent on the initial size of the borehole, when the drilling operator encounters a second or even a third cave before the water table is reached, he will be unable to drill further due to the small size of the borehole and the borehole will be abandoned.

Due to these hazards, often more than one borehole is drilled before a successful borehole finally reaches the water table and yields sufficient water. In this process, many boreholes damage unknown caves. Even worse, many unsuccessful boreholes drilled into caves not previously exposed to the atmosphere are simply abandoned without rehabilitating them and sealing the entrance. As a result of atmospheric pressure changes on the surface, these boreholes "breathe", usually blowing in the mornings and sucking in the late afternoons. This introduces oxygen into the previously oxygen-free underground environment. Oxidation of minerals and metals will occur. Iron and manganese will be oxidised from their soluble to the insoluble form. The blue-white speleothems that were being formed in an oxygen-free environment will become stained with a layer of dark orange to black iron and manganese oxides, potentially millions of years before the cave eventually reaches the surface (**Figures** 10.9 and 10.10). Apart from oxygen, insects will invade an immature cave, while often these unused caves are also used for waste disposal while the author has observed on more than one occasion that these unused boreholes are used as toilets.

If potable water is supplied in the Cradle and due to the cost of drilling boreholes in karst, the number of new boreholes that are likely to be drilled, and the associated damage to unknown caves, will decrease considerably.

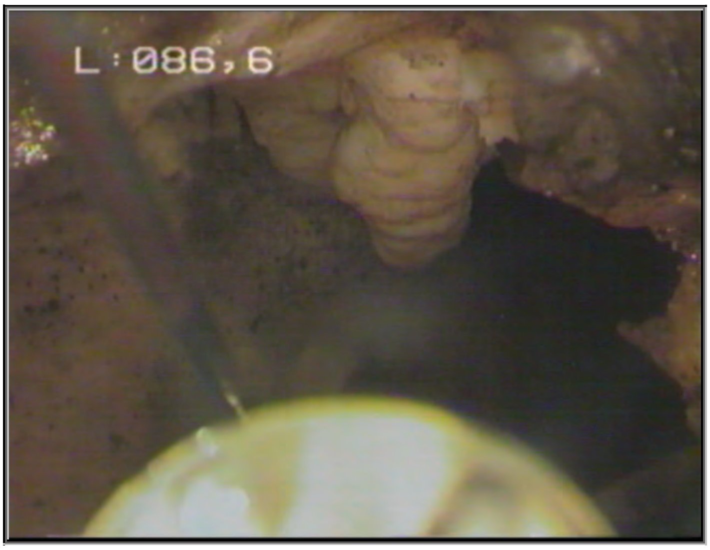


Figure 10.9: A cave intersected at 86.6 m below surface at the end of an unsuccessful borehole in the Cradle of Humankind. This borehole was drilled on Portion 129 of the farm Sterkfontein 173 IQ, the photo was copied from a video done by the Dept. of Water Affairs and Forestry after the cave was encountered by the drilling operation. Note the rock fragments and dust on the formations from the drilling bit. This particular cave was linked to a much larger cave system as a large volume of air was "breathed" in and out of the borehole when atmospheric pressures changed on surface. Unlike most other unsuccessful boreholes, this borehole was subsequently sealed with a concrete plug (photo: W.G. Krige).

Fig. 10.10: The effects oxygen has on a previously sealed cave in the Cradle. This cave was blasted open in a dolomite quarry and within a few decades, the effect of oxidation of the dissolved iron and manganese in the water seeping from the cave roof had completely discoloured these once spectacular speleothems (photo: W.G. Krige).

10.3.7 The alteration of the karst botanical ecology by human activities and the subsequent alteration to the recharge of groundwater

The living sphere covering the dolomitic deposits of the Cradle is the grassland. Relatively insignificant to the casual observer, this vegetation type has such an intricate and complicated history of which we are still to learn. It bears witness to the potential for adaptation to the climate and other factors by the plants inhabiting the mostly adverse edaphic realm.

As far as the natural history of the area is concerned, in many ways the grasslands are absolutely unique and can be considered the cradle of life (Hilton-Barber and Berger, 2002). Any serious study of a vegetation type requires some investigation into the edaphic factors which play a crucial role in the life of all plants, since they are sessile organisms and completely dependent on external factors for their survival. Special adaptations do occur and it is usually to the soil and/or climate, as these two aspects are the most important factors beyond the plant's control.

The grasslands can be considered relatively new in geological terms, since they only originated about 65 million years ago and have been maintained by the fire regime ever since (Bredenkamp *et al*., 2002, Willis and McElwain, 2002). Even though the vegetation type seems very uniform, being a short vegetation type dominated by grasses, a closer observation reveals a wealth of different and beautiful plants, most of which appear in springtime. When considering the reproduction and dispersal processes in the grassland, it can be regarded as an evolutionary advanced vegetation type.

It is clear that the grasslands observed today originated from a delicate interplay between savannah and grassland. The savannah became the dominant vegetation type during periods of increased temperature and precipitation, while grassland was dominant when conditions were colder and drier (Bredenkamp *et al*., 2002, Bredenkamp and Brown, 2003).

From a purely botanical point of view, Acocks (1988) mapped the Cradle and its surrounding grasslands as a single vegetation type (Bankenveld), but recognised three different variations in the vegetation. Of these the dolomitic regions were named the Western Variation on dry sandy plains. The other two types are the Central Variation of the Witwatersrand area and the Eastern Variation on wetter sandy soils. Low and Rebelo (1996) classify the Cradle area as Rocky Highveld Grassland.

At present this vegetation type is located in a transitional climatic zone between temperate grassland and subtropical savannah. It is, however, separated from lower-lying and warmer savannah by the Magaliesberg and its eastern and western expansions. The low temperatures and fire regime helps to maintain this biome. The species that do occur on the dolomitic grassland are able to thrive on relatively nutrient-poor soils. Due to the properties of the mother material, the soil is alkaline in character which accounts for the general absence of fynbos elements that grow on more acidic soils (Bredenkamp, 1999; Bredenkamp and Brown, 2003).

Because of the strong selection for species that can tolerate fire, some trees are pachycauls or underground trees such as *Erythrina zeyheri* (plough breaker) and *Elephantorrhiza elephantina*. The bulk of these trees are hidden underground with only the tips of branches protruding from the surface, indicating their presence. Fire alone, however, does not exclude trees from the dolomitic grassland of the Cradle, but low temperatures do. Bredenkamp *et al.* (2002) confirms that there are no cold-adapted deciduous or evergreen angiosperm or gymnosperm trees indigenous to Southern Africa.

Models predicting the future climatic conditions, taking into account the effect of global warming, forecast that the climate will become hotter and drier. This creates an ideal niche for Karoo type vegetation and many Highveld species may be lost in the process if these models prove to be correct. It is, however, uncertain if Karoo vegetation will ever be able to grow on such a substrate. Presently the grassland on the dolomite within the Cradle is home to several endemic species that specifically grow on an alkaline substrate and that is adapted to cold and dry environmental conditions. Many different forms of species can also be distinguished from their counterparts on more acidic substrates.

Unfortunately, as a result of urbanisation and the subsequent subdivision of the Cradle into smaller farms and smallholdings, many people have been following a policy of non-burning, or burning at the wrong time of year, even though the absolute essential role of fire in this area cannot be over-emphasised. The fact that most species' renewal buds, especially those of the grasses, are at or below the soil surface, suggest that the plants occurring in the grassland have adapted over millions of years to fire and grazing to such an extent that it has become an essential growth factor for them. The wild flowers follow a lifestyle of resprouting as opposed to reseeding.

By excluding fire in a grassland area, one could predict several consequences to the vegetation. Firstly, grasses will take over locally, increasing the biomass to an unproductive extent. So many of the herbaceous plants are completely dependent upon fire and are literally born again after a fire. Fortunately these plants are extremely resilient and they are able to grow to some degree in tall grass that have not been burnt the previous season, but there is no doubt that the grass will eventually take over and be followed by thorny shrubs and trees if regular burning does not take place. Eventually both the grasses and wild flowers will die and bush encroachment will occur. The most likely woody species to initiate this is *Acacia karroo* with its many ecotypes that are specifically adapted to take over grasslands that are protected from fire. It is a pioneer species in the succession from grassland to savannah (Bredenkamp *et al.,* 2002). As biomass accumulates, the inevitable lightning fire is likely to cause extensive damage to the vegetation, animals inhabiting the area and any human settlements, since the fire will be too hot.

The process of bush encroachment occurs at such a slow rate that it is not noticed within one human generation. Only when recent photographs are compared with photos of the same area that were taken some 50 or 100 years ago, is the extent of the bush encroachment realised.

The alteration of the vegetation cover of the Cradle will lead to a gradual alteration in the general hydrology of the area. The groundwater recharge rate and the surface run-off factors will change over time. This could have an effect on the quantity and quality of the groundwater environments of the Cradle. As this process trails the process of bush encroachment, the resultant impacts will only be noticed generations later. It is, however uncertain if the more rapid process of urbanisation in the catchment of the Cradle would overshadow and mask the effects bush encroachment would have on the groundwater environment.

10.3.8 Transportation of hazardous substances across the Cradle of Humankind World Heritage Site

The main highways between the metropolitan area of Johannesburg and Botswana as well as the platinum mines around Rustenburg traverse the Cradle or its catchment.

Many types of hazardous chemicals and other substances are transported to and from these areas daily. The chances exist that an accident could result in a serious spillage of a hazardous substance from a truck. Neither the local nor the district municipalities are really geared to handle such spillages, even though they claim the contrary. The rapid infiltration rate of dolomite and dolomitic soils could create a situation where a full tanker load of hazardous liquid would infiltrate the groundwater environment before the emergency services arrive at the site. The more vehicles there are on a particular road, the greater the chance of such a scenario developing.

Furthermore, Petronet has an underground petroleum pipeline crossing a large part of the Cradle's catchment from Randfontein via Tarlton to Rustenburg. Although they have excellent early warning systems in place, and would be able to stop pumps within minutes of a break in this pipeline, many thousands of litres of petroleum products could be spilt into the ground. All dolomite is considered to be unstable ground and ground movement could lead to pipe breakages.

In particular, the N14 roadway carries heavy hazardous traffic. During 1998, a study by the Western District Municipality found that at that time, 200 heavy vehicles carried hazardous substances (bearing "HazChem" signs) across the catchment of the Cradle along the N14 roadway. (J. Jordaan, Director Public Safety Western District Municipality, pers. com., 2006).

In April 2002 a fully laden fuel tanker truck was involved in an accident at Oaktree resulting in its entire fuel load being spilled into a storm water canal alongside the N14 roadway. Local residents attempted to contain the spillages by constructing berms across the storm water trenches along the road, but almost all the fuel eventually infiltrated into the ground before the emergency services arrived at the scene. In November 2005, a 10-Ton truck carrying organophosphate cattle dip, acetone, sulphur powder and an unquantified amount of other substances used in the manufacture of illegal drugs was involved in an accident in Krugersdorp. Leaking containers of acetone and cattle dip mixed with the sulphur powder and caused spontaneous combustion of the mixture. The gasses produced by the fire overcame the truck driver who drove the truck into a canal, a tributary of the Blougatspruit flowing into the Cradle.

The Emergency Services of Mogale City Local Municipality experienced similar reactions as the driver of the truck did when they attempted to put the fire out using water. Most of the cargo of this truck was eventually washed down this canal into the dolomitic aquifer of the Cradle via the Blougatspruit. Neither the local nor the district municipalities are really geared to handle such spillages. The distance from their depots to the Cradle is too great and the highly permeable soils covering the dolomite in this part of the Cradle allows most liquids to infiltrate into the ground long before the Emergency Services arrive on the scene of an accident. Furthermore, the Emergency Services need to be geared up to neutralise chemical hazards to protect people and property. Often this is done by the application of some or other liquid solvent onto the contaminated areas. This effectively increases the mobility of the spilt substance and assists its already rapid infiltration rate into the ground.

10.3.9 Subdivision of land, change of land use and alteration of surface run-off coefficients

The metropolitan area of Johannesburg is expanding. As a consequence of this, more and more agricultural land is being converted to residential or business stands. Only a few years back, the parts of the N14 highway to the east of the Cradle and Hendrik Potgieter Drive, traversed areas covered mostly by smallholdings and farms. Today, most of these smallholdings have been converted to high-density security-type housing complexes each with a residence occupying almost the entire stand. The increasing numbers of people making use of municipal services are causing increasing traffic and sewage problems. Add to these other municipal services that simply cannot cope with the increased demand. The urban sprawl has reached the boundaries of the Cradle and in some instances has already spilled over into the Cradle.

As veld is converted to roads, paved and roofed areas, the natural run-off coefficients are altered. More water runs off paved and roofed areas than would be the case with naturally vegetated areas.

Furthermore, in an attempt to make available as much land as possible for urban development, drainage lines, small streams and wetlands are canalised. The natural attenuation properties of these streams are therefore lost during this process. The nett result of the alteration of the run-off values for an area is the increase in flood peaks as well as the increase in the intensity of such a peak, albeit over a shorter time span. In other words, a storm's run-off, which would discharge a relatively low peak through a stream over a relatively long period, now rushes through the same stream at a much faster rate over a shorter period causing a high flood peak. Furthermore, less attenuation time allows a shorter period for infiltration into the groundwater environment, further increasing the flood intensity. This has a pronounced effect on downstream users and riparian properties and also impacts on the recharge of the groundwater aquifers.

A recent example just outside the Cradle is the increase in flood peaks experienced down a previously insignificant stream (a tributary of the Muldersdrift se Loop, Crocodile River Catchment) draining the new security complex, Pinehaven, at the intersection of the N14 and R28. To complicate things even further and due to poor civil engineering planning, the sewage pump station for the entire complex is located alongside and within the flood zone of this stream. Regular failure of the pump station resulting in continuous sewage spillages into this stream has resulted in a Supreme Court interdict against the Mogale City Local Municipality.

Another example of the alteration of run-off values occurred when the N14 was upgraded at Oaktree, opposite Bats' Cave in the Cradle. Storm water diverted off the road surface via a culvert, accumulating on the side of the road at the N14/R563 interchange. This caused a sinkhole right next to this busy road a mere 3 years after the road was upgraded. The problem has not yet been resolved some 7 months later.

Once a land use type has been changed, it cannot be undone and the natural resource has been lost forever. As it is, the Cradle does not form a hydrological unit as far as catchments are concerned. Furthermore, the demarcated land use types (as shown on the website www.cradleofhumankind.co.za) do not conform to the actual dispersal of caves.

The area known as *Sterkfontein Farm Estates*, which was subdivided into smallholdings a few years ago, located to the south and southwest of Bolt's Cave, is riddled with caves, many harbouring fossils. Yet this area is classified as a "Moderate Intensity Zone" in terms of the *Land Use Master Plan* map on the website, www.cradleofhumankind.co.za. Recently, disputes arose between landowners and the authorities relating to development in close proximity to caves. Yet these same authorities allowed the subdivision of land in the first place. These smallholdings are now used for residential and industrial purposes, while a wedding/conference venue has also been constructed on one of the stands. In addition to the Cradle not forming a hydrological unit, the Cradle also does not form a geographical unit.

10.3.10 Tourism

Since the Cradle has been declared a World Heritage Site, the perception has arisen that this opens the doors for any means of profiteering from the larger number of tourists visiting the area, whether the theme of the activity is in line with the theme of the Cradle or not. Many restaurants, wedding/conference venues, shops and other businesses have sprung up within and around the Cradle. Other activities include go-cart tracks, bungee jumping and rock climbing activities, totally unrelated to the theme of the Cradle. In addition, the increased numbers of tourists that visit the area also increases the pressure on the Cradle. More litter and sewage is produced, more water is pumped from the ground and more feet trample over the rocks and vegetation of the Cradle, causing increased damage and erosion. Without proper control of urbanisation within the Cradle and its catchment, there is no guarantee that a situation similar to the one along Hendrik Potgieter Drive will not occur.

The large number of tourists visiting the commercial caves, in particular, the Sterkfontein Cave, has also impacted severely on the interior of the caves. For example, very few areas exist where someone has not written, burnt or engraved some graffiti on the cave walls (**Figure** 10.11). It appears as if this cave in particular has been mismanaged from the day it was discovered and blasted to pieces by the lime miners in 1896.

Apart from the increased number of people visiting the Cradle, the landowners alter their environments to make the general area more attractive to the tourists. Hillsides are landscaped, roads are built where no roads previously existed, and grasslands are replaced with lawns and trees - often exotic species - to make the venue more attractive. Water features and dams are constructed and kept full with groundwater pumped from underground. It is understandable that for example, a wedding venue or conference centre in the open veld would attract fewer customers than the venue located among lush Oak trees, water features and green Kikuyu lawns. All these alterations to the landscape do, however, contribute to a general change in the environment.

Figure 10.11: Very few areas exist on the walls of the Sterkfontein Cave within reach of people where visitors have not written, burnt or engraved some sort of graffiti. This demonstrates the impact on the most important cave in the Cradle, but is also indicative of inexcusably poor management on behalf of the custodians of the cave (photo: W.G. Krige 03/02/2004).

10.4 Conclusions

This paper specifically addressed the impacts of urbanisation on the dolomitic groundwater compartments underlying the Cradle of Humankind World Heritage Site and included their catchments as part of the study, even though these catchments extend beyond the boundaries of the Cradle. Although the Cradle covers an area of 47 000 ha, the dolomite within the Cradle only covers approximately half of this area (22 890 ha). However, the catchment of these dolomitic compartments cover a total area of 47 745 ha, slightly more than the surface area of the Cradle. This catchment extends into the towns of Krugersdorp and Randfontein and covers large areas where gold has been mined for over a century.

Available data has shown that in the year 2000, there was a population of 98 729 people living within the catchment of the dolomitic compartments of the COH WHS.

The paper also shows that there are many impacters on the Cradle's water resources both within and outside the boundaries of the Cradle. This paper has shown in particular that the largest impacts on the water resources of the Cradle originate from outside the boundaries of the Cradle, but still within the catchment of the Cradle.

During the study, it has also come to light that many people living within the Cradle, within its catchment or travelers traveling through the Cradle, do not fully understand the meaning of the World Heritage Site and the necessity to protect it.

10.5 Recommendations

There are only two effective methods of protecting an environment - regulation and education. The one should go hand-in-hand with the other and should also go hand-in-hand with coordinated cooperation among the authorities. These two methods of protection should be supported by research and monitoring to identify and quantify the impacts on the Cradle and to propose mitigation measures to remediate these impacts. This protection should not only be focused on the Cradle itself, but also on the catchment of the Cradle outside the boundaries of the World Heritage Site.

10.5.1 Regulatory recommendations

There are a number of authorities that regulate activities within the Cradle. These include the Department of Water Affairs and Forestry (DWAF) that regulates the surface and groundwater aspects, Department of Agriculture that regulates the agricultural aspects, Gauteng Department of Agriculture, Conservation and the Environment that regulates the environmental matters, Department of Minerals and Energy that regulates the mining activities within the catchment of the Cradle and the district and local authorities that perform some of the regulatory functions on behalf of the national and provincial authorities. This paper has shown that there is not always sufficient communication between the different authorities.

South Africa has sufficient legislation to cover virtually all aspects requiring regulation within the Cradle. The problem is that there are not enough officials to enforce the laws. Neither is there communication among the authorities having jurisdiction over the Cradle. If there were more officials policing the Cradle and its catchment, aspects such as pollution of streams entering the Cradle, illegal development, cultivation of streambeds and flood plains, the uncontrolled abstraction of groundwater and uncoordinated urbanisation would not occur. Some steps have been taken in the right direction, but there is still need for improvement.

RESPONSE:

There is need for an overall regulatory authority to coordinate all activities within the Cradle and its catchment. This body should not create new regulations, but should rather act as a coordination body to ensure that all the existing regulation is adhered to and that all governing bodies are consulted during every environmental process. At present, each governing authority looks at items pertaining to their area of jurisdiction in isolation from the other disciplines and sometimes authorisation is given to projects that should never have been authorised. A holistic approach is required and this overall regulatory authority could administrate this function.

Consideration should also be given to the rezoning of the catchment of the Cradle to a Special Standard area as far as the requirements for the purification of wastewater or effluent are concerned (Gov. Notice No. 991 of 18 May 1984 as amended by G.NR.1930 of 31 August 1984, G.N.R.1864 of 15 November 1996). Currently the Cradle and its catchment fall within the General Effluent Standards zone. Almost all the sewage effluent produced by the two sewage plants discharging water into the Cradle recharges via streambed loss into the Zwartkrans Compartment of the Cradle while, originally all, and now part of the water decanting from the defunct gold mines enters the groundwater environment of the Cradle. A new set of effluent standards or guidelines should be formulated aimed specifically at the protection of the Karst water systems of the Cradle. The General Effluent Standards are not good enough considering the volumes of effluent being recharged into the groundwater of the Cradle and considering the importance of the Cradle as a World Heritage site.

10.5.2 Education

Although a great deal is being done as far as education in the Cradle is concerned, this education is often targeted at the wrong audiences. The educational facilities at Sterkfontein Caves and Maropeng are excellent and of world standard, but only reaches the tourists visiting these sites, mostly from outside the area or even the country. Furthermore, these educational facilities concentrate mostly on the anthropological history of the early hominids and do not pay any particular attention to the other unique botanical, zoological and geological features of the Cradle.

Education in all forms and for all types of audiences is required, but the most important foundation should be laid with the local residents. After all, they are the people owning, living in, running their businesses from and impacting upon the environment of the Cradle on a day-to-day basis. Education will lead to a sense of ownership amongst the residents and a form of voluntary self-policing could result from this. Most residents are unaware of what the Cradle stands for. They have never been informed and as most of them do not specialise in environmental matters, simply do not understand the issues and how they could help play a part in the protection of the Cradle.

It is the responsibility of the authorities to inform the residents as to the uniqueness of the area and how each resident/landowner can play a role in protecting the heritage site.

RESPONSE:

The education at Sterkfontein Caves and Maropeng is a good starting point, but should be expanded to include the other aspects of the Cradle and not focus solely on the anthropological aspects of the early hominids.

A concerted effort should be made by the authorities to target all the residents within the Cradle and even more importantly, the residents and businesses outside the Cradle, but still within the catchment of the Cradle. This is an enormous task, especially if all the role players outside the Cradle are to be reached. The education should also not be done as a once off process, but should continue as an on-going process.

The education could be done in a number of ways. The simplest is to distribute pamphlets informing people of the Cradle and emphasizing the important role that residents could play in protecting their heritage. If this method is successful, a sense of ownership will result among the residents of the cradle. All landowners and businesses within the Cradle receive some form of municipal or electricity bill. A monthly newsletter relating to the Cradle could be included in the distribution of these municipal bills. In this way, at least all the land and business owners within the Cradle will be reached. A different newsletter could be distributed in a similar matter to the landowners and businesses outside the Cradle but still within the catchment. As a result of the security situation in rural areas, virtually all landowners belong to one of the security firms operating in the Cradle. Most of these firms have a monthly newsletter, which is sent via post or email to their clients. It is unlikely that these firms would object to including a few paragraphs on the world heritage site into their newsletter.

The second form of education should be in the form of information dissemination meetings. There are many resident associations and policing forums throughout the Cradle. These associations have regular meetings and are usually run by people enthusiastic about their environment. Guest speakers should be welcome at these meetings.

Residents and farm workers that do not own land but still live within the area can be reached through public meetings at the public centres within the Cradle.

In many cases, travelers travel through the Cradle without even being aware of this fact. The N14 highway passes through part of the Cradle and crosses a significant part of the catchment of the Cradle. Although there are signs alongside the roads indicating the Cradle of Humankind, this is not enough to bring about a sense of place to the travelers. It is recommended that all the entrances to the Cradle be demarcated and that the traffic is brought to a standstill when entering the Cradle. It is also recommended that speed control devices be installed to reduce the speed, particularly of trucks that often transport hazardous substances through the Cradle.

When the local residents are educated properly and kept up-to-date with current and new matters and legislation, while casual travellers travelling through the Cradle are also made aware of the existence thereof, prosecution and successful conviction of transgressors, where these persist, will become easier as most residents would cooperate with the authorities.

10.5.3 Monitoring and Research

As a direct result of the decanting mine water from the defunct gold mines in the catchment of the Cradle, a great deal of monitoring is currently being done on the water of the Cradle. Most of this work is, however, being done by different disciplines and in isolation and a significant amount of duplication is experienced. A committee, the "*Western Basin Void Technical Group*" has been established under the chairmanship of DWAF. The aim of this technical group is to coordinate monitoring and to ensure the implementation of remedial actions to mitigate the impacts of the mining industry on the water resources of the Cradle. This technical group is, however, only concerned with the mine water.

There are insufficient monitoring points in the Cradle, especially for the monitoring of groundwater. DWAF had a number of monitoring points drilled during 1986, but these only cover the Tarlton area.

Research is required on a whole range of subjects to determine exactly how much pressure the Cradle can withstand before losing its appeal and natural heritage. This is a difficult task as not only the caves are vulnerable to overexploitation, but the general karst environment and its groundwater resources are also under threat of degradation. The problem is further worsened by the fact that the most significant impacters are located outside the Cradle, but within its catchment.

RESPONSE*:*

A single body or task team should be established. This body should be tasked with identifying the need for, and coordinating the water research and water monitoring undertaken within the Cradle. The *Western Basin Void Technical Group* could be expanded to encompass this role or a separate body could be established to perform these tasks. One of the functions of such a task team would be to establish an in-stream water quality objective for the streams entering the Cradle. This would involve the establishment of monitoring points within the surface streams where chemical, bacteriological and flow rates of the streams are monitored. This would identify ingress points into the groundwater, but, more importantly, a continued monitoring programme would identify polluters of the streams.

Another function of this task team would be to identify monitoring points throughout the Cradle where groundwater, in particular, could be monitored. Two groups of monitoring boreholes should be established. The first would be water quality boreholes. These boreholes should ideally be pumped regularly so that the water in the aquifer is sampled and not the water in the immediate vicinity of the borehole, as is the case with boreholes that are not regularly pumped. Ideally, these boreholes would be residential or commercial boreholes used for domestic or irrigational purposes. A second group of boreholes should be set aside for water level monitoring only. These boreholes should be located some distance from pumped boreholes and should not be pumped as pumping a borehole often creates a drawdown cone and would often result in false water level readings. Where perched water tables are encountered, water level monitoring boreholes should be placed in pairs, one for monitoring the shallow and one for monitoring the deep aquifer.

The data collected from these monitoring points should be compiled into a database and should be made available to everyone concerned.

REFERENCES

ACOCKS JPH (1988) Veld types of South Africa (3rd edition), *Memoirs of the Botanical Survey of South Africa* **57**, pp. 1-146.

BARNARD HC (2000) *An Explanation of the 1:500000 General Hydrogeological Map Johannesburg 2526*, Department of Water Affairs and Forestry.

BREDENKAMP GJ (1999) Grassland In: Knobel, J. (ed.) *The magnificent natural heritage of South Africa*, Sunbird Publishing, Llandudno, pp. 74-83.

BREDENKAMP DB, VAN DER WESTHUIZEN C, WIEGMANNS FE and KUHN CM (1986) *Groundwater supply potential of dolomite compartments west of Krugersdorp*. Technical Report Gh3440. Directorate Geohydrology. DWAF.

BREDENKAMP GJ, SPADA F and KAZMIERCZAK E (2002) On the origin of northern and southern hemisphere grasslands, *Plant Ecology* **163**, pp. 209-229.

BREDENKAMP GJ and BROWN LR (2003) A reappraisal of Acocks' Bankenveld: origin and diversity of vegetation types, *South African Journal of Botany* **69**, pp. 7-26.

BRINK ABA (1979) The First 2000 Million Years of Geological Time In: *Engineering Geology of Southern Africa 1*, In:. Building Publications. Pretoria. Not in the text

CARRUTHERS V (2000) *The Magaliesberg*, Protea Book House, Pretoria. Not in the text

CREPET WL and FELDMAN GD (1991) The earliest remains of grasses in the fossil record, *American Journal of Botany* **78**, pp. 1010-1014. Not in the text

GALL J (1983) *Ancient sedimentary environments and the habitats of living organisms: introduction to palaeoecology*, Springer-Verlag, New York. Not in the text

GROENEWALD J (this report) The impacts of agriculture on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site In: *The Karst System of the Cradle of Humankind World Heritage Site*, Issue Paper 11, WRC Consultancy Project No. K8/624, pp. 217-257.

HILTON-BARBER B and BERGER LR (2002) *The official field guide to the Cradle of Humankind*, Struik Publishers, Cape Town.

INGROUILLE M (1992) *Diversity and evolution of land plants*, Chapman and Hall, London. Not in the text

JAMISON AA (2004) *A Geological Assessment of Ground Disturbances Associated with the Western Rietfontein Wrench Fault System in the Percy Stewart Waste Water Sewage Works, Krugersdorp*, unpublished report for the Mogale City Local Municipality

JAMISON AA (2005) *Geological Aspects Of The Area Of The Tarlton Pump Station And Their Implications For The Petronet Refractionator Project*, unpublished report for the Western District Municipality.

JANIS CM (1993) Tertiary mammal evolution in the context of changing climates, vegetation and tectonic events, *Annual Review of Ecology and Systematics* **24**, pp. 467-500. Not in the text

KENNETT P (1983) *Palaeoecology*. Longman, York. Not in the text

KRIGE A and VAN WYK B (2005) The mystery of the silver vegetation, *Veld and Flora*, June 2005 not in the text

KRIGE WG and VAN BILJON M (this report) The impact of mining on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site, In: *The Karst System of the Cradle of Humankind World Heritage Site*, Issue Paper 9, WRC Consultancy Project No. K8/624, pp. 160-188.

KRIGE WG (1999) *An investigation into groundwater recharge derived from the upper Klip River tributaries where these cross the Main, Bird and Kimberley reef outcrops and associated shallow mine workings*, unpublished report for JCI Limited. Not in the text

LEEDER MR (1982) *Sedimentology Process and Product*, George Allen and Unwin Publishers, London. Not in the text

LOW AB and REBELO AG (1996) *Vegetation of South Africa, Lesotho and Swaziland*, Department of Environmental Affairs and Tourism, Pretoria.

PELCZAR MJ, REID RD and CHAN ECS (1977) *Microbiology*, McGraw-Hill Publishers, New York. Not in the text

SCOTT R (1995) *Flooding of the Central and East Rand Gold Mines*, WRC Report No. 486/1/95. not in the text

SA Explorer (2004) Municipal Demarcation Board.

TRUSWELL JF (1977) *The geological evolution of South Africa*. Purnell Publishers, Cape Town. Not in the text

VAN BILJON M and KRIGE WG (2005) *Cost apportionment for the treatment of contaminated water decanting from the Western Basin mine void.* Unpublished report for Harmony GM Co. Ltd.

VAN BILJON M and KRIGE WG (2005) *Proposed Water Management in the West Rand Basin Mine Void*, unpublished report for Harmony GM Co. Ltd.

VAN WYK AE and VAN WYK P (1997) *Field guide to trees of southern Africa*, Struik Publishers, Cape Town. Not in the text

WILLIS KJ and MCELWAIN JC (2002) *The evolution of plants*, Oxford University Press, Oxford

ISSUE PAPER **11**

THE IMPACTS OF AGRICULTURE ON THE WATER RESOURCES AND WATER-BASED ECOSYSTEMS OF THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

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ABSTRACT

This paper deals with agricultural impacts on groundwater specifically, but also on the environment in general which includes surface water, soils, fauna and flora. Agriculture is the largest consumer of surface and groundwater worldwide. In South Africa 72 per cent of all freshwater resources are utilised by agriculture, therefore it has a huge impact on water resources. Although water in general is a renewable resource, pollution can limit the quantities available for consumption. When groundwater is polluted it can be harmful for a certain period. It therefore needs to be protected at all costs and polluting activities managed as effectively as possible.

Agriculture has large-scale impacts on natural resources due to the waste products produced and application of fertiliser and pesticides for production. Both quantity and quality problems are associated with agriculture. Intensive animal husbandry, dairy farms, chicken farms and piggeries, cause the highest concentration of nitrate pollution to the soils, surface and groundwater through leaching or surface runoff of leachate. Fertilisers also cause nitrate and phosphate pollution if applied in excessive quantities. Pesticides, if applied in excess or due to spillage are also leached into groundwater or may be transported in the runoff to surface water bodies. Other sources of pollution that are associated with agriculture but not directly a cause thereof, include septic tanks or pit latrines, leaking fuel tanks and informal waste disposal. Inorganic, organic and microbiological substances as well as trace metals are the main contaminants derived from these activities and are only dangerous if present in high concentrations.

Although the majority of contaminants end up in the water resources, soils are also affected and pollutants end up in the food chain through vegetation growing on contaminated soils.

Good farming practices, if practised by the farming community as a whole and not just individually, could help tremendously in lowering contamination to these resources. Thus education to the farming community especially in the disadvantaged upcoming communities would be crucial to the sustainability of the environment.

The Cradle of Humankind World Heritage Site is famous for its caves where hominid fossils were found. These are all hosted within the

dolomite karst geology. This is a very intricate lithology with a maze of fractures created by dissolution. It thus forms a very advanced groundwater system or aquifer that is difficult to model conceptually. Pollution transport is not well understood in these terrains worldwide and is seen as a very vulnerable aquifer system. It is also extremely responsive to acidic waters causing dissolution of the dolomite, therefore any acidic contaminated water can be seen as a threat to cave formations and speleothem. Contaminants can be flushed through this system quite radically to end up in surface water downstream in the catchment or be trapped in "dead end" conduits or matrix where they could build up.

Agriculturally derived contaminants are already reported in higher concentrations throughout the Cradle in surface and groundwater samples. This could indicate historical build up as well as current pollution. Monitoring of pollution should be established throughout the Cradle to manage the resources and to ensure that the Cradle will be sustainable. Research in the agricultural field is by no means concluded especially in dolomitic terrains and should therefore be continued. A Cradle workgroup with task teams must be established to look into these various disciplines and ensure that authorities are informed of any misconduct that leads to degradation of the environment and to police this effectively. This group should also ensure that the overlapping tasks do not duplicate efforts.

The paper attempts to inform management about the possible dangers of agricultural activities, the resources that could be harmed as well as the extent of the damage with possible options to prevent this from happening. Prevention is much cheaper than remediation.

11.1 Introduction

Traditionally water use in South Africa was approached with a "don't care attitude" assuming limitless availability. In reality however, South Africa is a semi-arid to arid country with a precipitation average of 464 mm/annum and ranging from 200 to 600 mm/annum from west to east. Furthermore, precipitation is unreliable and unpredictable with below average figures being the norm. To add to this, ever increasing activities and population growth put pressure on the available resources. It was thus necessary to change the situation with the new Water Act that came into effect in 1998 to conserve and preserve the potable resources of the country through pro-active management. To this effect, a complete document with different sections covering all aspects of water use was compiled, with guidelines on water quality (DWAF, 1996). This document concentrates mainly on agriculture's impact on water resources with specific reference to the dolomitic area situated within the borders of the Cradle of Humankind World Heritage Site.

Agriculture is the biggest consumer of water resources of South Africa including both surface and groundwater resources. It is estimated (DWAF) that 62 per cent of all groundwater abstracted is used for irrigation and another 6 per cent for stock watering. There is an urgent need to manage South Africa's resources very carefully against over exploitation and pollution to optimise the amount of water available. With agriculture being the major consumer it is important to focus more efforts and resources in understanding the effects of agriculture on the Cradle of Humankind.

The use of water in agriculture in general impacts on water quantity as well as quality. In countries with high numbers of renewable freshwater resources, water quantity is usually not a problem, but in South Africa where water quantities are limited, agriculture could have a major effect on the resources, especially groundwater. Quality of water resources is usually the major concern of the two.

It is known worldwide that agriculture contributes to diffuse contamination through irrigation practices, animal feedlots and the use of fertilisers, pesticides and herbicides. Other pollution sources linked to agriculture in contributing to point-source contamination are typically pit latrines, insufficient septic tanks, uncontrolled disposal of household and agricultural waste products. Probably the most important factor to curb these and improve the situation is education (Braune *et al.*, 1991).

Understanding these sources of contamination is only part of the study while the complete hydrological cycle, with storage and ways of transport is probably the more critical part. For management and remediation purposes, it is also critical to understand the strata and geology through which contaminants move. Surface water is usually easily understood but groundwater is more difficult to characterise because it is generally not visible. Therefore it is usually easy to purify contaminated surface water sources while groundwater could take many years to purify. The Cradle area is even more complex due to the karstified dolomite underlying the area.

Agricultural activities in the Cradle area consist mainly of dairies, piggeries, feedlots, poultry, game farming, crop farming, horticulture and aquaculture. A number of associated problems occur due to pollution by agriculture, ranging from salinisation and over-saturation of toxic elements in soils and water to enteric diseases due to viruses and bacteria.

During a project undertaken for the Department of Mineral and Energy (DME) by the Council for Geoscience, hydrological samples were collected and analysed for inorganic chemistry. The results indicated typical agricultural pollution trends, although a more thorough temporal study needs to be conducted to pinpoint the origin and aerial extent thereof. Other tests and studies would also be beneficial for the management of the water resources of the COH WHS.

11.1.1 Objective and Scope

The purpose of this paper is to broadly explain the technical issues around pollution by agricultural activities on the immediate and surrounding environment. The environment includes the air, soil, rock surface and groundwater, although the emphasis will be mainly on the effect of pollution on the aqueous environment. The paper also highlights important steps that can be taken to minimise the pollution and ideas and research suggestions on how to improve management to ensure sustainability of resources.

11.1.2 Literature Review

Due to the nature and purpose of this paper no new research was undertaken or scientific methods applied. However, some new data was acquired from other projects which will be used to illustrate or explain some of the topics discussed. In order to satisfy the criteria listed in the purpose above, it was necessary to collate all current information on agricultural activities and their effect on the environment locally and internationally. Numerous publications are available on this topic in South Africa as well as abroad. New research was funded by the Water Research Commission (WRC) on issues not previously addressed due to several reasons. Most of these focus intensively on the technical aspects of the various specific problems. A comprehensive table of such publications appears in a publication by Conrad *et al.,* 1999, and Barbash and Resek, 1996. Table 11.1 gives a summary of the most important agricultural activities and their risk to surface and groundwater. From this review the most important processes are summarised and discussed.

11.1.3 Approach

As this paper only attempts to inform the reader on the current state of knowledge and not engage in new research, a brief description of each topic will be given to facilitate the understanding of the hydrologic regime. This will lay the foundation to understanding the impacts that agricultural activities might have on the hydrologic environment. A case study is presented in which the activities having the most severe impact on the COH WHS area are identified. The available data is then used to explain the extent of these impacts on the Cradle area. Furthermore, shortfalls in the available knowledge are identified and suggestions for further research are made.

The scope of the study and topics includes:

- Agriculture's influence on groundwater and surface water, especially if these resources are over-exploited in terms of quality and quantity;
- An explanation of the hydrodynamics and interaction between surface and groundwater specifically in South Africa's COH WHS;
- Over-extraction of water for irrigation - its effects on the fracture systems and how this could be managed;
- Application of fertilisers (and the excessive use and/or accumulation through time) as well as pathogenic influences from livestock - how this affects the system and what can be done to manage and remedy the situation;
- Effects of pesticides and fertilisers as well as the effect that alteration of the surface area and the banks of streams may have on the underlying dolomitic groundwater aquifers;
- Negative effects of salination on soils where water with high Total Dissolved Solid (TDS) content is used for irrigation.

Table 11.1: Most important agricultural activities and their impacts on water resources (modified from Conrad *et al.*, 1999).

Agricultural Activities	Impacts on water quality			
	High	Medium	Low	Unknown
Crop farming			✓	
Land clearing		✓		
Ploughing	✓			
Fertiliser application	✓			
Sludge application to land			✓	
Sowing			✓	
Dry-land crop farming	✓			
Irrigation-induced salinity				✓
Land-treatment systems	✓			
Pesticide application			✓	
Harvesting			✓	
Fallow				
Stock farming				
Feedlots	✓			
Ranching or extensive farming			✓	
Dips			✓	
Infrastructure				
Damming poor quality water			✓	
Waste disposal		✓		
Sewage disposal		(✓)		
Cemeteries		(✓)		
Storage		(✓)		

(✓) Best Management Practice

Response (actions required):

- Regulatory response required;
- Management response required;
- Research required – research gaps;
- Monitoring required.

11.2 The Soil Environment

Soil refers to the loose material occurring between the ground surface and the solid rock. It supports various forms of life and is essential to various processes required to ensure sustainability of life. Soils are a function of various physical, chemical and biological processes that are constantly at work changing soils over geological time.

Soil pollution is often thought of as resulting from chemical contamination such as through the use of excessive amounts of pesticides and fertilisers which in turn leads to surface or groundwater contamination. However there are other forms of soil pollution or degradation such as erosion, soil compaction and salinity. Soils have often been neglected when they are used for land disposal of waste chemicals and unwanted materials. Most soils are capable of adsorbing and neutralising many pollutants to harmless levels through chemical and biochemical processes. There are limits however, to the ability of soil to accept wastes without being affected in a negative way (Pierzynski *et al.,* 1993 this is 1994 in the reference list).

Soil physical properties are important when looking at infiltration rates and how liquids will move through the pores. Size grading of material is the most important factor as this will indicate what can move through the soil. Various countries have devised different classification systems. Soils can be partitioned into different horizons according to size, organic and mineral content.

Mineral solubility, soil reactions (pH), cation and anion exchange, buffering effects, and nutrient availability are major chemical properties of soils. These are primarily determined by the nature and quantity of clay and organic content present in the soil.

- Clay minerals have a large influence on the chemistry of many soils due to their large active surface area, which refers to its capability to be charged positively or negatively. Clay can substitute within its structure different minerals in the structure causing negatively charged surfaces and due to expansion of surface of some clays causes a larger area for adsorption of cations. Cation exchange capacity (CEC) refers to the surface area available for adsorption and releasing of cations. Clay is also fairly impermeable with very low conductivity and can thus help to chemically and physically capture and retard the movement of contaminants.
- Organic matter contributes to soil properties in structure, macro and micro nutrient supply, cation exchange capacity and pH buffering and is a source of carbon and energy for microorganisms (Table 11.2). Soil organic matter is comprised of decomposed plant and animal residue and is a highly complex mixture of carbon compounds that contains N, S and P. Table 11.3 lists the basic properties of soil organic matter and their effects on soils. From an environmental point of view, organic matter can either be beneficial or detrimental. It can adsorb trace elements (e.g. Pb, Cd and Cu), which reduces contamination of surface and groundwater. Organic matter can also adsorb pesticides and other organic chemicals and reduce the carryover effect, enhance both biological and non-biological degradation of pesticides and organic chemicals and adsorb inorganic and organic gases. However, negative effects include over-utilisation of pesticides in soils with high organic matter with the obvious possibility of percolation of these substances to groundwater. Due to its high adsorption rate it can lead to the accumulation of organic matter that could be toxic to animal and plant life as well as to humans consuming food.
- Ion exchange is one of the most significant functions of soils. It promotes the CEC of the soil and can also be pH dependant. It basically enhances leaching and transport of heavy metals and organic chemicals and other pollutants.

The biosphere is composed of the living portion of soils and includes plants, animals and microorganisms. They can be grouped into two major categories, *autotrophs* (producers), which assimilate C from CO_2 and obtain energy from sunlight through oxidation of inorganic compounds and *heterotrophs* (consumers), which use organic carbon as a source of energy. These organisms create tunnels in soil that are extremely important as preferential pathways in the recharge process of groundwater, but can also be very quick pathways for contaminants.

Table 11.2: Mechanisms of adsorption for organic compounds in soil solutions (from Yaron *et al.*, 1996).

Mechanism	Principal organic functional groups involved
Cation exchange	Amines, ring NH, heterocyclic N
Protonation	Amines, heterocyclic N, carbonyl, carboxylate
Anion exchange	Carboxylate
Water bridging	Amino, carboxylite, carbonyl, alcoholic OH
Cation bridging	Carboxylate, amines, carbonyl, alcoholic OH
Ligand exchange	Carboxylate
Hydrogen bonding	Amines, carbonyl, carboxyl, phenylhydroxyl
Van der Waal's interactions	Uncharged, nonpolar organic functional groups

11.3 Pollutants From Agriculture: Soil And Groundwater Quality

Several activities associated with agriculture and their impact on the environment were listed in Table 11.1. Specific pollutants arise from these activities due to a number of different processes taking place, but pollutants may also be formed during natural processes. The main pollutants are nitrogen, phosphorus, sodium (chloride) and trace metals, organic chemicals (pesticides) and sulphur. By far the most abundant is nitrate as nitrogen. Water quality, be it surface or groundwater quality, is influenced negatively by these pollutants if the agricultural activities are not managed correctly. Natural processes may also lead to the same problems, but the effects are limited when compared to anthropogenic contributions.

11.3.1 Nitrogen

Nitrogen can be found in many different forms including molecular N, organic molecules, geologic materials, gases and soluble ions. It is a very dynamic element, capable of being transformed through chemical or biochemical processes called the nitrogen cycle. The nitrogen cycle deals with the interaction between all the components, however this paper deals with the soil-N-cycle as this is where possible contamination of soil, ground and surface water could occur. The most important processes would be mineralisation, immobilisation, denitrification, leaching, erosion and biological N-fixing.

Figure 11.1 depicts the soil nitrogen cycle and the different processes involved in the transformation of the nitrogen element. Mineralisation is the process where organic forms like proteins and sugars, etc. are converted into inorganic N as ammonium-N (NH_4^+). The organic N may be part of the soil formation or added in the form of crop residues, animal manure or municipal wastes. The process is mediated by heterotrophic organisms (bacteria, fungi, etc.) that produce extracellular enzymes capable of degrading proteins (proteinases, peptidases) and non-proteins (chitanases, kinases) into ammonium. The organisms in turn derive energy from oxidation of soil organic matter and N is released during decomposition to produce amino acids and proteins essential for population growth. The reactions involved are as follows:

$$\text{Organic N} \rightarrow \text{Amino} - \text{N}(\text{R-NH}_2) + CO_2 + \text{Energy, by-products}$$

$$\text{Amino} - \text{N (R-NH}_2) \rightarrow NH_3 + H_2O \rightarrow NH_4^+ + OH^-$$

When ammonium has been mineralised it can be taken up by plants, nitrified, immobilised by soil microorganisms or held as exchangeable ion by clays and soil colloids. Mineralisation of N from soil organic matter provides a significant proportion of vegetation requirements. Ammonium is the preferred source of N for vegetation as compared to nitrates. Typical production of N by mineralisation is 15-70 kg –N/ha/a while recommendations for annual crops are in the range of 50-200 kg – N/ha/a (Pierzynski *et al.,* 1993 it is 1994 in the reference list).

Table 11.3: Soil organic matter and their associated effect on soil (after Pierzynski *et al.*, 1994).

Property	Remarks	Effect of soil
Colour	The typical dark colour of many soils is caused by organic matter.	May facilitate warming.
Water retention	Organic matter can hold up to 20 times its weight in water.	Helps prevent drying and shrinking. May significantly improve the moisture-retaining properties of sandy soils.
Combination with Clay minerals	Cements soil particles into structural units called aggregates.	Permits exchange of gases, stabilises structure and increases permeability.
Chelation	Forms stable complexes with Cu^{2+}, Mn^{2+}, Zn^{2+}, and other polyvalent cations.	May enhance the availability of micronutrients to high plants.
Solubility in water	Insolubility of organic matter is because of its association with clay. Also salts of divalent and trivalent cations with organic matter are insoluble. Isolated organic matter is partly soluble in water.	Little organic matter is lost in leaching.
Buffer action	Organic matter exhibits buffering in slightly acid, neutral and alkaline ranges.	Helps to maintain a uniform reaction in the soil.
Cation exchange	Total acidities of isolated fractions of humus range from 300 to 1400 cmol/kg.	May increase the cation exchange of CEC of the soil. From 20% to 70% of the CEC of many soils (e.g., Mollisols) is caused by organic matter.
Mineralisation	Decomposition of organic matter yields CO_2, NH_4^+ , NO_3^- , PO_3^{4-}, and SO_2^{4-}	A source of nutrient elements for plant growth.
Combines with Organic molecules	Affects bioactivity, persistence and biodegradability of pesticides.	Modifies application rate of pesticides for effective control.

Nitrification is the process where ammonium is converted into nitrite (NO_2^-) and then into nitrate (NO_3^-) through the actions of chemoautotrophic bacteria (that are obligatory aerobic) whereby CO_2 is decomposed into C and energy from oxidation of NH_4^+ or NO_2^-. Initially, bacteria of the genera *Nitrosomonas, Nitrosospira* and *Nitrosococcus* oxidise NH_4^+ to hydroxylamine (NH_2OH) and then, through not well understood intermediate compounds, to NO_2^-. It is important to note that the oxidation state of N changes from -3 to +3 leading to acidification of the soil by the hydrogen ions which are produced when ammonium is oxidised:

$$2NH_4^+ 3O_2 \rightarrow NH_2OH \rightarrow 2NO_2^- + 2\ H_2O + 4H^+ + \text{Energy}$$

Bacteria from the genera *Nitrobacter, Nitrospora* and *Nitrococcus* continue the oxidative process to convert nitrite into nitrate and change the oxidation state from +3 to +5:

$$2NO_2^- + O_2 \rightarrow 2NO_3^- + \text{Energy}$$

Nitrate can then be used by plants or lost from the root zone by denitrification, leaching or runoff. In most soils this is a rapid process.

Immobilisation is the reverse of mineralisation whereby inorganic N is transformed into organic compounds during microbial metabolism and growth. Plant uptake is a form of immobilisation. The formation of nitrogenous organic compounds is controlled by the amount of carbon available for production of amino acids and proteins. When large amounts of carbon are available to the inorganic N, microbial growth and consumption of soluble N will be stimulated. The ratio of C:N must be high to prevent formation of excessive soluble N that could be lost to the soil zone.

Nitrogen can also be lost from the soil zone through volatilisation and denitrification. Denitrification is the process where nitrates are reduced to gaseous forms of nitrogen by aerobic chemoautotrophic bacteria, although these bacteria can also operate under anaerobic conditions. Leaching, erosion and runoff can also contribute to the removal of nitrogen as nitrate from the soil root zone or from direct surface applications. Leaching occurs mainly due to the low capacity of most soils to retain anions. Leaching is affected by rate of plant uptake, denitrification, loss to the atmosphere and percolation rates and is more likely to leach to groundwater under the following conditions:

- High rates of nitrogen loading;
- Low ratios of C:N increasing the availability of nitrogen for mineralisation;
- High soil temperatures increasing nitrification;
- Well aerated soil encouraging nitrification;
- Low levels of plant uptake due to bare ground, low crop requirements or seasonally variable requirements;
- High levels of precipitation or irrigation;
- High vertical soil permeability;
- Shallow unconfined water table or perched aquifer.

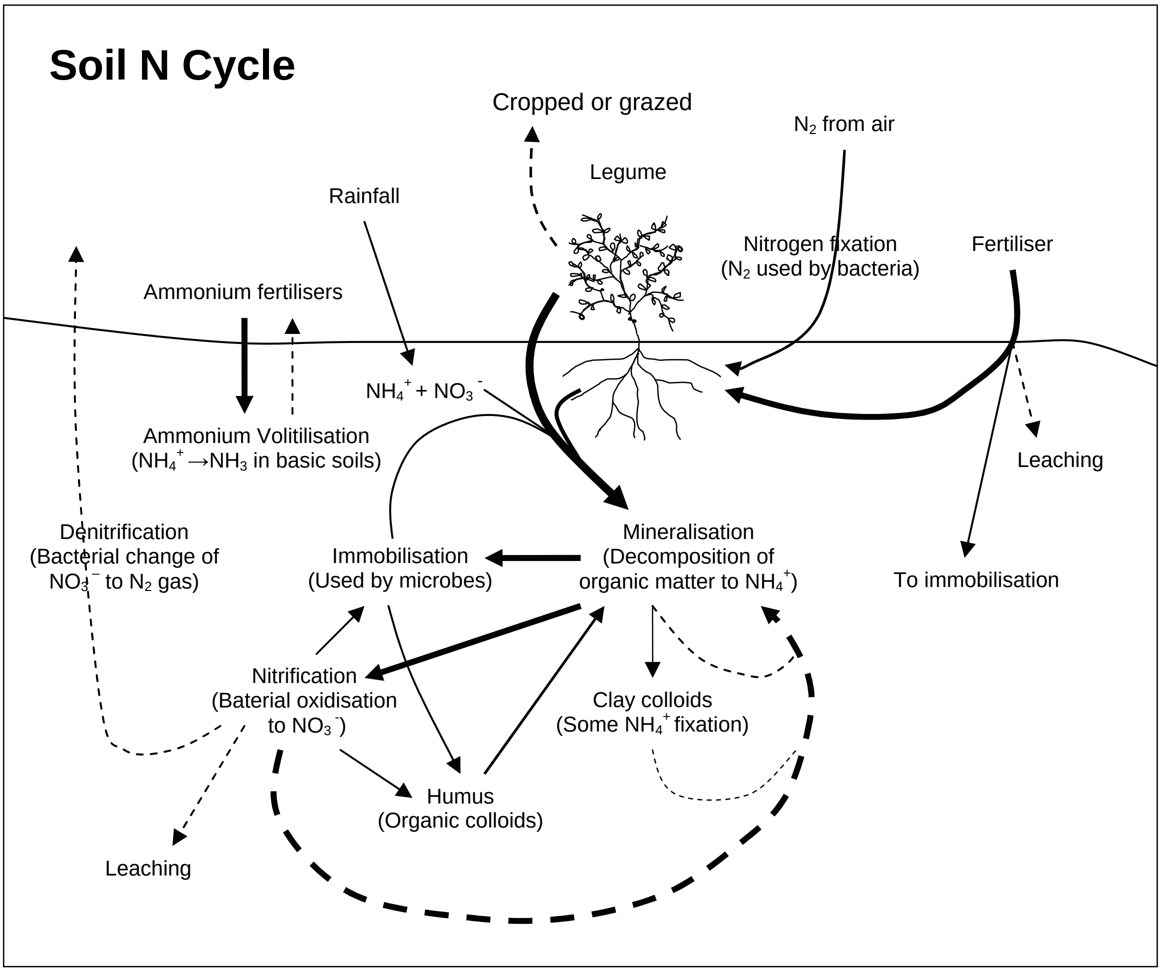

Figure 11.1: Nitrogen soil cycle.

Nitrates are rarely reported in fully confined aquifers due to the reductive environment. Although nitrate is the more soluble form of nitrogen, plumes of organic nitrogen and ammonium have been reported due to effluent application to soil surfaces (Conrad *et al.,* 1999).

Sources of nitrogen include inorganic and organic. Table 11.4 lists the major commercial nitrogen fertilisers and their properties while Table 11.5 lists the most common organic wastes.

Some of the effects of nitrogen pollution on the environment and human health are listed in Table 11.6. Nitrogen effects on human and animal health are basically associated with the consumption of nitrate in excessive concentrations from drinking water. *Methaemoglobinaemia* ("Blue baby syndrome") and possible carcinogenic effects due to nitrosamines, are the main health problems associated with nitrogen consumption. *Methaemoglobinaemia* is not caused directly by nitrates but occurs when bacteria in the digestive track of humans and animals reduce nitrate to nitrite, which then oxidises the iron in the haemoglobin molecule from Fe^{2+} to Fe^{3+}, forming methaemoglobin, which cannot perform the oxygen transport functions of haemoglobin. This results in the bluish discoloration in infants. Infants between 3-6 months are the most vulnerable to this syndrome as adults develop acids that are strong enough to suppress the activity of the bacteria. Animals may also be susceptible to this disease, but at much higher nitrogen concentrations.

Table 11.4: Most popular commercial fertilisers.

Nitrogen source	Chemical composition	%N
Ammoniacal N sources:		
Anhydrous ammonia	NH_3	82
Aqua ammonia	$NH_3.H_2O$	20-25
Ammonium chloride	NH_4Cl	25
Ammonium nitrate	NH_4NO_3	33
Ammonium sulfate	$(NH_4)_2SO_4$	21
Nitrate N sources:		
Calcium nitrate	$Ca(NO_3)_2$	15
Potassium nitrate	KNO_3	13
Sodium nitrate	$NaNO_3$	16
Urea materials:		
Urea	$CO(NH_2)_2$	45
Urea-ammonium-nitrate solution	30-35% Urea:40-43% NH_4NO_3	27-32
Ureaform	Urea-formaldehyde	38
IBDU	Isobutylidene diurea	32
SCU	Sulfur-coated urea	36-38
Nitrogen-phosphorus materials:		
Monoammonium phosphate (MAP)	$NH_4H_2PO_4$	11
Diammonium phosphate (DAP)	$(NH_4)_2HPO_4$	18-21
Ammonium polyphosphates (liquid)	$(NH_4)_3HP_2O_7$	10-11

Table 11.5: Organic sources of nitrogen.

Organic N source	Total N (%)	Organic N Mineralised* (%)
Animal manures		
Beef	1.3-1.8	25-35
Dairy	2.5-3.0	25-40
Poultry	4.0-6.0	50-70
Swine	3.5-4.5	30-50
Sludge products		
Aerobic digestion	3.5-5.0	25-40
Anaerobic digestion	1.8-2.5	10-20
Composted	0.5-1.5	(-10)-10
Other wastes		
Fermentation wastes	3.0-8.0	20-50
Poultry processing wastes	4.0-8.0	40-60
Paper mill sludges	0.2-1.0	(-20)-5

Note: Average values from various sources.
* Organic N mineralised estimated from laboratory incubation studies. Negative values for composts and paper mill sludges indicate that immobilisation of N occurred.

Eutrophication is defined as an increase in the nutrient level of natural waters and causes accelerated growth of algae or water plants, depletion of dissolved oxygen, increased turbidity and general deterioration of water quality. The level of nitrogen causing eutrophication is much lower than the level of nitrogen that needs to be present to regard drinking water as being contaminated. The N:P ratio in water is an important dependant but concentrations for eutrophication are in the order of 0.5-1.0 mg N/ℓ.

Table 11.6: Causes and effects of nitrogen pollution to the environment.

Environmental issue	Causative mechanisms and impacts
Human and animal health:	
Methemoglobinemia	Consumption of high nitrate drinking waters and food; particularly important for infants because it disrupts oxygen transport system in blood.
Cancer	Exposure to nitrosoamines formed by reaction of amines with nitrosating agents; skin cancer increased by greater exposure to ultraviolet radiation due to destruction of ozone layer.
Nitrate poisoning	Livestock ingestion of high nitrate feed or waters.
Ecosystem damage:	
Groundwater contamination	Nitrate leaching from fertilizers, manures, sludges, wastewaters, septic systems; can impact both human and animal health, and trophic state of surface waters.
Eutrophication of surface waters	Soluble or sediment-bound N from erosion, surface runoff, or groundwater discharge enters surface waters; direct discharge of N from municipal and industrial wastewater treatment plants into surface water; atmospheric deposition of ammonia and nitric acid; general degradation of water quality and biological diversity of freshwaters.
Acid rain	Nitric acid originating from reaction of N oxides with moisture in atmosphere is returned to terrestrial ecosystem as acidic rainfall, snow, mists or fogs (wet deposition) or as particulates (dry deposition); damages sensitive vegetation, acidifies surface waters, and, as with eutrophication, can unfavourably alter biodiversity in lakes, streams, bays
Stratospheric ozone depletion, global climate change	Nitrous oxides from burning of fossil fuels by industry and automobiles and from denitrification of nitrate in soils are transported to stratosphere where ozone destruction occurs; ultraviolet radiation incident on earth's surface increases as does global warming.

11.3.2 Phosphorus

Phosphorus is essential to all life forms and has no known toxic effects. Large inputs of bioavailable P from rivers or groundwater induces the growth of biomass and causes eutrophication. The occurrence of P in soils is much less than nitrogen or potassium and specifically in South African soils, P levels are much lower than what is required to sustain crops. As with nitrate, a set of chemical and physical reactions transforms the state of phosphorus and is referred to as the soil phosphorus cycle (**Figure** 11.2). Two forms of P (although P in soil is relatively immobile and insoluble) are available, inorganic (available for plant uptake) and organic P which has to be transformed to be available for plant uptake. However, point sources are the major origins of pollution that are carrying large concentrations of P.

The main problematic source of P is found in feedlot waste where P values can be as high as 400 mg/ℓ. It occurs mainly in faeces of livestock rather than urine (Conrad *et al.*, 1999). Table 11.7 lists the major agricultural sources of phosphorus into the environment

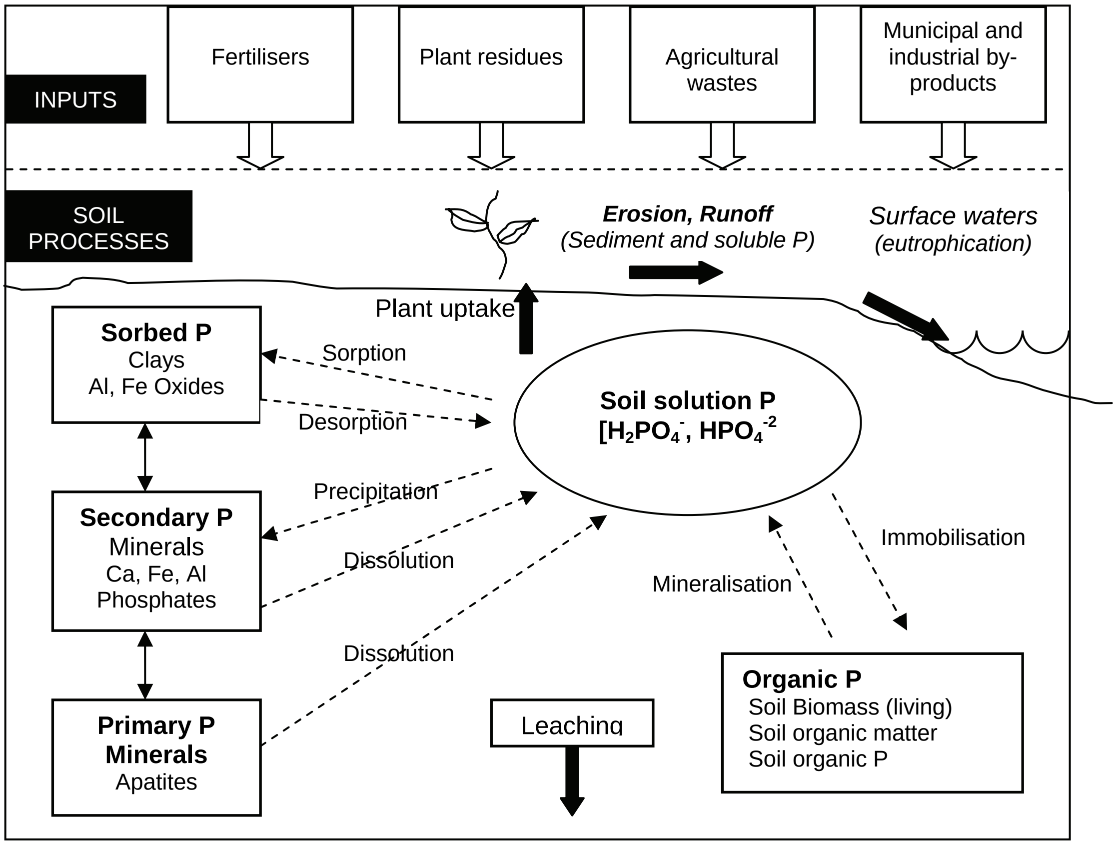

Figure 11.2: Soil Phosphorus cycle (after Yaron *et al.*, 1996).

11.3.3 Salts

The soil liquid phase as well as all water reaching the soil, is characterised by a specific salt content. The distribution of the ions between the soil liquid and solid phases is governed by the exchange properties of the solid phase and controlled by the ion exchange process. As an example, chemical examination of solutions obtained from soils in arid and semi-arid regions identified sodium, calcium, potassium, chloride, sulfates, bicarbonate and carbonate as major ionic species. Due to human input, the concentrations as reflected by its quantity and ionic ratios could become harmful to the environment.

The anions chloride and sulphate could both become pollutants due to excessive application of irrigation waters with high salt content. Due to the high chloride content in irrigation water, disturbance of the soil-chloride balance occurs. The result is that the content of the chloride within the soils exceeds crop tolerances and causes damage to the leaves.

Sulphur reaches the soil when municipal sewage effluents with high concentrations of sulphate are used for irrigation. Natural sulphur originates from atmospheric sulphur and rock-bearing minerals. Sulphur may be toxic to humans and animals.

The cation sodium is the most important pollutant originating from anthropogenic sources. Sodium chloride is the most important halide mineral in soil, is very soluble and is easily removed from the soil by leaching with water.

The presence of sodium in the soil therefore has to be the result of accumulation of large external quantities in soils. Due to exchange processes sodium can exchange calcium and magnesium to the exchangeable soil complex and accumulate in the soil. Sodium is potentially toxic to vegetation when tolerable concentrations are exceeded. The sodium adsorption ratio (SAR) is an index of the potential of a given irrigation water to induce sodic soil conditions. (Soil sodicity is usually defined as the percentage of a soil's cation exchange capacity that is occupied by sodium ions). It is calculated from the concentrations of Na, Ca and Mg in water, and gives an indication of the level at which the exchangeable sodium percentage (ESP) of the soil will stabilise after prolonged irrigation.

Changes to the ESP start in the topsoil and move progressively down to lower layers, therefore short-term variations in irrigation water SAR affects the soil profile ESP only marginally, but largely determines the ESP at the soil surface. The SAR of an irrigation water increases in soil when its sodium, calcium and magnesium content increases together with that of other ions when water is lost through evapotranspiration. This gives rise to a progressive increase in soil ESP from the top to the bottom soil layers in tandem with the increasing salt concentration from top to bottom. By decreasing the leaching fraction, both the salt concentration and ESP in the bottom soil layers are thus increased, and *vice versa* (DWAF, Water Quality Guidelines, 1996).

Table 11.7: Most common agricultural sources of phosphorus into the environment (after Yaron *et al.*, 1996).

Phosphorus source and chemical composition		%P	%P_2O_5	Other nutrients
Commercial fertilisers:				
Ordinary superphosphate	$[Ca(H_2PO_4)_2 + CaSO_4)]$	7-10	16-23	Ca, S (8-10%)
Triple superphosphate	$[Ca(H_2PO_4)_2]$	19-23	44-52	Ca
Monoammonium phosphate (MAP)	$(NH_4H_2PO_4]$	26	61	N (12%)
Diammonium phosphate (DAP)	$[(NH_4)_2HPO_4]$	23	53	N (21%)
Urea-ammonium phosphate	$[CO(NH_2)_2,NH_4H_2PO_4]$	12	28	N (28%)
Ammonium polyphosphates (liquid)	$[(NH_4)_3HP_2O_7]$	15	34	N (11%)
Rock phosphates:				
U.S. (Florida)	$[Ca_{10}F_2(PO_4)_6 \cdot XCaCO_3]$ (varies between mineral deposits)	14	33	Major impurities: Al, Fe, Si, Fe, CO
Brazil		15	35	
Morocco		14	33	
Former U.S.S.R.		17	39	
Organic phosphorus sources:				
Beef manure		0.9	2.1	N, K, S, Ca, Mg, and microelements
Dairy manure		0.6	1.4	
Poultry manure		1.8	4.1	
Swine manure		1.5	3.5	
Aerobically digested sludge		3.3	7.6	
Anaerobically digested sludge		3.6	8.3	
Composted sludge		1.3	3.0	

11.3.4 Trace Elements

Trace elements are those minor constituents that occur in small concentrations per volume although some might occur at higher concentrations in soils and rocks e.g. titanium, iron and aluminium. They are mainly transported in soil sediments to the hydrological regime and also through anthropogenic additions. Some are beneficial and required for human and animal sustenance but when tolerance levels are exceeded may become extremely toxic. Sources of trace elements from agricultural activities are mostly through feeds and animal wastes. Table 11.8 summarises the estimated extent of trace element poisoning in the world while Table 11.9 lists the species affected by different trace elements. **Figure** 11.3 is a diagram depicting the trace element cycle in soils.

Table 11.8: Estimated magnitude of the extent of trace element poisoning (after Nriagu, 1988).

Element	Global emissions (1000 mt/yr)			People affected	Comments
	Air	Water	Soil		
Pb	332	138	796	>1 billion	Blood Pb > 20 µg/dℓ
Cd	7.6	9.4	22	500 000	Producing renal dysfunction
Hg	3.6	4.6	8.3	80 000	Certified Hg poisonings
As	18.8	41	82	>100 000	Skin disorder and H_2O As >2 µg/ℓ

Table 11.9: Species affected by certain trace elements (after Nriagu, 1988).

Element	Species adversely affected				
	Humans	Animals	Aquatic organisms	Birds	Plants
Cd As, Pb, Hg, Cr, Se Cu, Ni, Zn Mo, F, Co B	* *	* * *	* * *	* *	* * *

11.3.5 *Organic Chemicals (Pesticides)*

Synthetic organic chemicals/compounds include pesticides, lubricants, solvents, fuels and propellants. Agricultural activities contribute probably most of these (perhaps excluding propellants) to the environment due to poor farming management. The most widely-used organic chemicals, however, are pesticides. Industrial waste in municipal sewage works also contributes synthetic organic chemicals when used as irrigation water.

Transport of pesticides through the soil medium into groundwater and removal and retarding processes as well as the modeling of the individual processes are quite complicated. The basic processes are depicted in **Figure** 11.4. Groundwater pollution from pesticides is mainly linked to leaching rates through the soil medium. Leaching rates are governed by adsorptive capacity of the soil, biodegradation and uptake by living organisms, amount of overhead water, and solubility of the leached compound or chemical. The more chemically stable the compound, the easier it will leach through to groundwater due to its resistivity against the above-mentioned factors.

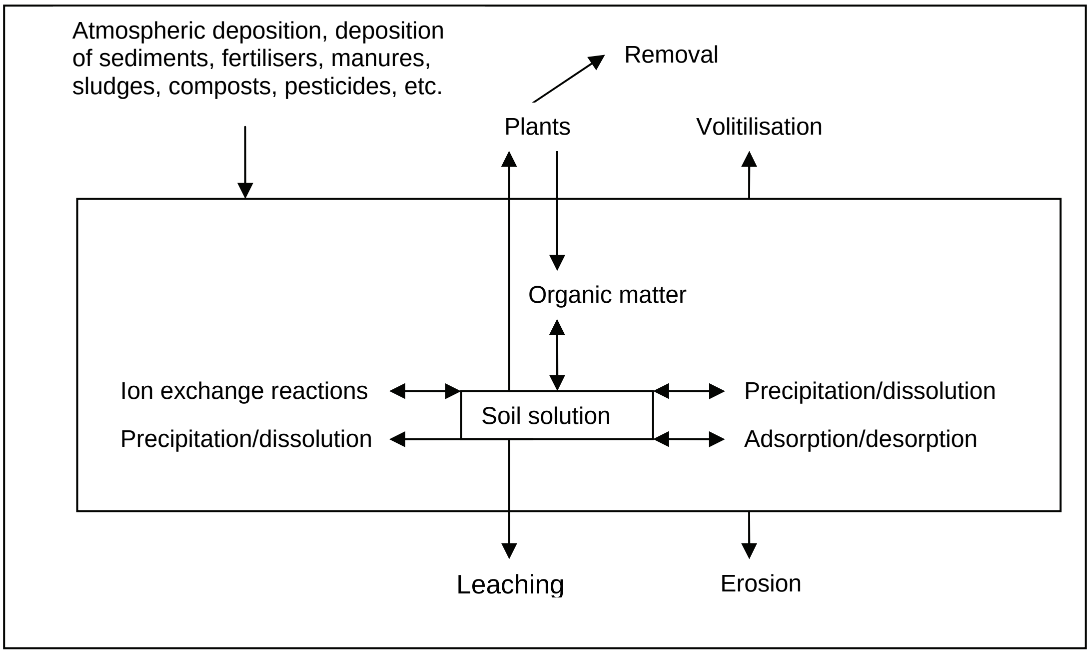

Figure 11.3: Diagram depicting the trace element cycle in soils (Pierzynski *et al.*, 1993 it is 1994 in the reference list).

Pesticides in high doses are harmful to plant life, humans, animals and microorganisms. However plants and microorganisms can build up a resistance to certain pesticides.

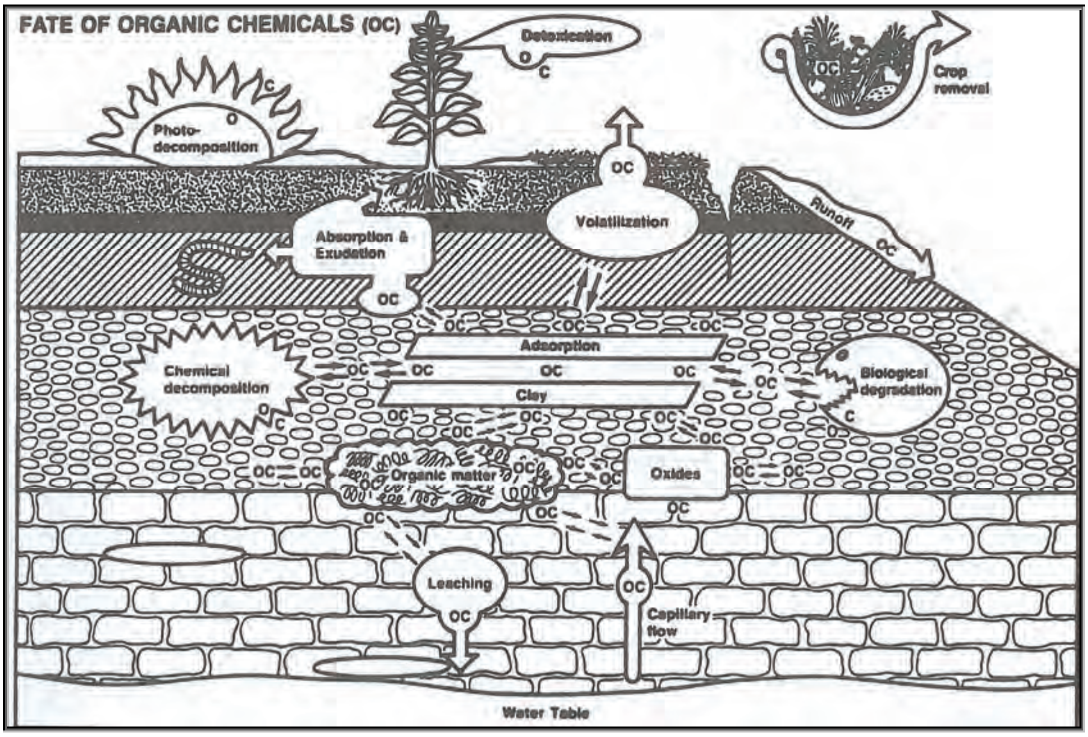

Figure 11.4: Organic chemicals cycle in the environment (from Pierzynski *et al.,* 1994).

The various elements and organic compounds mentioned above are listed along with the specific sources of pollutants in Table 11.10. These are specifically for South African conditions and should be the same for the Cradle environment.

Table 11.10: Sources of pollution from agricultural activities and the associated pollutants derived from agriculture in South Africa (after Conrad *et al.*, 1999).

Source	Nutrients	Trace metals	Salinity/ Acidity	Synthetic organics	Other organic	Microbial pathogens
Inorganic fertilisers	NO_3 NH_4K PO_4 DOC	As Cd Cr Cu Fe Pb Mn Hg Ni Zn	Salinity SO_4 Cl			
Sewage sludge	NO_3 NH_4K PO_4 DOC	Possibly Cd Zn		Traces of industrial chemicals e.g. PAH		bacteria viruses & parasites
Wastewater irrigation	NO_3 NH_4K PO_4 DOC	Possibly Cu Pb Ni Zn				bacteria viruses & parasites
Pesticide & herbicide application		As Pb		carbonates, chlorinated insecticides, chlorophenols, naphthalene, organo-phosphates, phenols, phthalates		
Animal wastes	NO_3 NH_4K PO_4 DOC		EC may be higher		hormones & steriods	bacteria viruses & parasites
Abattoirs	NO_3 NH_4K PO_4 DOC		EC may be higher	Pesticides	biogenic amines	bacteria viruses & parasites

11.3.6 Microbial Contaminants

In Table 11.11 some of the common bacteria found in water are listed. Faecal coliform bacteria are found in the faeces of humans and other warm-blooded animals. These bacteria can enter rivers through direct discharge from mammals and birds, from agricultural and storm runoff carrying wastes from birds and mammals, and from human sewage discharge into the water.

Faecal coliforms are not pathogenic as such. Pathogenic organisms include bacteria, viruses, and parasites that cause diseases and illnesses. Faecal coliform bacteria naturally occur in the human digestive tract, and aid in the digestion of food. However in infected individuals, pathogenic organisms are found along with faecal coliform bacteria.

If faecal coliform counts are high (over 200 colonies/100 mℓ of water sample) in the river, there is a greater chance that pathogenic organisms are also present. A person swimming in such water has a good chance of getting sick from swallowing disease-causing organisms, or from pathogens entering the body through cuts in the skin, nose, mouth or the ears. Disease and illness such as typhoid fever, hepatitis, gastroenteritis, dysentery, and ear infections may be contracted in waters with high faecal coliform counts.

Pathogens are relatively scarce in water, making them difficult and time-consuming to monitor directly. Instead, faecal coliform levels are monitored, because of the correlation between faecal coliform counts and the probability of contracting a disease from the water.

Table 11.11: Common bacteria found in water that could cause disease (water microbiology: http://www.lenntech.com/faq.htm).

Bacteria	Disease/ infection	Symptoms
Aeromonas	Enteritis	Very thin, blood and mucus containing diarrhoea
Campylobacter jejuni	Campilobacteriose	Flue, diarrhoea, head and stomach aches, fever, cramps and nausea
Escherichia coli	Urinary tract infections, neonatal meningitis, intestinal disease	Watery diarrhoea, headaches, fever, homiletic uraemia, kidney damage
Plesiomonas shigelloides	Plesiomonas-infection	Nausea, stomach aches and watery diarrhoea, sometimes fever, headaches and vomiting
Salmonella	Typhoid fever	Fever
	Salmonellosis	Sickness, intestinal cramps, vomiting, diarrhoea and sometimes light fever
Streptococcus	(Gastro) intestinal disease	Stomach aches, diarrhoea and fever, sometimes vomiting
Vibrio El Tor (freshwater)	(Light form of) Cholera	Heavy diarrhoea

11.4 Groundwater Quantity Problems

South Africa is a semi-arid country with low precipitation recharging its surface and groundwater resources. Crops requiring irrigation are therefore not suitable for this region, especially where two or more crops are required annually. In fact, the country is barely suited for normal seasonal crop production (once per annum). Groundwater is therefore mostly utilised as supplement to the natural precipitation in this arid climate to produce crops. The amount of water necessary for this is huge and millions of cubic meters of water are used annually. Braune and Coetzer reported in a study in 1990 that a total of 1.3 million ha of land were under irrigation of which 58 041 ha were using groundwater.

Most of the aquifers in South Africa are of the secondary fractured type, with mainly dual porosity systems. This means that small aperture fractures serve as the conduits for millions of cubic meters of water stored in matrix or low permeable fracture zone networks to yield water for production. To utilise the groundwater, boreholes are mostly drilled into these semi-confined aquifers to a depth where the major fractures are encountered. These fractures can be from a few millimeters to a couple of centimeters in aperture. In a balanced undisturbed equilibrium the pressure of the water basically keeps these fractures open and groundwater flow continues. When farmers use water from boreholes for production they insert pumps just below these fracture openings (or so called water strike zones) where the best blow yields were encountered. Boreholes, when drilled by percussion drilling machines, are tested on the basis of the machines' capabilities to displace the water from the borehole, or blow yield. These yield values are then communicated to the farmer who applies these optimistic per hour yields for production. However, this is seldom the conservative sustainable yield that the aquifer system can provide and most of the time the water table drops below the intake of the installed pump either after long periods or even after a short space of time, depending on the aquifer characteristics.

Usually the opened fractured system closes due to the release of pressure support from the water in the fractures during equilibrium. When this happens it is almost impossible to reopen these fractures and such a borehole is damaged.

The other scenario is when extensive pumping or extraction from an aquifer causes the storage from the matrix to be depleted before actual recharge to the system can take place. This usually happens when the aquifers have not been tested for sustainable use, after low precipitation seasons for several consecutive years or in the few instances where water is paleo-recharged over millennia and then depleted.

In dolomitic karst terrain, when huge volumes of water are extracted, surface features collapse creating dolines or sinkholes. This occurs when the water table which supports the surface bridges over solution openings or cavities are lowered which causes surface collapse into these openings. The first few meters of the surface, 0 to 5 metres of soil and unconsolidated material will give way or fall into openings at the lower level. Natural fluctuations due to differing climates over the millennia have caused similar collapses and have resulted in the cave system which is currently observed. However, a fast track of these natural processes is now causing excessive damage to cave systems which include the aquifer systems found in the Cradle. These aquifers are being depleted due to irrigation farming at alarming rates, and are not properly recharged due to the problematic climatic conditions and sporadic precipitation.

Proper management and education will be the only tools in preventing complete damage to aquifers. Monitoring of water levels and modeling of water consumption to ensure sustainability will have to become requirements for groundwater irrigated farms. Negative impacts on aquifers have to be minimised in dolomitic areas - current licensed groundwater users in stressed areas, currently monitored by DWAF, will be required to reduce consumption. Proper management of groundwater consumption in these stressed areas must be enforced.

11.5 Quality Problems Due To Agriculture

As can be seen from the previous section, a number of pollutants derived from agricultural activities can contribute to contamination of different environments. Water quality is the most important issue to consider when looking at potential damage due to agricultural activities, because although a farmer may have the required quantity of water, it might not be fit for use in general.

Quite a number of activities to produce food and ensure food security are in fact responsible for contaminating the different environments to a greater or lesser degree. A study conducted for the WRC by Conrad *et al*., 1999 investigated the different activities and the pollution caused to the environment. The most important contributors are crop farming and associated activities and animal husbandry. These were well researched and documented. A brief summary of these case studies will be discussed to explain the methods of contamination by the pollutants listed in section 11.4 and the receiving environment.

11.5.1 Animal Husbandry

The most concentrated pollutants arise from animal husbandry and are usually of point source origin. They include aquaculture, dairy farming, poultry, feedlots, pig farming and ostriches in breeding or feeding camps.

A feedlot, piggery and dairies were investigated during the study. The study was conducted at three commercial farms of which two are situated in the Western Cape and one in Gauteng. The main environmental impact from Intensive Animal Husbandry (IAH) is caused by the large volumes of animal waste products concentrated in small areas. These are usually disposed of by selling or are used as on-site fertiliser for cropped land. Obvious main concerns are pollution due to surface runoff, effluent disposal into surface streams, infiltration due to percolation to groundwater as well as the odour released and the resulting attraction to flies which becomes a nuisance. The legislation for Conservation of Agricultural Resources Act No. 43 of 1983 and Sections 21 to 26 of the Water Act of 1998 both recognise the importance of protecting the environment, crop lands and the receiving water areas downstream. Effluent leaving these sites should comply with water quality standards and should not exceed the following maxima:

- Electrical Conductivity (EC) of 250 mS/m
- Free and bound ammonium-nitrogen of 10mg/ℓ
- Soluble orthophosphate of 1 mg/ℓ
- Sodium of 200 mg/ℓ
- Residual chlorine of 0.1 mg/ℓ
- Suspended solids of 25 mg/ℓ

It was found that the impacts due to IAH on groundwater, mainly due to mismanagement, are the following:

- Storage of liquids and solid wastes, unsealed effluent dams and manure heaps with uncontrolled runoff;
- Distribution and disposal of solid waste, particularly when carried out without crop/pasture requirements in mind;
- Cleaning from stalls and pens, and not keeping the interface layer intact;
- Abandonment of stalls and pens, with the resulting shrinkage causing cracks followed by infiltration;
- Periodic concentration of livestock in areas with limited compaction such as feeding troughs and gates resulting in pasture-high levels of urine and manure;

- Burial of livestock carcasses which can lead to contamination in areas with vulnerable shallow groundwater;
- Storage of feeds which can cause contamination of groundwater if the feeds are not covered.

The study concluded that all groundwater samples indicated some degree of contamination by animal wastes. Though nitrogen is the contaminant of greatest potential concern due to high loadings of animal waste, other pollutants include Dissolved Organic Carbon (DOC), ortho-phosphates, potassium and microbial indicators of faecal pollution. Parameters that were found to aid in the prevention of groundwater contamination were topographic gradient, low bulk densities of clay-rich soils and thickness of the unsaturated zone.

Other poor management practices that contributed to groundwater pollution were irrigation of effluents onto pasture, intermittent concentration of livestock into limited areas of pasture, leakage from constructed effluent channels and leakage to the unsaturated zone from effluent lagoons where the self-sealing layer had been removed. Good management practices preventing contamination were found to be runoff control, maintenance of a feed pen interface layer, storage of waste on constructed areas and siting of feed pens on a slope, with areas of cattle congregation around the feed troughs up the gradient.

The most important factor controlling contamination seemed to be the vulnerability of the aquifers and the geological diversity that hosts them. Understanding these seems to be the most crucial aspect when management strategies are developed. A summary of the contamination by IAH for the study area investigated is shown in Table 11.12.

Table 11.12: Summary of contaminants found on three sites investigated associated with IAH (after Conrad *et al.* 1999).

Probable IAH groundwater contamination:	**Site A**	**Site B**	**Site C**
Nitrates	Yes – to a max of 27mg/ℓ associated with the dairy operations (?). Also associated with waste slurry flooding.	Yes – to max of 156mg/ℓ associated with cow concentrated at feed trough in pasture. Also in effluent irrigated pasture.	No
DOC	No	Yes – to max of 55mg/ℓ next to waste channel. Also in effluent irrigated pasture and at feed trough in pasture.	No
Potassium	No	Yes – to max of 259mg/ℓ at feed trough in pasture. Also in effluent irrigated pasture and at feed trough in pasture.	No
Ortho-phosphates	No	Yes – to max of 6mg/ℓ in effluent irrigated pasture also next to waste channel.	No

Microbiological indicators	Yes to a max of 2 faecal Strep. per 100 mℓ assoc. with the dairy operations (?)	Yes – to max of 37500 faecal coliform per 100 mℓ in effluent irrigated pasture. Also close to waste channel.	ND
Impact of IAH activities on groundwater quality.	Significant w.r.t. nitrate and microbiological indicators, localised.	With a wide range of determinants, variable, apparently localised.	None
(?) Further research needed to confirm			
ND Not determined			

11.5.2 Application of Fertilisers

Three sites were used for the study on application of fertilisers of which two were in the Western Cape and one in the Free State. The same sampling criteria were used but nitrogen isotope tests were also conducted to differentiate between the specific nitrogen species to identify the origin of nitrogen pollutants (organic, fertiliser or industrial).

The main risk associated with fertiliser originates as a result of inadequate management of volume and timing of fertiliser application. Fertilisers are mainly used to replenish the soil nutrients depleted by continuous crop production. These are normally replenished naturally by death and decay of bio-organisms and the cycles explained in Section 11.4. Nitrogen, phosphorus and potassium are the major elements needed for plant growth. Fertilisers normally contain:

- Nitrogen, as ammonium salts, nitrate salts or urea. Nitrogen is essential for plant growth particularly for leaves as it is a constituent of amino acids and proteins, which must be created to produce new cells.
- Phosphorus, for root growth. Usually a slightly soluble form of phosphate such as superphosphate or triple superphosphate is applied.
- Potassium, ions for flowering often provided as potassium sulphate. Thus, when correctly applied, fertiliser restores the nutrient balances of the soil.

The main hazards due to fertiliser application are soil acidification, soil structure degradation and water pollution. Nitrogen leaching to groundwater, production of ammonia and nitrous oxides by volatilisation and denitrification and soil acidification is caused by over-application of nitrogen. Pollution from phosphorus is mainly due to leaching and runoff of soluble P. The nutrients, if leached or forming part of the runoff to surface waters, may occur at toxic levels and cause eutrophication.

The study concluded that nitrate levels in groundwater are not entirely due to fertilisers, but also due to ploughing and other farming activities. Table 11.13 is a summary of the study sites and the findings.

Table 11.13: Summary of contaminants at three sites associated with application of fertiliser (after Conrad *et al.*, 1999).

Climate	529 mm (1996), winter rain	350 mm (1996) winter rain	843 mm (1996) summer rain
Unsaturated zone	2-3 m, alluvial soils	2-3 m, sandy soils	5m, clay rich soils
Aquifer Type	Unconfined	Unconfined	Confined
Hydrochemistry	Ca, Mg, Cl and SO_4	Na, Cl	Ca, Mg, CO_3, HCO_3
Potential groundwater contamination from other sources	Pit latrines and septic systems	Pit latrines and septic systems	None
Groundwater contamination:			
Nitrate	Yes 0 to 13.2 mg/ℓ	Yes 0 to 23.7 mg/ℓ	Yes 6.9 to 20.4 mg/ℓ
Phosphorous	No	No	No
Potassium	Low 0.2 to 18 mg/ℓ	Low to med. 1.3 to 121	Low 3.2 to 7.1
EC	Low to med. 2 to 140 mS/m	Low to high, 31 to 840 mS/m	Med. 61 to 83 mS/m
Impacts of fertilizers on nitrate concentrations in groundwater	Essentially minimal, although higher in localized areas. The % that fertilizer contributes to total nitrate concentration undetermined.	Essentially low. The % that fertilizer contributes to total nitrate concentration undetermined.	Potentially moderate. The % that fertilizer contributes to total nitrate concentration undetermined.

11.5.3 Sludge Application to Agricultural Land

Municipal treatment works produce large volumes of sludge, of which the nature depends on the quality of the water being treated. Waste water treatment plants (WWTP's) in South Africa typically produce 421 kg dry mass for every megalitre of waste water treated. This sludge is a putrefactive, concentrated aqueous suspension of particulate organic material containing mainly biodegradable but also inert substances.

Benefits of sludge application to cultivated lands are as follows:

- Major source of plant nutrients (nitrogen, phosphorus and to a lesser extent potassium) which are released slowly;
- Source of micronutrients (Zn, Cu, Mo, Fe and Mn);
- The addition of organic matter improves the physical properties of the soil, in particular its water retention capacity which in turn reduces soil erosion and prevents nutrient leaching;
- Between a half and two thirds of the total phosphorus in sewage sludge is available for plant uptake;
- Sewage sludge is a very good soil conditioner.

Hazards associated with this practice are mainly contamination of the soil, surface water and groundwater as well as nuisance odours. The following are other important problems:

- Introduction of toxic substances to the food chain (N, P, K, toxic organics such as policarbonated biphenyls (PCBs), phenols, dioxins, polycyclic aromatic hydrocarbons, heavy metals such as zinc, nickel and copper, etc.);
- Introduction of pathogens including bacteria, protozoa, helminthes and viruses;

A high organic content causes higher oxygen demand that creates anaerobic conditions that could limit plant growth.

Contamination via the food chain is thought to be the pathway most likely to expose humans to toxins. Due to its low solubility, only excessive application of nitrogen above the agricultural requirements could cause leaching to groundwater and is thus not seen as a major threat to groundwater pollution. Some of the contaminants found associated with sludge application are listed in Table 11.14.

The three sites investigated indicated that nitrate contaminated the soil and water sources, with decreasing concentrations further away from the source. Geology and soil cover seems to play the most important part in limiting contaminants to reach groundwater. No other contaminants were found to be significant

Table 11.14: Summary of contaminants at three sites associated with sludge application (after Conrad *et al.*, 1999).

	Site A	**Site B**	**Site C**
Hydrochemistry	$CaCO_3$ with elevated nitrate and sulphate. TDS 700-1700 mg/ℓ Reduced at depth.	NaCl. TDS 100-400 mg/ℓ	$CaCO_3$ with NaCl. TDS 540-2200 mg/ℓ Reduced at depth.
Groundwater contamination from other sources	Sulphate (?)	Nitrate – decaying *Acacia* vegetation	Nitrate and DOC from other fertilisers (?)
Groundwater contamination from sludge:			
Nitrate	**Yes** – to > 30 mg/ℓ at a distance of > 1 km with a peak of 268 mg/ℓ.	**Yes** – seasonal, localized (?), by 2-15 mg/ℓ.	**Yes** (?) – contribution to extensive (?) increase to 38 mg/ℓ in shallow samples.
EC	**Yes** – from ≈180 to 300 mS/m due to high nitrate levels	**No**	**No**
DOC	**Yes** – from < 2 mg/ℓ to ≈10 mg/ℓ in shallow samples in the field.	**No**	**Yes** (?) – to ≈30 mg/ℓ in shallow samples in the field.
Microbiological indicators	**No**	**No** (?)	**No** (?)
Metals	**Yes** (?) -Cd to 0.01mg/ℓ	**No**	**No**
Other ions	**Yes** (?) -K	**No**	**No**
Impacts of sludge appli-cation on groundwater quality	Long term, significant and extensive.	Temporary, insignificant and localized (?).	Long term (?), significant at shallow depths, extensive (?).

11.5.4 Irrigation Practices

Although irrigation has enormous benefits, there are major disadvantages like the chemical deterioration of the receiving water to downstream sources. Irrigation water, especially municipal or industrial waste water, always contains varying concentrations of salts. Evapotranspiration will consume some of the water but not the salt and will thus concentrate the salt in the remaining soil water. Irrigation water can also mobilise the salts, increasing the mobility of the water further down to the groundwater, causing increased salinity. Surface water can directly be affected by this concentrated waste water when runoff that is not utilised by crops, reaches streams or dams, or just by plain spillage of water off-site.

Cation exchange, precipitation and dissolution make up the most important processes involved in salinisation of the environment. SAR (sodium adsorption ratio) measures the degree to which sodium in irrigation water replaces the adsorbed calcium and magnesium in the soil clays and thus damages the soil structure. Because of the preferred adsorption by clays of sodium relative to heavy metals, the latter are likely to be released.

Most of the problems due to irrigation are caused by over-utilisation of irrigated water with high concentration of salts. These are typically waste water from municipal and industrial treatment plants that have to conform to the quality standards set by DWAF for release of treated water into the environment. Although the concentration of salts in this water is acceptable, over-irrigation or continuous irrigation causes a build-up of salts in the soil layers that could leach through to the unsaturated zone. From here it could gravitate to the groundwater or be remobilised by a rising water level from the capillary zone back to the root zone. A build-up over several seasons could accumulate sodium and be leached to groundwater if fresh water reaches the system. Build-up in root systems of more tolerant plants can also take place. Due to the toxicity of sodium to plants it is important to prevent the build-up in the soil layers. Over-application of water with a high concentration of salts can damage plants when applied directly to the leaves as well.

Sodium is an essential dietary element important for the electrolytic balance and the maintenance of many essential physiological functions. However a large concentration will damage vegetation. DWAF has developed standards for sodium concentrations in irrigation water.

It is thus very important to carefully manage irrigation with waste water in order to prevent build up of salts in runoff to surface water bodies where return flow can take place. Perched aquifers are most susceptible to salinisation especially those with impermeable boundaries where fluctuations occur regularly.

11.5.5 Agricultural Use of Pesticides

To increase crop production, fertilisers and pesticides are applied. The well-planned and managed use thereof should not be damaging to the environment. In South Africa though this has not been the case, and in the past the health of the environment and water resources were not the first priority when pesticides were applied. The major mode by which pesticides reach water resources is by surface runoff and infiltration during precipitation. Over-application and spillage is a common problem. Some pesticides rely on rain or irrigation to be washed into the upper soil layers. Groundwater contamination by pesticides is strongly linked to the leaching rate through the soil. Leaching rate is governed by the adsorptive capacity of the soil, the amount of overhead water and the solubility of the compound leached.

The fate of a pesticide applied to soil is governed to a large extent by its adsorption on soil colloids, desorption of the adsorbed fraction and degradation and persistence. Part of the pesticide is washed off by rain or misses the target zone and lands on the soil surface. Dissipation of pesticides infers that the chemical is transformed into by-products, and is further transformed until it disappears, or becomes too low to detect. These are known as transfer or transformation processes. The important avenues of dissipation are chemical degradation, leaching, and microbial degradation, uptake by living organisms, photo decomposition and volatilisation.

The most important transfer processes (described in detail by Conrad *et al.,* 1999) are:

- Adsorption on and desorption from, soil colloids;
- Uptake by plants (absorption);
- Exudation and retention by living organisms;
- Movement on the soil surface (runoff);
- Volatilisation;
- Leaching (downward movement in soil);
- Capillary movement (upward transport in soil).

A number of software programs can now be utilised to model the fate and transport of pesticides in soil. Two sources of pesticide have been distinguished, i.e. diffuse source and point source. Diffuse source contamination takes place mostly as discussed above, while point source pollution occurs where containers in storage may spill or leak.

Not much research has been done on the agricultural use of pesticides in South Africa, in contrast with the USA where researchers have studied this in systematic detail and quite a number of publications and papers are available. The most-studied pesticides in South Africa are listed in Table 11.15.

Table 11.15: Summary of the most studied pesticides in literature

Common name	No. of experiments	Pesticide type
Atrazine	58	Herbicide
Alachlor	22	Herbicide
Aldicarb	20	Insecticide, Nenoticide
Cyanazine	14	Herbicide
Simazine	10	Herbicide
Metolachlor	9	Herbicide
Metribuzin	8	Herbicide
Isoproturon	7	Herbicide
Carbofuran	6	Insecticide, Nenoticide
Picloram	6	Herbicide
Terbuthylazine	6	Herbicide

A case study of two sites in South Africa was conducted by Conrad *et al* (1999), the Hex River valley and the Vaalharts irrigation scheme. Due to the high cost involved (around R1000 per sample) for the determination of organic elements in soil and water samples, the number of samples taken was much lower than required. The following pesticides were tested for on these two sites: aldicarb, aldicarb sulphone, dimethoate, fenamiphos, fenamiphos sulphone, fenamiphos sulfoxide, methidathion, mevinphos, nuarimol, penconazole, propoxur, prothiofos and simazine.

In the Hex River valley none of the pesticides were detected at detection limits of 0.0005 mg/ℓ except for aldicarb where the detection limit is 0.025 mg/ℓ. However, high nitrates and phosphates were detected at these points, which indicated that agricultural chemicals were leaching to the groundwater. The reason could be due to low soil pH and degradation due to high temperature conditions.

At the Vaalharts sample stations, tests were mainly conducted to determine atrazine, parathion, trifluralin, carbofuran, EPTC, bromoxynil and endusulfan which are representative of pesticides used most commonly throughout the area. In this area low soil pH leads to a lower half-life for atrazine which has been reported as being 2 weeks and up to 106 weeks. The similarity between climatic conditions in other areas (described by different authors) and this area would indicate that atrazine would be degraded after 90 days. EPTC was detected at low levels once while carbofuran was detected in five samples. Again nitrate was detected in high concentrations in almost all sites.

The study concluded that the reason for pesticide problems in Europe and USA compared to SA could be due to:

- Higher ambient temperature which speeds up degradation;
- Lower precipitation decreasing recharge;
- Higher clay content of soils increasing retardation;
- Deeper water tables which increases travel time;
- Lower soil carbon content which decreases retention.

A substantial amount of research however still needs to be undertaken in SA. Thus, although pesticides have not been detected, it does not necessarily mean that they do not contribute to contamination of water resources.

11.5.6 Conclusions from Case Studies

From the case studies at the different sites it is clear that different soil horizons and geology play the major role in the transport of agriculturally-related contaminants to surface and groundwater. In general, the thicker the soil horizon and the more clay content, the less chance of contamination to groundwater. Vegetation and climate also play an important role in the retardation and degradation of contaminants. Good management and correct agricultural practices however, seem to be the biggest factor towards the prevention of pollution.

Nitrates were by far the most important agricultural contaminant found in surface and groundwater. Other important contaminants found were ortho-phosphates, potassium and microbiological indicators of faecal pollution. DOC levels were also elevated at some sites. TDS and EC were important parameters to monitor for salinisation.

Pesticides were found to be a minor problem; however this could be due to budgetary constraints during the investigations as these tests are extremely expensive, thereby preventing proper testing. This field is also open for more research considering the South African conditions.

No real damage to the environment could be ascertained during these studies except for specific crop damage in the Hex River Valley and at other sites. The damage was however mainly due to inadequate management, although this was not the intended focus of these studies.

11.6 Agriculture in the COH WHS

Studies done so far on the organic content of a number of samples covering an area from the Harmony mines south of the Krugersdorp Game Reserve all the way north to the John Nash Reserve indicated possible agricultural contamination. These studies were performed as part of the Department of Mineral and Energy's (DME) Mine Ingress and Decant Project undertaken by the Council for Geoscience to monitor the possible influence of acid mine drainage (AMD) to the receiving environment downstream of the catchment. This was mainly a once-off sample run with some temporal data for specific sites and should thus not be seen as substantive evidence of agricultural pollution. The results of the study should rather be seen as an initial data set to compare and reference future and ongoing studies. The data set was basically for the dry season and a wet season acquisition is in progress.

Figure 11.5: The formation of algae in a stream in the COH WHS due to elevated phosphate content causing eutrophication in surface streams.

Figure 11.6: Eutrophication well advanced in a leachate dam at a dairy farm in the COH WHS.

The main purpose of this study was to trace sulphates and some heavy metals or trace metals that are typical of industrial- or mining-related pollution. During this exercise it was found that elevated levels of nitrates and ortho-phosphates were detected in quite a number of sampling sites geographically distributed from the source. These coincided mainly with farms where IAH, dairy and crop farming are practiced. Although the nitrate as nitrogen levels were below the drinking water standards, Fetter (1994) maintains that values above 5 mg/ℓ acts as warning signs of agricultural contamination. Although there are currently no minimum standards for phosphates, it is clear that eutrophication occurs in some of the surface water streams in the area (**Figures** 11.5, 11.6 and 11.7) and that a standard for phosphates for the area has to be determined.

Figure 11.7: Standing leachate forming at a feed pen at a dairy farm in the COH WHS (photo: M. Buchanan).

The higher values of phosphates and nitrates found in local streams could partly be originating from the Mogale City Waste Water Treatment Plants. These effluents are also used to irrigate some intensive crops and vegetable farms in the area. Springs, streams and boreholes on these farms have elevated nitrate values, which indicate that they could be connected in some way to each other. The consequence of these elevated nitrate and phosphate levels are continuous growth of algae and alien plants such as water hyacinths which eventually completely occupy surface water passages. This in turn causes depletion of dissolved oxygen essential for sustaining aquatic organisms and life.

A conceptual model developed by Delleur (1998) (**Figure** 11.8), illustrates how surface inflow (and some direct groundwater flow from the Wits geological section into the dolomitic section) enters the sunken streams in the south and flows in karstic conduits towards the north where it reappears in springs, entering streams flowing towards the Crocodile River catchment. Due to the thin soil cover in this part of the Cradle it is also likely that preferred pathway flow and leaching occurs directly to the dolomite in most of these farming areas. Degradation of pesticides and other agricultural chemicals therefore might not be as effective as in thick soil layers with high clay content. This means that agricultural contaminants can find their way much faster into the groundwater system and in turn into the downstream surface streams. The way in which some of the karstic cave conduits are interlinked with each other is still uncertain as sections with secondary matrix flow (very low conductivity) seem to exist, e.g. the Sterkfontein Caves which seems to be a low energy groundwater system.

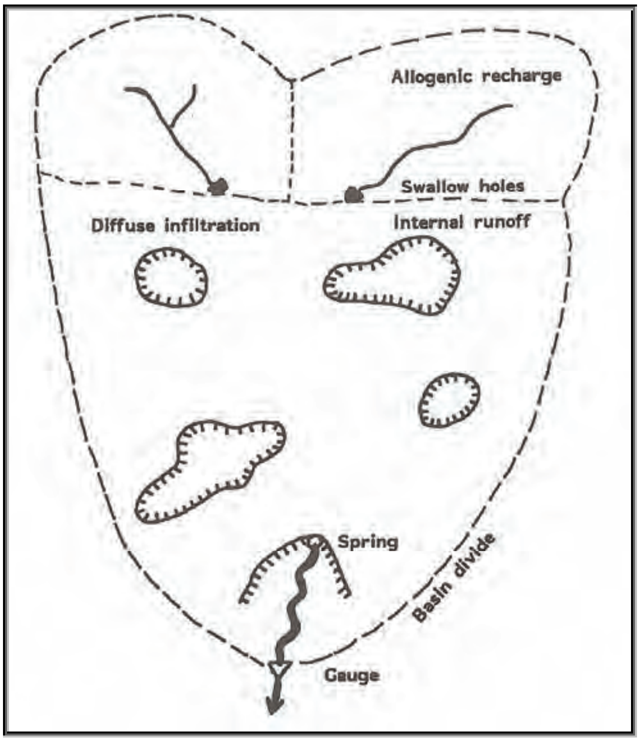

Figure 11.8: Conceptual model of a karstic groundwater flow system (from White, 1998, Delleur, 1998).

The consequence of this is that some contaminants that could arise from upstream and local agricultural activities could easily be flushed down the system but could also be trapped in some sections where build-up over time could occur. This could have impacts on the potable water quality for humans and animals and could even exceed the tolerance of riparian and other vegetation along the flow path of ground and surface water. It also contributes to the continuous increase in contaminants to the receiving downstream river systems, which in turn, flow into some of the larger dams like Hartbeespoort Dam. This increases costs to farmers of getting water to an acceptable quality for producing crops, etc.

Actual statistics from the land-use audit could not be obtained in time for this publication to establish the specific agricultural activities within the Cradle. However, it would seem that a fair percentage of land is used for irrigation farming, utilising groundwater resources as well as waste water. A large number of poultry farms as well as dairies also fall within the catchment area. Of particular concern is the effluent created specifically by two farms south and north of the Sterkfontein Caves where the highest elevated nitrate values were recorded in ground and surface water. **Figure** 11.9 is a false colour RGB (Red, Green, and Blue) grid depicting the nitrate as nitrogen values, where higher values are assigned to purple/red colours and lower values to blue colours. This clearly indicates the higher nitrogen values found to the south of Sterkfontein Caves where a number of agricultural and industrial activities still take place and the effluent from the purification works enters the catchment. The northern portion and the area where the dairy farm is situated can be seen as the very dark red/purple patch to the north east.

Figure 11.10 is a box and whisker plot representing all nitrate recorded to date as nitrogen values, indicating that on a number of sites, general elevated values of above the 5 mg/ℓ level occurred. Of these, most are related to farming activities. It also indicates the range of values found where temporal sampling was done over different seasons. Another cause for concern which is related to agriculture is the number of septic tanks used for the disposal of human wastes from owners and farm labourers. These tanks are usually old and not constructed to standards or are operating at higher loads than designed for, due to changing uses such as tourism, etc. Furthermore, low cost or informal settlements may have no or poor reticulation systems in place which usually results in the disposal of wastes directly into either groundwater or surface water streams. In the case of the Cradle these settlements are situated at the origin of the catchment.

No samples have so far been taken for organic pesticide determination and therefore no knowledge of such contamination exists. However, organic pesticides are most likely being applied on crops and therefore, some pollution may be possible. Literature from other case studies suggest that climate, thin soil cover and other conditions may cause the pesticides to either flush away from the system too rapidly to be measured, or be degraded by several processes

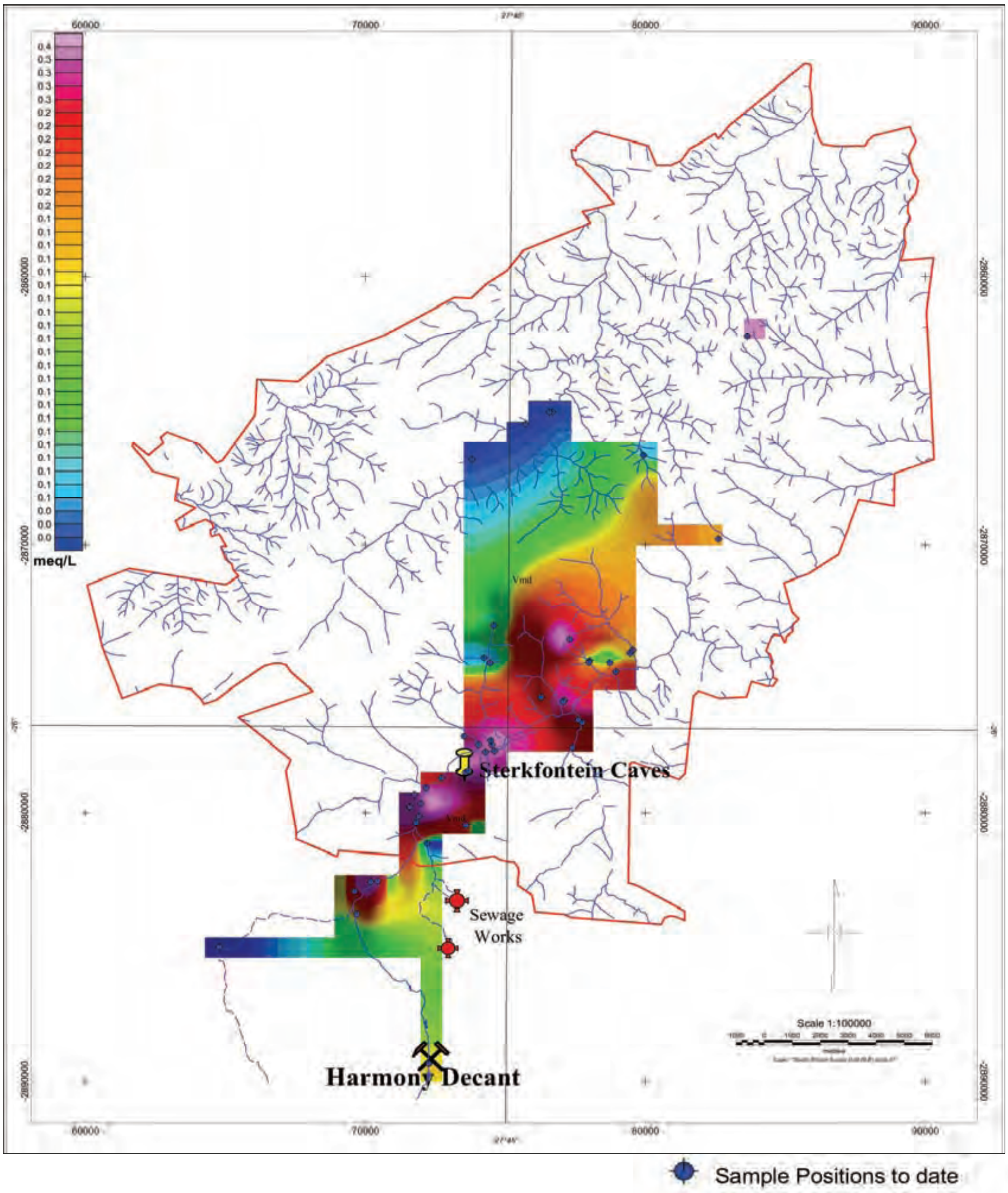

Figure 11.9: False colour grid depicting nitrate as nitrogen values (meq/ℓ).

Salinisation does not seem to be a major problem in the area although no formal interviews with farmers have been conducted to ascertain crop damages. The chloride values (**Figure** 11.11) as well as the sodium values (**Figure** 11.12) are well within DWAF standards for crop applications The high elevated values were found in the highly contaminated acid mine drainage (AMD) samples at the decant point. **Figure** 11.13 is a SAR diagram showing that the sodium hazard associated with salinisation is low and of no danger. A relatively high salinity hazard exists which could be directly linked to the higher electrical conductivity values that were found at some sites. In turn, these are most likely due to higher sulphate values originating from the mines and WWTPs which are contaminating the water resources. High TDS values in the dolomites in general are a function of the high calcium and magnesium content due to chemical weathering (de-dolomitisation).

Some sites have higher concentrations of trace metals, zinc and lead and this may also be the result of mining activities and cannot be explained yet. It is also possible that the dolomites act as a buffer for acidic waters, making it more alkaline.

The buffering effect of the dolomite could be a significant issue as highly acidic leachate originating from a variety of activities can infiltrate the groundwater system where dedolomitisation can occur at a rate much higher than in natural processes. The inability to see below the surface makes it difficult for assessments of the damage to be carried out - therefore people remain unaware of the consequences of their activities.

Microbiological indicators are continuously monitored only by DWAF at a few points. The total coliforms and *E. coli* counts from these points indicate that water resources have become polluted. Analyses show elevated values of microorganisms, high enough to cause diseases if the water is used without treatment. The situation may be similar for agriculture-related sites in the COH WHS.

Several farms in the area use groundwater for irrigating crops and other purposes. A water level marker was installed in the Sterkfontein Caves in 1985 – since then the water level has dropped at least 6 m (personal communication, Mike Buchanan). This is due to the increased use of groundwater for irrigation purposes. As a consequence of this, new sinkholes may be formed, fracture systems may collapse, and aquifers may be damaged while cave systems and land surfaces may be altered. Groundwater flow models developed by DWAF indicated that a decline in groundwater levels of no more than six meters may be tolerated to ensure that cavities do not collapse and to ensure sustainability of boreholes (aquifers).

CONCLUSIONS OF THIS SUMMARY:

- It is clear from the preliminary once-off study that agricultural activities have contributed to contamination of surface water, groundwater and possibly, also of soils of the Cradle catchment;
- Proper management to limit agricultural contamination is lacking throughout the area;
- Although there is visible eutrophication in parts of the surface streams, no real environmental changes due to agricultural activities have been observed;
- No knowledge of pesticide contamination is currently available;
- Over-extraction of groundwater is evident over a period of time;
- Interaction between the acidic water, the cave formations and dolomite is not fully understood and documented.

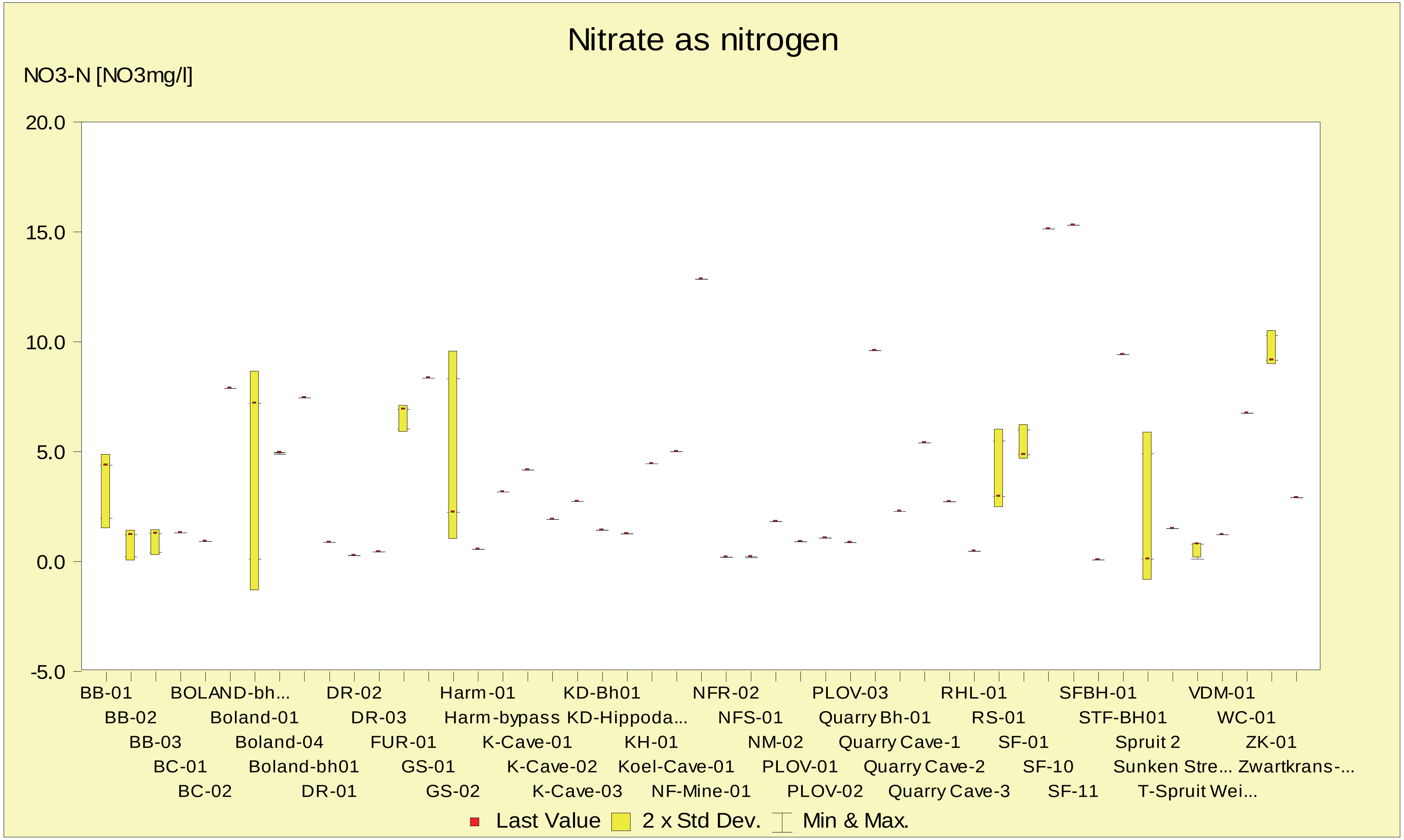

Figure 11.10: Box and whisker plot indicating elevated nitrate as nitrogen values (negative values not possible but an artifact of the statistical 2x standard deviation processing by the software)

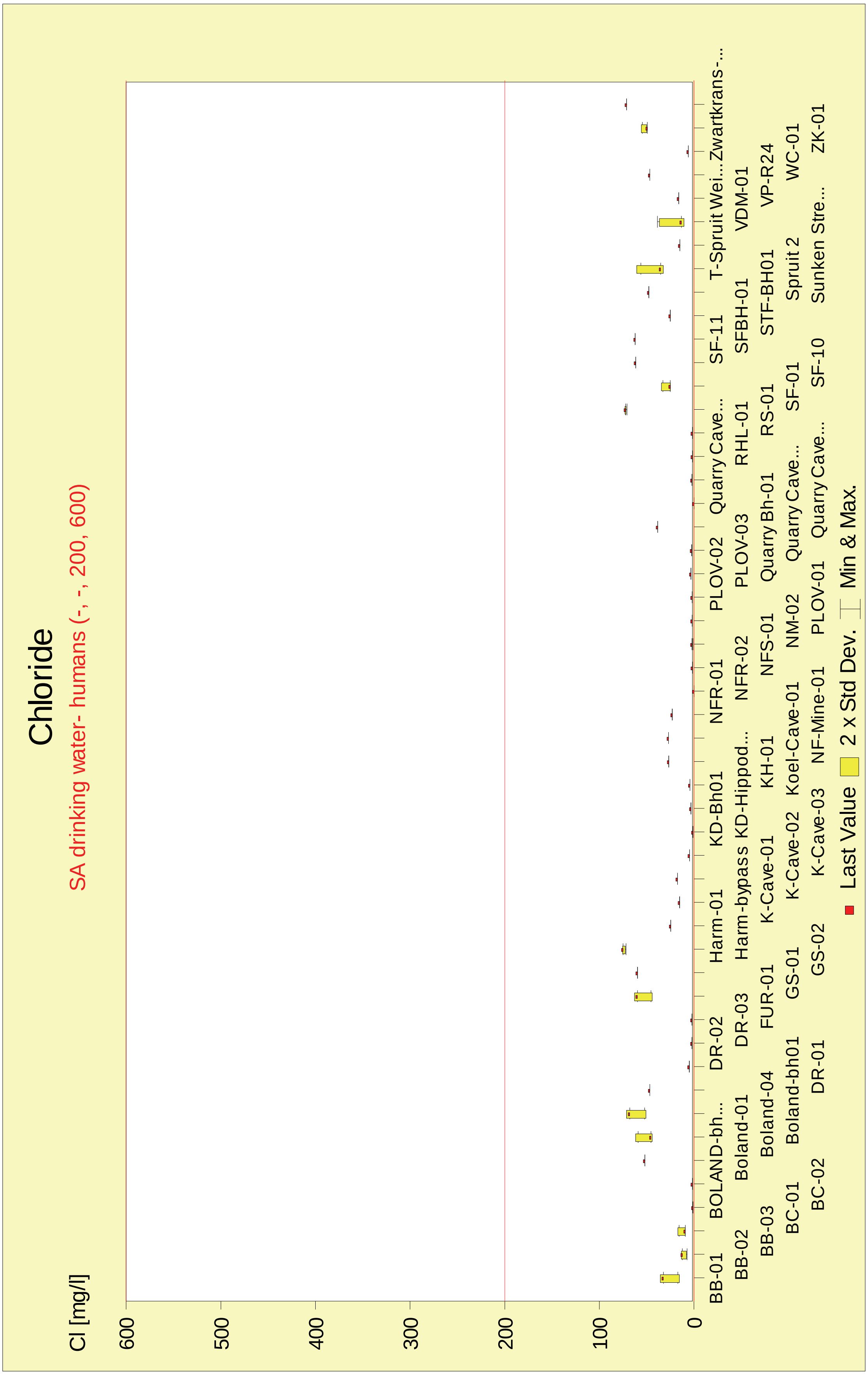

Figure 11.11: Box and whisker plot indicating chlorine values.

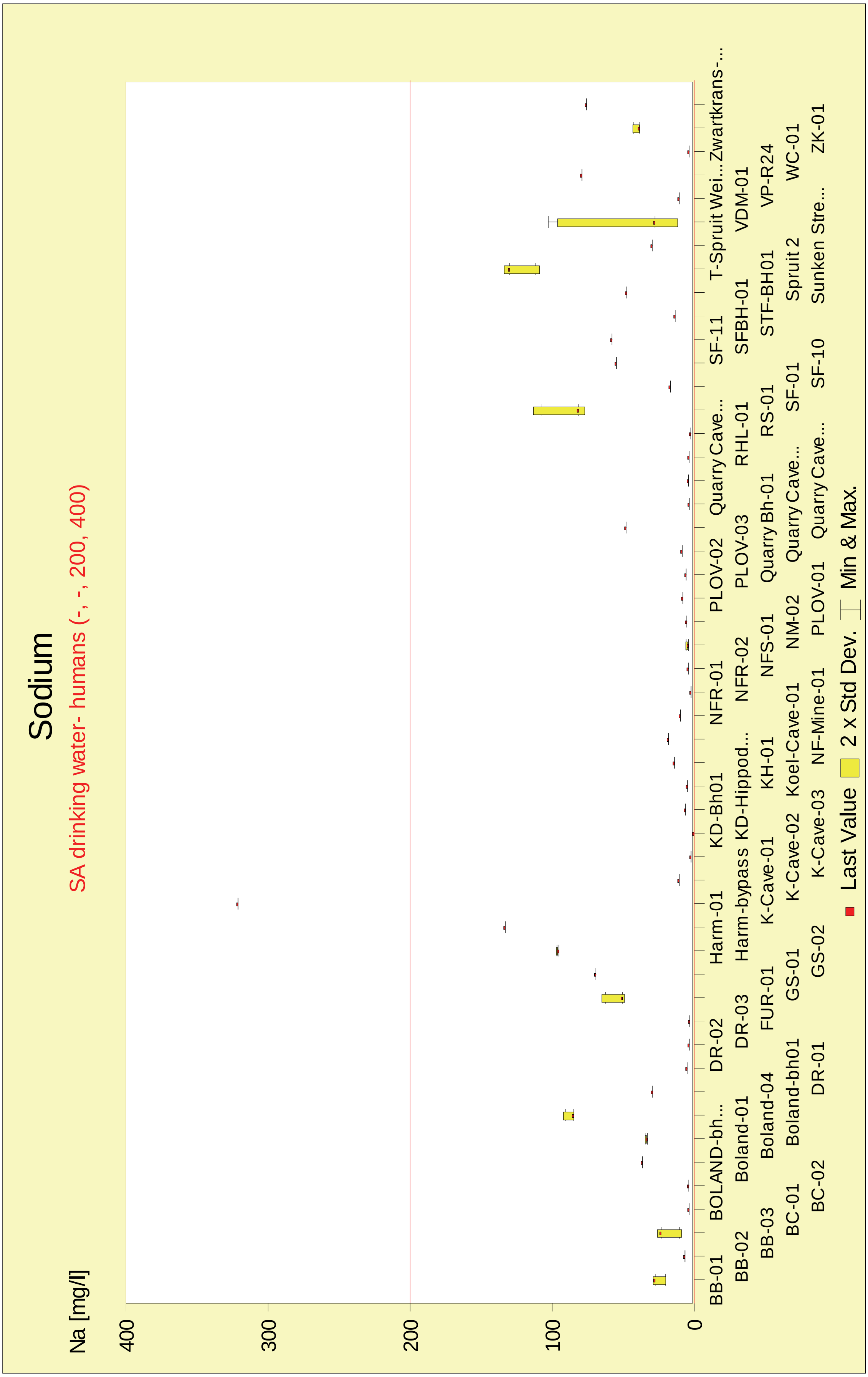

Figure 11.11: Box and whisker plot indicating sodium values.

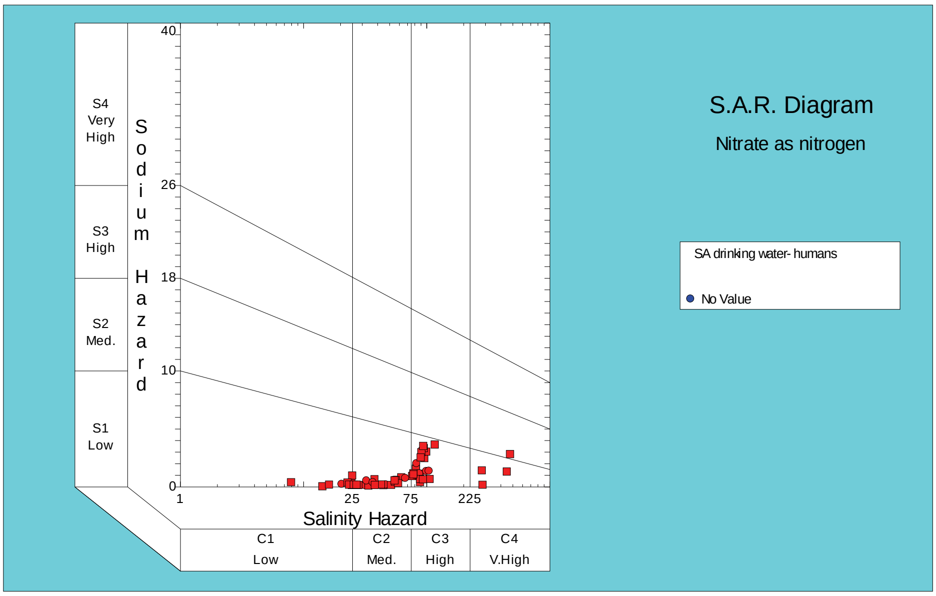

Figure 11.13: Sodium Adsorption Ratio diagram depicting salinity and sodium hazards for irrigation of crops.

11.7 Good Farming Practices

Guidelines on good farming practices were developed by the WRC. A summary extracted from the booklet on the different practices recommended for farmers to improve management of their activities, can be found in Box 11.1.

Box 11.1

Good Farming Practices (Summary from the Handbook of Groundwater Quality Protection for Farmers, Conrad and Colvin (2000).

1. Intensive Animal Husbandry

Natural processes can be found to help with waste management at intensive animal farms, if they are understood. For instance, in the case of active feedlot pads and effluent lagoons, a layer with very low permeability will naturally form and serve to protect groundwater if it is maintained.

The potential for seepage of nutrients to the groundwater below effluent lagoons is reduced due to accumulation of solids and clogging by bacterial cells and fine organic matter. Infiltration may occur from new unlined ponds but, with several months' accumulation, many become self-sealing. A settling basin or solid separator is usually required to maintain an efficient life span for an effluent lagoon.

Self sealing may not be established in areas with coarse sands, fractures or fissures. In these areas artificial pond lining is required. In anaerobic effluent lagoons any nitrate that forms is usually denitrified. This chemical reduction combined with low permeability at the base of the lagoon tends to migrate nitrate leaching.

Cases of groundwater contamination from effluent lagoons are associated with the rupture of the lagoon seal by seasonal drying out. Moist conditions at the base of a lagoon should be maintained at all times and scraping out the base lagoon avoided as this will destroy the self sealing layer.

Feedlots receive a high loading of bovine waste but generally low levels of infiltration and

Box 11.1 (continued)

Forming a low permeability, anaerobic layer at the manure-soil interface. Water cannot easily permeate this layer therefore care should be taken when removing surface manure from pads not to remove the interface layer.

Correct siting of feedlot pads and good drainage goes a long way to prevent contamination. Feedlots should not be sited in areas with greater than 750 mm rainfall per annum. Pads should be sited on a 2 to 5% slope with feeding and drinking troughs at the upper end. The slope will minimise standing water and run off should be collected in channels and directed to an effluent lagoon. The risk of ground and surface water contamination is greatest during the first rains of a wet season. This is known as the first flush effect. Careful management of this run off is required to prevent it reaching surface water or areas where it may infiltrate to groundwater. When a pad is abandoned the manure dries and shrinkage cracks form. The permeability of the pad base or interface layer is then increased and the risk of infiltration increases. At this point all manure and the interface layer should be removed.

The literature shows that nitrate leaching to groundwater from areas of land disposal of waste and effluent is significant and widespread. Application to land is widely practiced as it provides an economic means of disposing of effluent and manure. Other forms of disposal, such as discharge to a surface water body, would require expensive treatment. Disposal to land is a beneficial use option where fodder crops are grown.

Problems of contamination occur due to high levels of contaminants in the waste, high application rates and aerobic conditions in the disposal area, which enhance nitrification and subsequent leaching. The risk of leaching is greatest where high volumes of effluent are applied or irrigation is carried out in addition to waste application. A limit of 170 kg of nitrogen per hectare per annum in manure applied to land is recommended in Europe. Additional irrigation should be avoided and the nitrogen loading in the effluent or manure should be matched to the requirements of the crop pasture. There is also need to minimise effluent irrigation to land overlying shallow, vulnerable aquifers.

For raw piggery waste, the following calculation can be carried out: Application rate (pigs per hectare) = nitrogen requirement of the crop pasture x 0.1. If the waste has undergone some treatment (anaerobic or aerobic) then nitrogen requirement maybe multiplied by 0.15. General good practice should also include the maintenance of grassed buffer zones several tens of meters wide next to surface water features. No effluent of manure should be applied to these buffers.

Significant leaching of nitrate to groundwater occurs beneath pastures. The leaching is mainly associated with urine patches which release nitrate more quickly than manure. The very irregular distribution of livestock wastes across a paddock results in many small patches where extremely high nitrogen concentrations result in leaching. Irregular patches occur due to excretion during grazing in pasture and heavier manure loads occur due to periodic livestock concentration such as at feeding or water troughs and gates. The impacts of this can be minimised by not exceeding the carrying capacity of the pasture and using mobile feeding and drinking troughs.

2. Fertiliser application

Nitrate is more likely to infiltrate to groundwater under the following conditions:

- The water table is shallow and the unsaturated zone is permeable;
- Fertiliser is applied at the time when it is not being taken up by the crop;
- Fertiliser is applied at a rate which is greater than the crop can use;
- Rain or irrigation water is present to carry the nitrate beneath the root zone and out of reach of crops.

Box 11.1 (continued)

If fertilisers are applied during a rainy period when the ground is bare and there is no uptake by plants, it is likely that a significant portion of the nitrogen supplied will be washed beneath the root zone. This means that the crop will not receive the correct amount of nitrogen for optimal growth and there is a high risk of contaminating groundwater with nitrate. .

In planning an effective schedule for fertiliser application the farmer needs to know:

- When does the crop require the most nutrients, particularly nitrate? This is usually around early periods of growth following planting and prior to fruiting. And
- How much fertiliser should be applied at the different times?

Working out the nitrogen balance for a crop can be a complicated procedure. It is usually carried out over a few years and is based on the practical experience of the farmer. Field observations, such as signs in the crop of excessive growth rates and measurements of the crop tissue, soil nutrient levels and groundwater chemistry all contribute to getting the right balance. Measurement of nitrate in the root zone soil (as opposed to organic nitrogen) gives an indication of some of the residual nitrogen that will be available.

Farmers need to be particularly aware of over fertilization risks in high rainfall areas or during rainy periods. Over irrigation may also lead to greater leaching losses where there is excess nitrogen in the soil. Irrigation should be scheduled to the crop requirements.

Fertilization:

- If groundwater is used to apply fertiliser, the concentrated fertiliser and water should not be mixed within 15 m of the borehole.
- Fertiliser should not be applied within 50 m of a borehole.

3. Sludge application

Particular care should be taken with sludge application where the following conditions apply:

- Shallow aquifers underlie the fields where sludge will be applied;
- Groundwater is used as drinking water for people or livestock on a farm or in the surrounding area;
- The quality of the groundwater is marginal.

Guidelines recommending safe sludge application rates exist in many countries. In South Africa guidelines are given by the Department of National Health and Population Development (DNHandPD). The maximum rate of application recommended is 8 t (dry mass)/ha/year. The concentrations of potentially contaminating substances such as heavy metals may restrict the application rate to less than this and limit the cumulative loading over a period of several years. From the point of view of metal mobility, sludge should not be applied to soils with a pH of less than 6. The guidelines also recognise that sludge application to agricultural land should not exceed the crop nitrogen requirements to prevent leaching of nitrogen to groundwater. Given the difficulties in accounting for available nitrogen from sludge and any inorganic fertilisers that maybe used, they provide only a general guide for crop nitrogen demand.

Sludge is classified into four types by the DNHandPD depending on its source, how it is treated and the level of potentially harmful substances it contains, as shown in table below.

Guidelines for sludge use:

Sludge should not be applied to a slope of greater than 6 % or to land underlain by an aquifer at less than 5 m. The sludge applied area should be greater than 500 m from a dwelling and greater than 200 m from a river, dam or borehole. Type B sludge should not be applied to a slope of greater than 4 % or to land underlain by an aquifer at less than 2 m. The sludge applied area should be greater than 200 m from a dwelling, river, dam or borehole.

Box 11.1 (continued)

4 Salinisation as a result of irrigation

The best solution to the mineralization problem of the groundwater is to minimise saline irrigation return flow. This can be achieved by:

- Reduction in the leaching fraction and over-irrigation;
- Reduction in the leakage from canals and dams;
- Application of a better quality irrigation water in order to reduce the input of water borne soluble salts;
- Artificial drainage to remove percolates rapidly from the soil body and to prevent build up of perched water tables;
- Choice of area and timing of new land development.

5. Pesticides

The recommended pesticide application limits on the label should always be adhered to. The limit recommended for atrazine is 2.5 kg of active ingredient per hectare per year. There is need to be aware of the effectiveness of the pesticide in a particular environment and a need to lower the application rate if possible. During cooler dry periods the pesticide may be able to attain the same level of control with a lower dose (depending on the pesticide).

If pesticides are mixed with groundwater this should be done at least 15 m from the borehole and the hose removed from the mixing tank before switching of the water supply. This avoids the risk of back-siphoning which may inject pesticides directly into the borehole. A back-flow prevention device should be installed if possible. It should be noted that spills at the mixing area result in a much higher loading than normal application would.

Some pesticides such as pre-emergent herbicides and the soil-applied pesticides benefit from a light rain, which washes the pesticide into the upper soil layers. Too much rain, however, washes the pesticide too deep into the soil profile or carries it away with surface run-off. Post emergent herbicides and plant applied fungicides and insecticides do not benefit from rain and the pesticide will wash off.

Farmers should be aware of the local weather conditions and avoid application before heavy rainfall.

Pesticide containers should be disposed of responsibly to a registered landfill site or returned to the supplier. These containers should never be used for water. The bottom of the container should be punctured to ensure that it would not be used. Similarly, excess mixture and rinse-water should be disposed of responsibly. Spray equipment should be calibrated to ensure that the pesticide is not over applied. Before spraying, the size of the nozzle tip, spray width per nozzle and flow rate from the nozzle should be checked. At farms where pesticides are regularly used, the best practice to inactivate pesticides in a controlled way is to construct a pesticide spillage safety trap. This makes use of the natural process of breakdown and pesticide adsorption to clays and organic matter. Once it is constructed all pesticide handling should be carried out over the special area. Construction details are given in the handbook.

11.8 Response required for sustainability of the environment

A number of role players are currently involved in managing the different resources in the Cradle. These include among others, GDACE (Blue IQ) for the environmental and overall management of the Cradle, DWAF as national custodian of surface and groundwater, the CGS investigating decant and ingress of defunct mines on behalf of DME and other NGOs trying to protect the World Heritage Site status as well as private individuals pro-actively working towards this goal. The most important role players, however, are the individual landowners making a living from the area. They, together with industries and mines operating on the fringe of the Cradle, are the players that influence the environment most profoundly.

Controlling and managing practices within the Cradle is a huge task and responsibility and although a number of projects and initiatives have been launched and conducted, a huge challenge still lies ahead to ensure the sustainable development of the area. Certainly all of these attempts start with appropriate management and education responses of which the following attempts to contribute to.

11.8.1 Regulatory response

As can be seen, a number of regulatory authorities are involved in ensuring that best practices are followed in agriculture. Most of these authorities have been discussed above, but there are a number of others pertaining to agriculture and the environment that were not mentioned, such as the Department of Agriculture and the Agriculture Research Council. These authorities are mostly able to address damage caused to the environment, although some could be stricter, especially regarding quality control of groundwater resources.

It is not as much the regulations that are lacking but rather the application thereof by farmers and policing by the authorities. It would seem that the main problem lies in the lack of manpower to enforce these regulations. Educating the individual role players would therefore bring enforcement one step closer to success.

11.8.2 Management response

It should be realized that a number of environmental protection issues have to be taken into consideration and that cooperation between all interested parties will be the key to successful environmental management of the Cradle and its immediate environment. The following are perceived to be such issues:

- Decant of AMD resulting from abandoned mines situated at the edge or origin of the COH catchment, which may ultimately lead to the contamination of the Cradle's water resources;
- Negligence or poor agricultural practices followed by piggeries, dairy farms, chicken farms, aquaculture and crop farming in and around the Cradle catchment may lead to the pollution of the whole environment;
- Pollution caused by small industries with wash bays, oil spillage, fuel tanks as well as old filling stations with leaking fuel tanks;
- Low cost housing with little or no infrastructure, creating raw sewage effluent;
- Municipal treatment works functioning above capacity or not cleaning effluents to prescribed standards;
- Accidental spillage of transported hazardous substances;
- Dust pollution from tailings dams;

- Pollution resulting from construction material derived from mining waste material;
- Climate change due to global warming;
- Protection of fauna and flora;
- Natural degradation or weathering of the environment;
- Natural attenuation of rocks and minerals.

These are all subjects for studies that have to be undertaken in the near future to ensure sustainability of the COH WHS. The abovementioned environmental issues are all interlinked or overlapping in some way or the other. Mostly it concerns the study of contamination of water resources by some source, be it mining or agriculture, etc., as most of these activities have an influence on the quality of water. Thus, studies conducted to investigate water-related issues should incorporate as many of the other disciplines as possible.

A management decision will have to be made on how to best approach this integrated environmental problem. It is strongly recommended that a team or working group from the different authorities should be established to report back to Blue IQ management, who in turn has to report back to the World Heritage Committee, to ensure that actions are taken when necessary. Currently there is a Cradle Working Group (CWG) that has been established under the auspices of DWAF as custodians of water. This group includes DWAF, GDACE, Blue IQ, CGS and the University of Pretoria. However, other groups and authorities should be included in this working group or similar group to ensure that all the above disciplines are cooperating.

It was suggested by the author to GDACE (now Blue IQ) that an initial workshop should be held at the Sterkfontein Caves to present details concerning all current projects or available literature from past studies to ensure that no duplication is performed during future work and that the different disciplines are informed of the current knowledge available. Such a workshop will be a cost efficient way to compile all work to date and a good forum to ensure that the right stakeholders and authorities play a role in any future projects for sustainable environmental protection.

Educating the Previously Disadvantaged Individuals (PDIs) and farmers on good practices to prevent contamination of resources is extremely important. Currently documentation is available and should be distributed or presented.

Good scientific principles and knowledge have always been the best tools for informed and effective management.

11.8.3 Research required

The following subjects are proposed for ongoing research to establish the impact of agricultural activities on the environment. However, it should be noted that a number of these studies will overlap with other investigations on water-related issues and studies should therefore be integrated to ensure that no duplication takes place.

- Soil studies are recommended, specifically on the impacts on the vadose zone due to rip ploughing and application of fertilisers and pesticides to soils and the depth of occurrence. The level of persistence of nitrogen from this is not well understood, specifically on dolomitic soils;
- As nitrate is the main contaminant of concern it is suggested that further investigations into the impacts of elevated nitrate levels on the environment and human health, be conducted;
- Methods to determine the rate of bioavailable nitrogen release from organic sources such as sludge, different soil types and manure;
- A number of publications are available on pesticide contamination of soils. However, in South Africa knowledge and expertise on the subject are scattered and should be combined in further investigations under South African conditions, specifically on an intricate system like dolomite;
- Research should be conducted to document damage to vegetation (both natural and cultivated) due to salinisation;
- Further research into microbiological indicators of soil condition and water quality at IAH sites and dairy farms and the release of harmful bacteria and viruses to the environment and their life span;
- Research on lowering of pH in water resources due to leachate from stock farming and how this can contribute to dedolomitisation;
- Research on the impact of local fuel storage sites and farm workshop wastes on surface and groundwater reserves;
- Establish phosphate standards for the COH surface streams, to prevent eutrophication;
- Investigate the impact of aquaculture (fisheries) on water resources;
- Research into heavy metal contamination and its origin in the COH;
- Research the origin and distribution of aromatic hydrocarbons (specifically DNAPL and LNAPL) in the COH.

11.8.4 Monitoring

The most important aspect in the effective management of the environment will be monitoring of the health of the ecosystem, especially the health of our water resources. This can not be emphasised enough as this is the starting point and continuous tool to ensure sustainability of the water resources. Currently there is no monitoring network in place in the COH to sample ground and surface water effectively. DWAF has a small number of insignificant sampling points forming part of their national monitoring network in the area. Although sampling takes place twice a year, the exercise certainly does not address the vital COH WHS water issues.

A proposal by the CGS to GDACE and Blue IQ makes provision for a monitoring network that will cover the entire COH WHS which should be adequate for most of the other disciplines. Due to the diverse geological formations in the

Cradle area and specifically, the highly vulnerable dolomite formations that host the important cave systems, it is difficult to establish such a network without prior information. It is envisaged through the project to census all boreholes in the area and sample them continuously until a spatial dry and wet season database is established. From this and other data, a monitoring network that will be representative of all contributing factors to the health of the ecosystem will be established.

Using manual and electronic data loggers, such a network will then be continuously monitored for quality and quantity of water resources as well as other variables. A geographical information database will then be established from which data will be available for management decision-making.

It is again important to determine parameters representative of all disciplines at these sites from a single sampling effort. This prevents management authorities from incurring unnecessary costs. Again a workgroup will be the vehicle to ensure this.

11.8.5 Other responses

If an assessment is made of other countries and their progress in the management of environmental issues, specifically their interdisciplinary response to disasters, South Africa is definitely trailing far behind. South Africa's regulations and legislation are probably the best in the world but there is a definite lack in the firm application of such legislation. The people of the country do not realise that most of the country's resources are not renewable and that if, for example, aquifers are contaminated or damaged, it will take thousands of years (if ever) to recover. Therefore there is a need to act now and to ensure that sufficient manpower and resources are invested into policing and curbing of hazardous activities.

Apart from the abovementioned workgroup, South Africa needs to have a responsive task team in place, consisting of scientists from all disciplines that can act immediately if disasters of any nature should occur. Over the past few years fish were dying on a large scale in a dam close to Sterkfontein Caves. Water samples were taken but no real problem could be identified from the analysis results. Obviously there were other sources of contamination which were not targeted during sampling. If a multi-disciplinary team was available to do a wide spectrum of tests, the problem could have been identified and steps taken to ensure that such catastrophes do not occur again, or if so, can be curbed to manageable levels. If a methodology could be developed for the COH WHS that is workable, obtainable and sustainable, such a methodology could also be applied at other sites in the country.

This of course would be Utopia! Several countries have policies and guidelines in place to assist in the management of any disaster and numerous publications exist to confirm their success in this regard. The question is: if South Africa wants to be a player in the world arena, should it not act accordingly?

REFERENCES

BARBASH E and RESEK EA (1996) *Pesticides in ground water*. Ann Arbor Press, Inc. Chelsea, Michigan.

BREDENKAMP DB (1986) *Groundwater supply potential of dolomite compartments west of Krugersdorp* , DWAF. Technical Report No. GH3440. Not in the text

BRAUNE E, BROWN SAP, HODGSON FDI, LEVIN M., REYNDERS AG and TREDOUX G (1991) *Groundwater quality management policies and strategies for South Africa*, Draft Document, Department of Water Affairs and Forestry.

CONRAD JE, COLVIN C, SILILO O, GÖRGENS A, WEAVER J and REINHARDT C (1999) *Assessment of the impact of agricultural practices on the quality of groundwater resources in South Africa*, WRC Report No. 64/1/99.

CONRAD JE and COLVIN C (2000) *Handbook of groundwater quality protection for farmers*, WRC report no TT 116/00.

DELLEUR JW (1998) The handbook of groundwater engineering In: *Groundwater flow in karstic aquifers* (White, WB ed.), CRC Press LLC., pp. 18-1 to 18-3.

DWAF (Department of Water Affairs and Forestry) (1992) *Water quality management policies and strategies in the Republic of South Africa.*

DWAF (Department of Water Affairs and Forestry) (1996) SOUTH AFRICAN WATER QUALITY GUIDELINES. 4: *Agricultural Water Use: Irrigation*, Second Edition.

FETTER CW (1994 It written as Fetter 1995 in the text) *Applied Hydrogeology*, Third Edition. Prentice Hall, Upper Saddle River, NJ 07458.

FETTER CW (1999) *Contaminant hydrogeology*, Second Edition. Prentice Hall, Upper Saddle River, NJ 07458. Not in the text

HOUNSLOW AW (1995) *Water quality data: Analysis and interpretation*. Not in the text

LIGTHELM R (1993) *Die Hidrogeologie van karstgebiede met spesiale verwysing na grondwater besoedeling Suid van Pretoria*. Unpublished MSc Dissertation, University of Pretoria. Not in the text

MARTINI JEJ, WIPPLINGER PE, MOEN HFG and KEYSER A (2003) Contribution to the Speleology of Sterkfontein Cave, Gauteng Province, South Africa, *International Journal of Speleology* **32**, pp. 43-69. Not in the text

NAZARI MM, BURSTON MW, BISHOP PK and LERNER DN (1993) Urban Ground-water Pollution: Case Study from Coventry, United Kingdom. *Ground Water* **31** (3), pp. 417-424. Not in the text

PIERZYNSKI GM, SIMS JT and VANCE GF (1994) *Soils and environmental quality*, Lewis Publishers, CRC Press.

SCOTT R (1996) *Geohydrochemistry and Pollution*. 3rd Edition, Institute for groundwater studies. Not in the text

USHER BH, PRETORIUS JA, DENNIS I, JOVANOVIC N, CLARKE S, CAVE L, TITUS R and XU, Y (2004) *Identification and prioritisation of groundwater contaminants and sources in South Africa's urban catchments*, WRC Report No. 1326/1/04. Not in the text

YARON B, CALVET R and PROST R (1996) *Soil pollution, processes and dynamics,* Springer-Verlag Berlin Heidelberg New York.

ISSUE PAPER 12 LEGAL ASPECTS OF KARST AND CAVE USE IN THE CRADLE OF HUMANKIND WORLD HERITAGE SITE

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ABSTRACT

The Legal Aspects of Karst and Cave Use in the Cradle of Humankind (COH WHS): focusing on a review of the existing legislation specific to the karst and caves and recommending improvements as necessary while taking into account other existing legislation which may have an impact on the end result. Such other legislation being existing conservation laws, laws pertaining to the protection of fauna and flora, forestry, building works, mining, agriculture and commercial activities.

The karst and caves of the Cradle of Humankind World Heritage Site (COH WHS) constitute a geological resource that is an invaluable and irreplaceable part of South Africa's Natural Heritage. The karst features both above and below ground are geological, palaeontological and archaeological resources of scientific, cultural and historic value. Minerals that occur in the karst and form in the caves are often rare and occur in unique forms of great beauty. Natural organisms and life forms found on the karst and in the caves are often unique, a limited resource under constant threat - many rare and endangered.

Furthermore, the karst and caves are natural conduits for surface water entering the water table and are highly subjected to pollution that may have an increasingly adverse effect on the aquifer. Karst and cave environments are threatened due to improper use by existing landowners, informal settlements, increased recreational demand, urban and industrial sprawl, commercialisation and a lack of good management guidelines and statutory protection. It is therefore declared to be the purpose of this paper and proposed legislation to protect and preserve the karst and caves of the COH WHS in a controlled and practical manner for scientific, educational and recreational purposes and for the perpetual use, enjoyment and benefit of all persons.

12.1 Introduction

This paper is intended to present a balanced assessment of legislation directly pertaining to the use of the caves and karst in the COH WHS. The paper evaluates existing legislation, focussing on the content of the specific law, the practical application of the law, the future sustainability of the law as well as the enforceability of such a law. The paper further recommends changes and additions to existing laws where applicable and recommends additional legislation where considered necessary.

The positive and negative aspects of such laws as applied to karst and cave use are discussed and recommendations on good management of the resource within the constraints imposed by legislation are proposed. It is anticipated that the outcome of the paper will be a working document wherein both legislation and responsible resource management can co-exist with good conservation ethics while engaging in developing guidelines for best operating practices (BOP) to ensure sustainable and selective utilisation of the COH WHS.

Both the existing laws and those yet to be written should serve the primary purpose for which they are intended. Consequently the laws applicable to the karst and caves of the COH WHS need to be modelled around the strict need for conservation and controlled utilisation while taking into account the activities, needs and opinions of all the stakeholders in the COH WHS. Therein lies the need for the laws to be clear, precise, reasonable, practical, applicable, enforceable and sustainable. Sustainable means that the karst and caves need to be managed in such a way as to achieve an acceptable balance between the need for conservation and sensible utilisation of the resource for the economic benefit of all stakeholders in the COH WHS but within the realm of the law. By achieving this, the laws will be considered workable and enduring.

Activities known to damage the karst and caves are described as well as activities that inadvertently damage the resource or have the potential to do so. Such activities are given special attention with the view of achieving a balance between the negative aspects of the activity, its potential economic benefits and the related legislation.

The further aim of this paper is to give input and substance to current legislation that are applicable to the COH WHS and to integrate accepted international standards on conservation, legislation and BOP with local content such that the emphasis is on conservation while accepting the case for controlled utilisation of selected resources offered by the karst and caves of the COH WHS.

12.2 Literature Review (Current State of Knowledge)

12.2.1 South Africa

12.2.1.1 PERTAINING TO THE LEGAL ASPECTS OF KARST USE

There appears to be no regulations in South African legislation specifically pertaining to surface activities on the karst areas of the country. Nor does it appear that there are any government karst management guidelines other than those for consultants published by the Department of Public Works entitled *Appropriate Development of Infrastructure on Dolomite* and the *Guideline for the Assessment, Planning and Management of Groundwater Resources within Dolomitic Areas in South Africa*, currently being drafted by the Department of Water Affairs and Forestry. All other existing laws and guidelines apply as much to karst areas as they do to any other area of application across the country. It is only where karst exists within areas that have been defined under the National Environmental Management: Protected Areas Bill or are subject to the specific terms of the National Environmental Management: Biodiversity Act, that existing laws and guidelines can be more specifically applied to the protection of the karst.

Other legal applications and guidelines apply where the karst areas fall within provincial and local spheres of government and where such areas are proclaimed as protected areas, nature reserves, wilderness areas, protected environments and areas of special interest. Private reserves and conservancies apply their own rules and guidelines but these are seldom published and primarily serve the interests of the owner. However, many private reserves and conservancies have modelled their rules and guidelines along national lines, which is a practice to be encouraged.

12.2.1.2 PERTAINING TO THE LEGAL ASPECTS OF CAVE USE

The only legislation specific to cave conservation and preservation in South Africa is contained within the Nature Conservation Ordinance, 1983, Chapter IX, Trading in and Preservation of Cave-formations and the Limpopo Environmental Management Act 2003 Chapter 10: Preservation of Caves and Cave-formations. The Nature Conservation Ordinance was promulgated in 1983 following the destruction and sale of the speleothems in Jocks Cave in the then Eastern Transvaal and the subsequent lobbying of the Transvaal Provincial Authority (TPA) by the Cave Research Organisation of South Africa and the South African Spelaeological Association (Transvaal Section). This law is now only applicable within the provinces of Gauteng, Mpumalanga, and the North West. The Limpopo Environmental Management Act 2003 is relatively new and is structured around the old TPA Ordinance. It is however known that Mpumalanga is currently drafting its own cave conservation laws, which will supersede the old ordinance.

Historically the only other attempt to legislate for cave conservation was in 1820 when the then Colonial Secretary instructed the Magistrate in George to inspect the Cango Caves and to draw up regulations for its preservation. As stated previously, only where caves exist within the boundaries of protected areas proclaimed within the three spheres of government in South Africa, are the surface features and entrances to caves protected in accordance with the specific laws pertaining to the conservation and management of the area.

Caves which fall under the jurisdiction of provincial authorities are also protected, not by laws but by the rules and regulations imposed by the authority with regard to access to the property and the cave and the activities therein (e.g. Wolkberg Cave). The same applies to caves in the former homeland areas and tribal trust lands. These caves were not protected as such, but remained largely unexplored and unspoilt because of their inaccessibility.

Caves on private property fall outside such legislation or rules and regulations and are subject to the conservation ethics of the particular landowner. Such ethics are subjective and largely focussed on the economic potential of the cave or the degree of ignorance regarding the significance of caves on the part of the landowner. Only the caving clubs across South Africa who have drawn up Caving Codes of Ethics and Cave Conservation Policies have been mainly responsible for maintaining and preserving the majority of caves in our country.

12.2.2 International

Pertaining to the legal aspect of karst and cave use

Communicating with many countries around the world with their own karst areas and caves has revealed a wealth of information both on the protection and management of karst areas and of the caves that exist within them. Some countries have well-defined guidelines and legislation although most of such guidelines are specific to a particular area or province or state. Few have national guidelines and laws while many others have started the process but have neither a coordinated plan nor a national policy. Regretfully, South Africa currently falls into the last category. The countries consulted were:

United States of America

Canada

United Kingdom

Belgium

Australia

New Zealand

It is interesting to note the similarity between all the guidelines and legislation that were reviewed during the course of the search. It is quite evident that a common approach to the matter has evolved and that the need for good management of the karst as well as the protection of caves is as much applicable in one country as in the next. There are of course specific guidelines relating to a particular environment or to the specific needs of the area and also with regard to the nature of the threats that the area is exposed to – all in accordance with the laws of that country. Recommendations contained in this paper have largely been based on the international literature consulted.

12.3 Problem Statement

An investigation of the area encompassed within the COH WHS revealed that there is a diverse range of activities taking place on the surface of the karst. Many traditional farming activities have been pursued for generations of farmers with seemingly little negative effect on the karst. However, a number of new activities have developed in recent years that may have a profound negative effect on the karst.

12.3.1 Known activities affecting the karst environment:

There is no doubt that every one of the activities listed below has some negative effect on the karst. However the purpose is to assess the severity of such negative impacts and to identify means by which sustainable development may now continue within regulations designed to be realistic, practical and enforceable. Hopefully, the negatively affected areas will recover and, through good management practice, will continue to provide for the future of the residents and the community.

Some of the known activities affecting the karst environment:

- Traditional livestock and agricultural farming methods: cattle, pigs, poultry, maize, feedlots.
- Trout farming - hatcheries and fishing ponds.
- Horse breeding.
- Horse riding trails.
- Hiking trails.
- Proliferation of coffee shops, resorts, conference facilities, restaurants.
- Informal settlements.
- Curio and adventure shops.
- Cafes, garages and trading stores.
- Nature reserves, game reserves and conservancy areas.
- Improvement of existing public roads and building of new roads.
- Making of private gravel roads.
- Subdivision of land and housing development.
- Construction of tourist centres and provision of pathways and infrastructure.
- Harvesting of "Pelindaba Rock".
- Quarrying and mining.
- Industry.
- Activities relating to palaeontology and archaeology.
- Commercial show caves.

12.3.1.1 NEGATIVE IMPACTS AND RISKS TO THE SURFACE OF THE KARST

Traditional livestock and agricultural farming

Livestock farming in the area has primarily focussed on cattle, pigs and poultry. The rocky nature of the karst and limited grasslands kept the cattle population down. Overgrazing is uncommon although areas around waterholes, saltlicks and winter-feeding areas do show high levels of trampling resulting in land erosion and the destruction of the natural flora. Poultry and pig farming are controlled activities in a restricted environment where the most negative aspect is the large accumulation of manure and the means of disposing it. Cattle manure and urine become a major problem when livestock are herded into enclosures close to natural drainage channels feeding the tributaries to the Blaauwbank Spruit. The problem is more prevalent during summer rains, especially where such camps are situated on the natural floodplain close to the river. As with all livestock farming, the main concerns are for diseases that may adversely affect the natural fauna, the destruction of the indigenous flora and the high level of pollution ultimately affecting the natural water resources.

In the case of livestock farming, a further cause for concern centres around the disposal of large numbers of dead animals. Poultry farming produces substantial numbers of dead birds, but the carcasses are more easily disposed of. Cattle and pig carcasses present a different problem because of the size of the carcasses - unfortunately these carcasses are often disposed of in sinkholes and cave entrances. In all cases the spreading of disease and the contamination of the water table are the main causes for concern.

Maize farming and the cultivation of feedstock primarily occur along the floodplain of the Bloubankspruit and its tributaries. However, scattered across the COH WHS area, farming activities may be found, mainly where water is available for irrigation. There are more extensive areas of agriculture on the karst of the buffer zone of the COH WHS southwest of the Sterkfontein Caves and upstream of the Bloubankspruit. Several intensive farming feedlots and market gardens have been established within the floodplain and fields for growing crops have been created where wetlands with reed beds once existed. Not only does wetland ploughing destroy the habitat and the natural filtration capacity of the wetlands but it also disrupts the natural watercourse, causes siltation and allows for massive soil erosion during annual flooding during the rainy season. Finally, all these events contribute to damage to the riverine habitats downstream, silting of the Bloubankspruit as it passes through the COH WHS and polluting of the water with nitrates from fertilisers and effluent.

Trout farming

Extensive trout farming takes place on the floodplain of the Bloubankspruit. The farm comprises a number of hatcheries and fishing ponds from which effluent is discharged back into the river. The effect that this activity may have on the water quality of the river system is not yet known but there is a possibility that the use of fish food as well as fish-borne disease may have a negative effect on the natural population of the downstream river system.

Horse breeding

Horse breeding occurs primarily along the north western side of the COH WHS. The activity appears not to be intensive and little is known of the effects it has on the environment. Most of the breeding facilities and dwellings are not located directly on the dolomite and it is therefore unlikely that the karst areas available to the horses for exercising and to enjoy a small measure of natural grazing, will be negatively affected by such activities. However, common equine diseases, some of which may be transmitted via their faeces, may have some effect on the indigenous fauna of the region.

Horse riding trails

Horse riding trails do exist in the COH WHS but they are not extensive. Although the activity is one of the least detrimental to the environment, it needs to be managed well. Poorly managed trails may have a destructive effect on the indigenous fauna and flora and overuse of trails may lead to erosion during the rainy season which will eventually spoil the natural environment. Littering along the trails is unsightly and may detrimentally affect the indigenous fauna when ingested and lead to pollution of the environment. These negative impacts have to be prevented and the horse rides should be used as an opportunity to educate riders on the importance of the karst.

Hiking trails

There are a few hiking trails currently operating within the area but this may change as the popularity of the area increases and tourists become aware of the rare beauty of the COH WHS. Hiking is an extensive and popular activity throughout South Africa and is generally well managed and it is important that the same level of good management be extended to the hiking trails of the COH WHS in order to sustain the activity and protect the environment. With the huge population of Gauteng on the doorstep of the COH WHS it is possible that hiking may become one of the most popular activities in the area. Unfortunately (unlike horse riding trails), hiking brings the hiker in direct contact with the environment and thus presents the opportunity for the uninformed to collect flora and rocks undetected. Littering equally presents a problem and unmanaged, overused and poorly maintained trails will lead to erosion and despoliation of the environment.

Coffee shops, resorts, conference facilities and restaurants

Coffee shops, resorts, conference facilities and restaurants have been on the increase over recent years as interest and accessibility to the COH WHS area have increased. Prior to the mid-eighties the only facilities that existed were a few cafes and petrol station along the Hekpoort Road southwest of the COH WHS, a few more along the Lanseria to Pelindaba road and a lone trading store in the Kromdraai Valley. A visitor centre and café also existed at the Sterkfontein Caves. In later years numerous restaurants, conference centres, resorts and the occasional coffee shop have opened their doors around the fringes of the COH WHS. These facilities now include Maropeng, the new cultural centre for the COH WHS and the new visitors centre at the Sterkfontein Caves. Apart from the positive aspect of encouraging visitors to the area, these facilities have the negative knock-on effect of increased noise and pollution levels associated with increasing traffic volumes, increased human traffic and waste generation, adding to the destruction of the natural flora, disturbing the natural fauna of the area and contributing to the general degradation of the karst and tranquillity of the environment.

Informal settlements

No official informal settlements currently exist within the COH WHS but there is an extensive informal settlement on the karst to the southwest of the COH

WHS along the upstream watershed of the Bloubankspruit adjacent to the Tarlton Road. This settlement has developed and grown over recent years and has the negative effect of polluting the area with human waste and rubbish which in turn leads to the pollution of the Bloubankspruit, especially during the rainy season. The local authorities do not provide services to the settlement. Unsubstantiated reports on a proposal for a low cost housing development behind the Kromdraai Trading Store in the COH WHS have raised concern amongst the local landowner community. Should this development come about it will inevitably have an associated negative impact on the karst environment. Proper investigation and assessment will need to be conducted should this proposal be considered for implementation.

Curio and adventure shops

There are only a few such shops within the COH WHS and they do not present a major threat to the karst or caves. Two are associated with the commercial caves of Sterkfontein and the Wonder Cave. Such facilities do however make a small contribution to those negative effects on the karst environment identified with the proliferation of resorts, conference facilities and restaurants. However, some positive aspects are that they attract tourists, generally promote those activities that exist in and around the COH WHS and are a source of educational material for the uninformed. This in turn promotes good conservation ethics among the visitors to the COH WHS to ensure the long-term sustainability of the area.

Cafes, garages and trading stores

These facilities largely exist on the periphery of the COH WHS and on the main traffic routes. Their existence primarily benefits the local community and the passing trade. However, they are conveniently located and provide an important service to visitors to the COH WHS. The proliferation of these services needs to be controlled carefully, as the negative impact that they may have on the karst environment could be as significant as that of resorts, conference facilities and restaurants. Although generally smaller in size they are often not as well managed with regard to waste disposal and pollution prevention. Garages are notorious for their lack of facilities for disposing of old oil. They are also ill equipped for dealing with pollution in the event of fuel spillages both above ground as well as from leaking underground tanks. Should these activities occur on the karst or in areas affecting the watershed of the COH WHS, the impacts could have severe detrimental effects on the environment.

Nature reserves, game reserves and conservancy areas

There are a number of these areas throughout the COH WHS. They exist either as a community initiative set up by local landowners or are privately owned. They all operate autonomously and have their own sets of rules. All of them exercise some control over the activities within the COH WHS and are therefore major contributors to the preservation of the karst environment. Through strict access protocols, the members of the conservancy and the owners of the private nature and game reserves are for the most part acting in the best interests of the karst and caves of the area.

Building works associated with the activities on some of the reserves as well as the proliferation of gravel roads within the reserves which are used by visitors to view the game and the scenery, may have a negative impact on the area. Commercial reserves are often stocked with traditionally endemic animals that have not been seen in the area for generations. Such animals that used to roam wild are now managed within comparatively small areas. This has a negative effect on the smaller animal species that have adapted to the modified conditions in the absence of the larger animals. Likewise, the natural flora of the area will also be affected. Some reserves are strictly private and exist for the sole benefit of the owner. These reserves are generally well-managed and since there is no financial incentive to attract visitors, the environment is normally better protected.

Improvement of existing public roads and making of new roads

Prior to the declaration of the COH WHS the area was bordered on all sides by major tarmac roads while all internal roads were minor gravel roads. Apart from the dust and the need for regular maintenance, these gravel roads lent a remote rural atmosphere to the area and created a greater sense of adventure for the occasional visitor. Undoubtedly the gravel roads served as a deterrent to many city dwellers that were reluctant to get their vehicles dirty, but without a doubt visitors were less intrusive and more attuned to the karst landscape. However with the need to develop the area in line with the goals of the COH WHS, the necessity for quick and easy access to the area has necessitated the upgrade of a number of major roads feeding the area, including the new road to the Maropeng Cultural Centre and the restructuring and tarmac surfacing of the primary through route along the Kromdraai Valley.

As with all road construction, the disruption caused by the cutting of new roads and the activities of machines and construction personnel have a negative short-term effect on the immediate environment and also affects the fauna and flora of the area. The improved roads lead to an increase in traffic flow and consequentially, an increase in noise and pollution. Likewise, more traffic resulted in an increase in "road kill", impacting on the natural fauna of the area and also to an increase in littering along the road perimeter.

Making of private gravel roads

Historically, few gravel roads other than municipal roads servicing the farming and landowner community and farm roads built on private property, existed within the COH WHS. Presently however there is a proliferation of gravel roads crisscrossing the COH WHS. Most of the roads are on private commercial game reserves but many are servicing the increasing number of residential developments. These roads are linked to a number of subdivisions in the area where new owners had to be provided with access to their properties. Together with the roads in the commercial game reserves, these roads are having an increasingly detrimental effect on the karst landscape and the natural fauna and flora of the area. Every new road is a potential killing zone, an eyesore on the landscape, and without proper design, has the potential to cause soil erosion and environmental degradation. Many new gravel roads fall in disrepair or are abandoned after a few years of seasonal rains and new roads are created alongside the ruts of the old road.

Subdivision of land and housing development

The subdivision of land and development of housing is mostly evident along the southeast, south and south-western side of the COH WHS as well as in the adjacent buffer zone. These activities are on the increase and will ultimately have a significant negative impact on the karst and caves of the area. The majority of the known wild caves within the COH WHS exists in the very areas affected by these activities and are increasingly under threat from developers, new landowners and homebuilders. Whereas in the past these caves were considered to be in remote areas and out of harm's way, they are now in peoples' backyards and are considered by many to be a nuisance. The same applies to the karst landscape in these areas. The damage to the natural rock formations and to the fauna and flora of the area is significant and on the increase. The pollution of the groundwater by human waste and illegal dumping in cave entrances and sinkholes is prolific throughout the area and is of major concern.

Construction of tourist centres and provision of pathways and infrastructure

The establishment of the COH WHS has led to an upsurge of construction activities in the area. The work at the Sterkfontein Caves Visitors Centre and at the caves themselves is indicative of the need to improve the attractions and the facilities to accommodate the anticipated influx of visitors to the COH WHS. The same applies to the Maropeng Cultural Centre, the focal point of the COH WHS. The construction of these facilities and those at Sterkfontein necessitated the building of new roads, pathways and infrastructure, all of which have both a short-term negative impact on the karst environment during the construction phase as well as a long-term negative impact.

Disruption of the immediate environment and also of the fauna and flora of the area brought on by the cutting of new roads, excavations and the activities of machines and construction personnel are some of the short-term negative effects. There are also negative effects resulting from the increase in the flow of traffic and construction equipment and the consequential increase in noise and pollution. The increase in "road kill" impacting on the natural fauna of the area and the increase in rubbish scattered along the road perimeter are also causes of concern.

In the long term, negative effects are experienced from the increase in human and vehicular traffic, littering, sewage and waste disposal, noise and light pollution, altered surface water runoff patterns and the local destruction of the surrounding fauna and flora with the possible introduction of alien species. Other factors include the possible proliferation of opportunistic business development in the area ranging from garage and shopping facilities to informal roadside traders. All these activities will have a negative impact on the surface of the karst.

Harvesting of "Pelindaba Rock"

Although this activity is discouraged, the collection of Pelindaba Rock occurs throughout the COH WHS though most often without the landowner's permission. The unique shapes caused by the weathering of the rock are of particular interest to landscape developers and gardeners. As the area is close to the vast urban sprawl of the Witwatersrand towns and access to the dolomite is relatively easy, many tonnes of Pelindaba Rock have been collected over the years and are found in gardens across the Witwatersrand.

This stripping of the dolomite pavement is detrimental to the karst and often results in soil erosion by destroying the natural rainwater ponding and runoff patterns. This in turn leads to changes in the levels of saturation, the properties of the soil, soil stability and the ability of the soil to maintain the critical balance necessary for natural plant growth. For a healthy karst landscape it is essential to have a stable natural ground cover to prevent erosion and provide for the natural flora of the area. Similarly, all activities which disturb the natural processes on the surface of the karst can be as detrimental to the caves and the water table below the dolomite.

Quarrying and mining activities

There are no quarrying or mining activities currently taking place within the COH WHS other than excavation work being undertaken for the purpose of building construction and scientific studies. Old mines and calcite excavations do however litter the area and detract from the natural beauty of the COH WHS. Some of these early excavations did provide the initial means for the discovery of many of the fossils found in the COH WHS and continue to do so today. The consequences of these activities are to destroy the natural karst landscape with all the negative impacts that have been discussed previously.

Quarrying activity at the Sterkfontein Quarry in the COH WHS buffer zone has ceased in recent years but has left a huge scar on the landscape - an eyesore to all visitors to the area. Plans to rehabilitate the quarry or put it to some positive use are being considered. A brickyard in the dolomite area to the southwest of the COH WHS at Tarlton continues to operate a quarry for the excavation of clay. This brickyard is also responsible for the destruction of the river bed and the banks of the Bloubankspruit.

Quarrying and mining are discussed further in the next section.

Industrial activity

No known industrial activity takes place within the COH WHS but there are random peripheral activities in the buffer zone that may have an effect on the area. The activity which has the most severe negative impact on the COH WHS is the

Percy Stewart Sewage Works, situated to the southwest of the COH WHS. This sewage works serves Mogale City and is very old. The works lies above the stream feeding the Blaauwbank Spruit and is responsible for releasing polluted water into the stream that then enters the spruit. It is also known that the sewage works is responsible for leaking polluted water directly into the aquifer via the numerous faults that intersect the dolomite in the area. This polluted water can have a disastrous effect on the quality of the water in the Bloubankspruit and on the ecosystems both above and below the surface in the COH WHS.

A brick-paving factory lies within the buffer zone adjacent to the Sterkfontein Quarry. The numerous caves and sinkholes that exist within the area have been severely damaged and many have been filled with rubble and waste material.

Other industrial activity occurs outside the COH WHS at Pelindaba at the opposite end of the Cradle and at Lanseria Airport. These activities have no direct effect on the COH WHS other than to contribute to air and noise pollution in the area. However they should not be ignored as the rate of their development and other such activities is expanding rapidly and it will not be long before such activities will be on the very doorstep of the COH WHS.

Archaeological and Palaeontological activities

These science-based activities are the foundation of the COH WHS and are being actively pursued at selected sites throughout the area. The activities are destructive and leave indelible scars on the karst landscape. The negative effects on the fauna and flora of the area are as described for other similar excavation type activities on the karst. The advent of tourism within the area to view these activities will also add to the levels of littering, trampling of vegetation and destruction of natural habitats. As the interest in the COH WHS increases there is no doubt that increasing pressure will be placed on these sites - ultimately requiring a permanent infrastructure to serve the needs of the increase in human visitation. This would further add to the burden the sites would need to bear.

Commercial Show Caves

Two commercial show caves currently exist in the COH WHS. Sterkfontein Cave is synonymous with the very existence of the Cradle of Humankind. Although part of the cave is run as a commercial show cave the adjacent areas have over the years produced an extensive array of archaeological and palaeontological finds. With the establishment of the COH WHS, the cave and surrounding area has undergone considerable change. The old buildings were demolished and a new visitors centre and museum have been constructed. Surface tours are conducted around the site to view the diggings and concrete walkways and raised timber and steel decks have been built to direct and control the movement of visitors. Inside the cave there are established routes and staircases and electric floodlights to highlight specific features and to show visitors the way. Wonder Cave (aka Van Wyk's Cave) is a strictly commercial venture. The cave has a tourist centre and surface pathways and concrete steps leading down to an elevator with a supporting steel structure which transports the visitor down into the cave. Visitors tour the cave along concrete pathways and electric floodlights light the cave.

In both cases infrastructure had to be built to provide for the needs of the visitors and roadways constructed to service the sites. As with other developments, these processes and activities have a negative impact on the local karst and ecosystems that will continue to escalate as the popularity of the caves increases.

12.3.1.2 NEGATIVE IMPACTS AND RISKS TO THE SUBSURFACE OF THE KARST:

Caves:

To appreciate why caves are so important it is necessary to understand why it is vital to protect and preserve them. Without going into details on how a cave is formed it is important to understand that caves are:

- A complete habitat for many unique species of fauna and flora.
- A conduit through which surface water can reach the water table.
- A source of mystery and adventure to human beings.
- Of religious and cultural importance.
- Of scientific interest and value.

Fragility of cave ecosystems

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 specialised 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, the geohydrological processes or both.

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). Caves have a very low nutritional status, and cave life is largely dependent on the energy source provided by bat guano and detritus washed into the cave system. Disturbance through visitation often displaces such fauna.

Consequently all activities within caves will have some degree of negative impact on the cave environment. It is therefore important to identify the activity and its subsequent impacts on the cave and to manage the process in such a way that the needs of the activity are balanced against an acceptable level of negative impact on the environment. Obviously, varying circumstances need to be taken into consideration, including the sensitivity of certain cave environments.

Commercial show caves

The commercialisation of any cave system undoubtedly subjects the cave to every conceivable negative impact. The process begins at the entrance with the alteration of the physical structure of the cave to provide access and to accommodate the movement of visitors. This process continues inside the cave with the construction of pathways, stairways and access routes for communications and electrical cabling. These activities, plus the tourist traffic, have numerous negative effects including the following:

- The alteration to temperature and humidity brought on through structural changes and altered ventilation.
- The introduction of alien materials such as metals, concrete, monitoring equipment, cables and lighting.
- The alteration of temperature, humidity and CO_2 levels brought about through human traffic.
- The alteration of air movement and micro-climate which affects cave humidity and the growth of speleothems.
- The alteration of the cave's water chemistry resulting from changes to the surface drainage system and from pollution both above and below ground.
- The subsequent reduction in the quality of the water moving through the cave system and the impact on the survival of rare isopod populations in some subterranean lakes.
- The installation of artificial light which encourages algal and fungal "blooms", on speleothems. Artificial light can also raise the cave temperature and disturb bat colonies.
- The disturbance of bat colonies which can result in their abandoning of the cave altogether. This in turn may lead to a loss of nutrient input in the form of bat guano.
- The erosion or disturbance of cave sediments and their contents and the compaction or liquefaction of floors brought about by high traffic levels destroying cave soil fauna and flora.
- The physical destruction of speleothems and mineral crystal growths by collectors, tourists, scientists, careless cavers and unauthorised persons.
- The disturbance and displacement of cave entrance dwellers such as porcupines, owls, rodents, etc.
- The introduction of alien organisms, e.g. algal and fungal spores and bacteria.
- The introduction of pollutants, e.g. paper, plastic, foil, lint from clothing, etc.
- Vandalism, graffiti and the raising of dust levels which spoil speleothems.

Considering all of the issues above, it could be said that there are no positive aspects relating to the commercialisation of caves. However, in relation to the COH WHS, commercial show caves have a role to play. Apart from attracting tourists and bringing income to the COH WHS the show caves should serve as a means to educate the public. If developed in line with the best international standards and managed properly the caves can provide a living classroom for future generations to understand the need for cave conservation. However it needs to be understood that commercial show cave operators are in the business to make money and although they provide a service to the general public, their primary aim remains financial gain. The most successful commercial show caves are those owned or managed by enlightened individuals who understand the need for reinvestment into the cave and who accept the responsibility for preserving the cave for their own benefit as well as for future generations.

Caving club activities in wild caves

Background:

Historically caving as a *bona fide* club activity has been the domain of a very small and dedicated group of enthusiasts belonging to only a few caving clubs countrywide. The oldest of these clubs was founded in the mid-fifties and comprised a section located in Cape Town and a section in Johannesburg. Later other clubs were formed and today there are five active clubs with four of the clubs belonging to the South African Spelaeological Association (SASA) and the other club remaining independent.

South Africa is not a well-endowed country with regard to the number and nature of its caves as compared to many other countries around the world. Being a country blessed with sunshine and an abundance of outdoor activities, most people prefer to stay above ground rather than to venture into the dark and dirty environment of a cave.

Consequently the membership of these clubs has traditionally been very small and the total number of club members countrywide has probably never exceeded 200 at any one time. The result has been that the majority of the known caves in the country have been discovered, explored and surveyed by only a handful of well-trained and experienced cavers. Consequently the bulk of our knowledge on the caves of South Africa is owed to these cavers and especially to those with a scientific background who have also been responsible for the majority of the available documentation on the caves.

Activities:

The activities of the various clubs are mostly focused on the areas closest to them:

- Cape Peninsular Spelaeological Society (CPSS) - Cape Peninsula and Cango Valley
- Spelaeological Exploration Club (SEC) – Gauteng, Far West Rand and North West Province.
- Cave Exploration Rescue and Adventure Club (CERAC) - Mpumalanga and Limpopo Province.
- Potch Potholers - Far West Rand and North West Province.
- Cave Research Organisation of South Africa (CROSA) - Gauteng and Limpopo Province.

However the CPSS and SEC who were former Sections of the South African Spelaeological Association (SASA) have been responsible for the discovery of the majority of caves across South Africa.

The clubs normally compile a six-monthly or annual meets list that identifies the caves to be visited, the reason for the trip and the responsible meet leader. Because of the nature of our caves and the inherent delays in moving through the restricted passages, caving is not an activity for a large number of persons. Consequently it is seldom that more than 6 to 8 cavers attend any one trip. Consecutive visits to caves are rare other than during ongoing exploration and survey work or for specific scientific reasons. Once explored, caves are seldom visited more than twice a year by any one club or even by all clubs.

Negative impacts to the cave environment:

The negative impacts that *bona fide* cavers may have on the cave environment are similar to many of those identified for commercial caves:

- The alteration to temperature, humidity and CO_2 levels brought about by human traffic.
- The alteration of air movements and micro-climates which affects cave humidity and the growth of speleothems.
- The alteration of the cave's water chemistry resulting from pollution below ground level and the impact on rare isopod populations in some subterranean lakes.
- The disturbance of bat colonies which could result in their abandoning the cave altogether.
- This in turn results in a loss of nutrient input in the form of bat guano.
- The erosion or disturbance of cave sediments and their contents and the compaction or liquefaction of floors brought about by cavers moving through the cave, destroying cave soil fauna and flora.
- The introduction of pollutants, e.g. paper, plastic, foil, lint from clothing, etc.
- The dirtying of formations and destruction of floors resulting from the passage of cavers.
- The physical destruction of speleothems and mineral crystal growths by careless cavers.
- The introduction of alien organisms, e.g. algal and fungal spores and bacteria into the cave environment.
- The raising of dust levels which spoil speleothems.
- The disturbance and displacement of cave entrance dwellers such as porcupines, owls, rodents, bees, snakes, etc.

However it must be recognised that any process of discovery and exploration is not achieved without some measure of destruction and disturbance of the environment. Consequently the degree of destruction resulting from the processes identified above is very small when compared to a commercial cave or from commercial adventure caving, and constitutes an acceptable level. Caving clubs impose strict codes of conduct on their members and are generally vigilant when it comes to proper behaviour within the cave environment.

Commercial adventure caving

Commercial adventure caving is a relative newcomer to the karst and associated cave environment although it can be likened to the early days of commercial tourist caving before the onset of the show cave concept.

During the eighteenth century South African explorer Carl Maunch ran a primitive tour operation in the Wonderfontein Cave, located just outside Carltonville in the North West Province. The cave was then called Carl Maunch's Cavern and history recalls that visitors were charged a fee and given a basic light source before being taken on a tour through the cave. Equally, in the early days the Sterkfontein Cave was operated on similar lines. In those days there were no electricity or established walkways and visitors were given nothing but hand-held carbide lamps to help them finding their way through the cave.

Today's commercial adventure caving operators operate on a similar basis. Customers are charged a fee, given basic protective clothing and a caplamp and are taken on a tour through the cave on a route designed to create the impression of exploring a new cave while the customer is exposed to some of the challenges of real caving.

None of these operators currently own their own cave but prefer to use wild caves owned by farmers and other landowners to further their own business aims. Those farmers and landowners who agree to have their caves exploited in this way, do so either for commercial gain or through ignorance. Over the years, many farmers have approached the caving clubs to obtain knowledge regarding their caves in the hope that these caves could be developed as tourist caves. One such farmer owned what was known as Van Wyk's Cave, which later became the Wonder Cave. However, many other farmers show no interest in their caves and have allowed caving clubs free access to their property and their caves. Unfortunately, some commercial operators took advantage of this free access to property and caves and it has been known that some of them visit caves with paying customers without the knowledge or consent of the landowners. This malpractice has caused considerable upset and has on occasion led to complaints by landowners. In other cases relations became stressed between landowners and the caving clubs or other bona fide organisations.

Of further concern is the special effort made by commercial operators to extend their activities to more and wilder caves as a way to expand their business. Commercial adventure caving operators solely exist to make money and although some will claim to have cave conservation at heart and to use their activities as a means to educate the general public, this is generally a smoke screen to enhance their acceptability by the concerned community and to further their own business aims. No adventure caving operator has yet been identified who has invested a share of profits into the rehabilitation and upkeep of the caves they use and any physical effort they may put in is purely cosmetic in keeping the cave clean for their own financial benefit.

Negative impacts of commercial adventure caving on the cave environment:

The negative impacts of commercial adventure caving on the cave environment are almost identical to those caused by the activities of caving clubs, but with important differences:

Most customers who go on an adventure caving trip have little or no knowledge of caves other than what they learnt at school and the ten minute awareness talk given by the operator prior to the trip. Most customers only go adventure caving once or twice in a lifetime. Unlike the members of caving clubs, most paying customers go adventure caving for the experience and not because of an interest in the cave as such. Also, most customers have no knowledge regarding cave conservation and show very little interest in any conservation measures. In the end, paying customers have a totally different perspective on caves and little to no knowledge on how best to minimise the human impact on the cave environment.

Equally, the adventure caving operators are in the business to make money and not because of a love for caves. Since the operators do not own the caves there is also no sense of ownership or any long-term responsibility for the preservation of the caves. Tour guides are also there only to earn money and not because of a love for the caves. Consequently the focus of their attention is on the paying customer and not on the cave and how to ensure that the group move through the cave with the minimum impact on its environment.

Unlike a show cave tour where the paying customer is restricted to pathways, has no control over the lighting and cannot access sensitive areas or formations, the adventure cavers are continuously in contact with sensitive areas and formations, while continuous observation by one or two guides is impossible. Consequently of all commercial tourist-caving activities, adventure caving is the most detrimental to the wild cave environment.

Effects on selected caves caused by human traffic

Human beings have been exploring and living in caves for thousands of years and although similar activities may be unacceptable in today's environment, there is no doubt that had they not done, so then our knowledge of our early ancestors would not be what it is today. In fact, caves have been the repositories for vast amounts of material and modern scientists model our understanding of the process of evolution on this ancient material. Caves have always been and will always be visited by human beings and it is therefore important to acknowledge that such visits will have both positive and negative effects on the caves.

In today's environment it is however necessary to concentrate on the more negative effects of human traffic on caves and to best illustrate this, four caves have been selected as examples:

Sterkfontein Cave –

Historically the most frequented tourist cave in the COH WHS it has over the years suffered under major impacts induced by humans. Although the cave was originally mined for calcite and later used for scientific research, the structural alterations to the cave to accommodate visitors and the subsequent passage of thousands of feet and the effect of dirty hands have taken the biggest toll. The major consequences are:

- Destruction of natural entrances and watercourses.
- Changes to natural airflow and subsequent humidity levels.
- Destruction of natural plant and animal habitats at cave entrances.
- Compaction of natural cave floors and siltation of underground watercourses.
- Damage to formations and muddying of cave walls.
- Destruction of underground microclimates and habitats that support troglobitic life forms.
- Pollution of groundwater and destruction of aquatic fauna.
- Negative impacts on the roosting and hibernation of bat species.
- Graffiti.

Grobler's II Cave –

This cave, until recently the sole domain of *bona fide* cavers, has seen an influx of commercial adventure cavers with the consequential negative results. The cave, although once mined for calcite, was one of the best-protected caves in the COH WHS. The mined access adit was concreted, closed and gated, leaving only the natural entrance shaft as entrance to the cave. Unfortunately the commercial adventure cavers got to know about the cave and the entrance gate was removed. An internal squeeze between formations was also opened forcefully and subsequent efforts by the caving clubs to gate the passage were defeated when the gates were repeatedly destroyed.

Prior to the advent of the commercial adventure cavers the cave was infrequently visited by the caving clubs and suffered the minimum negative impact. Today the cave is showing signs of relatively high traffic volumes and the subsequent wear and tear associated with the passage of people. In more recent months, the owner has complained about these activities to the Landowners Association and to the Speleological Exploration Club, and the adventure caving activities have been stopped.

Bats' Cave –

This extensive cave of 4km has always been considered a sacrificial cave by caving clubs. The cave was historically mined for calcite but because of its location and easy access it has always attracted casual visitors and adventurers out to discover what the cave had to offer. Over recent years the cave has become the main venue for commercial adventure caving operators and although this activity does exercise a degree of control over the cave it also means that operators are responsible for the high levels of human traffic passing through it. The major consequences of abuse over the years are:

- The cave has mostly been stripped of its formations
- The major routes are well trampled
- The cave is often full of rubbish
- The entrances are used as rubbish dumps
- Pollution and destruction of habitats and environments
- Pollution of groundwater
- Destruction of troglobites
- Destruction of entrance fauna and flora
- Disruption to bat breeding and hibernation cycles
- Graffiti

Boon's Cave –

Although this cave is not in the COH WHS, it is a good illustration of the negative impact that humans can have on a cave and therefore serves as a warning to all concerned parties. The cave is located in the North West Province and is an extensive system with a number of large chambers. The cave was originally mined for lime and later during the 1940s it was mined for phosphate during a shortage of fertiliser. The cave has a natural shaft entrance and a mined inclined adit where visitors may enter. The adit is protected by a substantial steel gate, which is kept locked by the landowner.

Apart from the historical damage to the cave caused by the mining, the cave is under a new threat by humans. At the bottom of the natural shaft the landowner has established a braai area with numerous log seats and a fireplace. Large groups of visitors from the local farming community are allowed to have picnics and braais in this area. Alcohol is consumed and the debris from the festivities left until someone is prepared to clean the area. Unfortunately, people enter the cave passage system and litter and human waste have been observed along some of the passages. A further activity takes place at the entrance to the cave around the natural shaft in the form of pigeon shooting with shotguns. The high number of spent cartridges found provides testimony to the level of the activity. The major negative impacts associated with these activities are:

- Pollution by human waste and litter
- The ingress of smoke into the cave atmosphere as the cave breathes to equalise the internal and external air pressures.
- The pollution of the natural cave atmosphere and the effects on the cave biota
- The disruption to the roosting and hibernation patterns of the resident bats
- The destruction of the natural birdlife around the entrance shaft

- The uncontrolled exploration of the cave by unskilled persons with no knowledge or concern for the cave environment and its natural inhabitants

Effects of archaeological activities on the caves

Although the archaeological importance of the various sites in the COH WHS was evident as far back as the beginning of the nineteenth century, it was only during the mid-1960s that these activities really took off and have continued unabatedly until the present day. Since archaeology revolves around the study of people, customs and life in ancient times, the research primarily concentrated on excavating the soft filling of the caves and cavities within the COH WHS. Furthermore, the activity was focused in the areas around the entrances of the caves and has seldom invaded the inner realms of the caves themselves. The negative aspects of these archaeological activities are:

- Disruption to the natural watercourses entering the caves and the resultant effects on the cave habitats and life forms.
- The alteration to temperature, humidity and CO_2 levels brought about by human activity at the entrance.
- The alteration of air movements and micro-climates which affects cave humidity and the growth of speleothems.
- The alteration of the water chemistry in the caves resulting from pollution entering from above ground and the impact on rare isopod populations in some subterranean lakes.
- The disturbance of bat colonies which could result in their abandoning the cave altogether.
- The resultant loss of nutrient input in the form of bat guano.
- The disturbance and destruction of cave sediments and their contents and the compaction or liquefaction of floors brought about by excavators which can destroy cave soil fauna and flora.
- The introduction of pollutants, e.g. paper, plastic, foil, lint from clothing, etc.
- The dirtying of formations and destruction of floors caused by the passage of researchers.
- The physical destruction of speleothems and mineral crystal growths by careless excavators.
- The introduction of alien organisms, e.g. algae and fungal spores and bacteria, into the cave environment.
- The raising of dust levels which spoil speleothems.
- The disturbance and displacement of cave entrance dwellers such as porcupines, owls, rodents, bees, snakes, etc.

Effects of palaeontological activities on the caves

Palaeontological research in the COH WHS has been one of the main focus points of the world's attention since the early 1900s although it was only in later years that the activity increased to the level that it is today. Palaeontology is the scientific study of all forms of life in prehistoric times as it is represented by fossils. It therefore stands to reason that the research process itself is probably the most destructive of all the associated sciences. The negative impacts of archaeological activities are the same as described above, but with the added element of the destruction of natural rock forms.

Sterkfontein Cave is a good example of the destructive processes brought about by humankind's scientific quest for knowledge. The natural rock and calcite formations have been destroyed in order to get to the bone breccias and fossils. Destruction by mechanical means and explosives left the dolomite in shattered form and also destroyed many cave entrances and passages. Piles of waste material are often left inside the cave system – most of the time wastes are just dumped around cave entrances.

Another cave damaged by palaeontological activity is situated in the Krugersdorp Game Reserve. This cave, which was extensively excavated, is littered with decaying sandbags and wooden walkways. During the excavations, members of the public were invited to join the dig and to learn more about the craft. However, when excavations ceased, the dig was totally abandoned and no attempt at restoration or repair was ever made.

Effects of different light sources on the cave environment

Various forms of lighting have been used to explore caves since the dawn of humankind. From burning bundles of sticks until today's modern electric lights, the cave environment has been exposed to a variety of light sources through the years. In the past the main requirement was to find one's way through the cave with no regard whatsoever to the negative effect that the light source may have on the cave environment itself. However, with today's emphasis on conservation of the natural environment, the type of the light we use to light up our caves is the focus of considerable research and debate.

We all agree that light in a cave, other than the natural light that enters the cave through the entrance, is detrimental to the environment and unnecessary as far as the cave is concerned. However, mankind will continue to explore caves and to visit them for recreational purposes as well as for scientific research and therefore, light in one or other form is here to stay. Some negative effects of light are:

Permanent electric light (as in show caves) from a generator or mains supply:

- Permanent electric light sources promote the growth of algae on rock walls and speleothems.

- Electric cables act as a pollutant and the magnetic field associated with the flow of electricity in the cable may affect the cave fauna negatively.
- Permanent electric light can destroy the cave biota and affect the breeding and hibernation patterns of resident bat colonies.
- Permanent electric light leads to increased cave temperatures, destroying natural habitats and environments.
- Permanent electric light encourages invasion of the environment by alien life forms which are not natural to the cave and may be destructive to the cave biota.
- Electric light fittings corrode in the cave environment and deposit rust and aluminium sulphate on the cave floor.

Portable electric light source (hand-held torch, headlight and miners cap lamp)

- Spent batteries are left in the cave to corrode and poison cave habitats.
- Corroded batteries contaminate the atmosphere.

Candles and paraffin lamps:

- While burning, candles and paraffin lamps release soot and other products into the atmosphere which may be poisonous to the cave biota.
- Careless positioning of candles in the cave may lead to the deposition of soot on rock walls and speleothems.
- Candles leave wax deposits which are often left behind and which may be detrimental to the cave environment.
- Candles and paraffin lamps are smelly and taint the atmosphere.
- Spent candles are often left as unsightly lumps of wick and wax on rock surfaces or speleothems.
- Paraffin may be spilt which will contaminate the cave floor and the cave atmosphere.
- Candles and paraffin lamps heat the atmosphere in the cave.

Carbide lamps:

- Carbide cap lamps that are not functioning properly may release soot and other combustion products into the cave atmosphere which may be poisonous to the cave biota.
- Carbide may leave soot deposits on rock walls and speleothems if the lamp is not positioned carefully.
- Spent carbide (if left in the cave) can pollute habitats and the cave environment.
- Carbide lamps are smelly and taint the atmosphere.

- Carbide lamps heat the atmosphere in the cave.

Dumping of animal carcasses, chemicals and refuse in cave entrances and sinkholes

Unfortunately to the uninitiated, cave entrances and sinkholes are often seen as a nuisance and as a convenient place in which to dump animal carcasses, refuse, discarded motorcars, domestic appliances and chemicals. Originally an activity primarily pursued by the farming community, the use of cave entrances and sinkholes for this purpose has now become common practice among land and home owners as urban sprawl has enveloped the fringes of dolomitic areas. Historically the caving clubs and some provincial authorities attempted to educate the farmers and landowners on the negative aspects of this practice. For caving clubs however, this has been a difficult task as they had no authority and needed to maintain a working relationship with the farmers and landowners in order to continue to have access to the caves. The negative aspects of this activity are:

- Poisonous by-products and chemicals are introduced into the cave environment which may spread through the cave with the associated destruction of cave habitats and biota.
- The ingress of poisonous by-products and chemicals into the dolomitic aquifer may lead to the destruction of aquatic life.
- The pollution of the aquifer and the resultant negative effect on human health.
- The possible introduction of harmful diseases into the cave environment and the effects on cave life and humans.
- The introduction of noxious fumes and gas and the pollution of the cave atmosphere.
- Despoiling cave and sinkhole entrance features and creating favourable breeding conditions for hazardous bacteria.
- Creating a dangerous environment for entrapping unsuspecting humans and animals.

Filling of sinkholes and closure of cave entrances

The filling of sinkholes and the closure of cave entrances are on the increase especially in karst areas suffering from the impact of urbanisation. Geographically the dolomite areas are rocky and sparsely covered and it is only on the flat plains where the karst is well covered as well as in the valleys where agriculture is most evident. Cattle farming, along with the raising of sheep and poultry are historically the main farming activities on the karst. Consequently the karst areas have been largely unpopulated and only where human activity bordered on areas with cave entrances and sinkholes have cave entrances been closed and sinkholes filled. Sinkholes and cave entrances on agricultural land until recently suffered most as they often got in the way of ploughing activities. However, farmers often fenced off large sinkholes or cave entrances and farming activities just continued around them.

Today however as towns situated on the dolomite expand due to population increase and the influx of traditionally rural people, farming areas are now turned into smallholdings and housing developments and sinkholes and cave entrances are often seen as being dangerous or a nuisance. The result is that indiscriminate filling of sinkholes and closing of cave entrances are happening. The negative impacts are:

- The closure of natural conduits for surface water entering the dolomitic aquifer.
- Pollution of cave environments from fill material leaching into the cave systems.
- The destruction of natural habitats and destruction of cave fauna and flora.
- Changes in temperature and moisture levels in the caves and the resultant negative effects on the cave ecology.
- The alteration of temperature and humidity following entrance closures and altered ventilation.
- The introduction of alien materials such as metals and concrete.
- The alteration of air movement and micro-climate which affect cave humidity and the growth of speleothems.
- The alteration of the water chemistry in the caves caused by changes to the surface drainage system and by pollution from above ground.
- The subsequent reduction in the quality of the water moving through the cave system and the impact on the survival of rare isopod populations in some subterranean lakes.
- The disturbance of bat colonies which can result in their destruction or abandoning of the cave altogether.
- The disturbance and displacement of cave entrance dwellers such as porcupines, owls and rodents.
- The destruction of the natural fauna and flora associated with the cave entrances and sinkholes.

Quarrying and mining activities

The destructive processes imposed on the karst and caves by these activities are perhaps not as well documented and understood as we would like to believe. Anyone familiar with South African history will recognise the importance of the mines and clearly understand that these activities go back a long way and are synonymous with the founding of Johannesburg and the economic development of the entire region. The sinkhole phenomena most prevalent in the Far West Rand during the 1940s and 1950s (the result of the dewatering of the dolomite undertaken to enable the mines to mine on deeper levels) was accepted as a necessity. At the time the threat to the population affected by the sinkholes (most notably the people of the town of Bank), was of major concern and although much was written about this and the geological aspects of the phenomena, nothing was written about the negative effects that dewatering was having on the karst and caves of the region.

Closer to the COH WHS are the gold mines of the West Rand along the Krugersdorp to Randfontein ridge. Although these mines are some distance from the Cradle and have had little surface impact on the area, the associated industries, township developments and urban sprawl emanating from the mining industry brought a number of negative impacts to the doorstep of the Cradle. These impacts are more associated with the water resources of the Cradle and are detailed in Issue Paper 9 (Krige and Van Biljon, 2007).

However, during the last decade mining houses came under pressure to review their activities and to accept the responsibility for their past actions. This has resulted in some of the mines establishing their own conservation committees whose responsibilities are to oversee the rehabilitation process, establish codes of best practice and advise on future mining activities. Equally it is only recently that environmentalists and conservationists have started studying and writing about the devastating effects that mining and its associated industries have had on the affected areas.

All mining and quarrying activities associated with the COH WHS have fortunately been on a small scale when compared with other areas. Mining for iron ore goes back into antiquity and very little evidence of the existence of these mines can be seen today. This mining activity extended right across the karst from Pretoria to the Far West Rand.

However the mining for gold, lime and other minerals are of more recent origin and it was the activities of lime miners which had the greatest impact on the landscape of the Cradle. At a time when the gold mines and associated industries were rapidly expanding and cement for construction and lime for the metallurgical plants was in high demand, the lime miners found cave formations to be a very pure source of lime, readily available and easy to mine. In the process many caves were partially or completely destroyed. Tragically most of these caves were beautiful and it is only by viewing their shattered remains and by visiting caves missed by lime miners that we appreciate the magnitude of the destruction that took place. On the positive side one has to admit that these miners also exposed fossil sites and although many fossils were undoubtedly destroyed, the remaining fossil sites led to the development of the COH WHS as it is today.

Apart from the mining for lime the Sterkfontein Quarry is the biggest quarry in the area. For many years this quarry was mined for aggregate for the road building and construction industry leaving a terrible scar on the landscape. Permission should never have been granted for the quarry to operate and throughout its life it remained a controversial issue which has yet to be resolved as the mine still has to be rehabilitated and decisions made as to the future of the pit.

Other small quarrying activities outside the Cradle which may have a negative impact on the area are clay quarries, existing mainly in the bed of the Bloubankspruit. The legality of these quarries needs to be investigated but the destruction to the riverbed is very evident while the potential for sinkhole development has increased. The threat of massive erosion of the streambed and subsequent silting downstream is of major concern. The impacts of these activities are well described in Issue Paper 11 (Groenewald 2007).

Acid mine drainage

Acid mine drainage is a direct consequence of the mining practices of the past and an inevitable result of the interference of humans in the natural order of things. In brief it occurs when the water table returns to its natural level in the now defunct mines and becomes contaminated through exposure to certain minerals, a process that would not occur under natural circumstances. The result is that contaminated water (which is highly acidic) flows through the dolomitic aquifer and eventually reaches the surface to flow down natural streams entering the COH WHS. This contaminated water has the potential to cause harm to both animals and humans. Much has been written about the problem and what is taking place to resolve the matter and is covered in detail in Issue Paper 9 (Krige and Van Biljon, 2007).

Industrial activities

The negative impacts that industrial activities have on the subsurface of the karst primarily extend to the contamination of the dolomitic aquifer from the ingress of effluent through the natural drainage channels and faults within the dolomite and from the dumping of waste material down sinkholes and cave entrances. These contaminants enter the cave environment with the same disastrous effects that we have described elsewhere in this paper. Also, the human activities associated with these industries have their own detrimental effects on the subsurface of the karst. Such activities may be in the form of new construction and development in the area or in the building of new roads. Although these activities appear to be restricted to surface areas, there is no doubt that they have an indirect impact on the subterranean areas and underground caves.

Equally, although the industrial activity may not always be situated on top of the dolomite formations, it is quite possible that due to the natural faulting of the strata, effluents may find their way through to the dolomite. This is certainly the case in the Percy Stewart Sewage Works and is well illustrated in Issue Paper 6 (Holland *et al.*, 2007) and Issue Paper 10 (Krige, 2007).

Effects on the water table

Surface and groundwater resources in the COH WHS are closely associated with the karst formation and cave development of the area and both are critical aspects when considering the future well-being of the site. Historically the area was considered to be a remote rural farming area for which nobody had any particular interest other than the farming community itself. It was probably this fact coupled with the early lack of knowledge, understanding and interest in the water resources of the area - a problem that largely extended across South Africa - that there was neither any focus on the management of the resource nor any need for planning for the future.

It was only later when the scientific value of the area was appreciated and when the Sterkfontein Caves became a tourist attraction that the number of visitors to the area increased. However, the negative impact that the farming community and visitors to the cave have had on the water resources was minimal when compared with the current situation. Today the water resources are under threat from many sides and urgent steps need to be taken to resolve current problems and to manage the resource into the future.

Some threats to water resources

The following issues are threatening water resources in the Cradle of Humankind World Heritage Site:

Surface water:

- Contamination of streams by chemicals and heavy metals.
- Pollution of surface streams caused by refuse and effluents.
- Destruction and siltation of watercourses and drainage channels.
- Stagnation of dams and ponds.
- Excessive consumption of water for irrigation.
- Excessive loss of water through evaporation.
- High water consumption by commercial and industrial enterprises.

Groundwater:

- Contamination by chemicals and heavy metals (including acid mine drainage).
- Pollution cause by effluents and chemicals.
- Excessive water consumption from boreholes.

12.4 Existing Legislation

Reference to The World Heritage Convention Act, The Protected Areas Bill, The National Environmental Management Act, The Biodiversity Act and The National Water Act indicate that they all apply to the Cradle of Humankind. Therefore as a declared World Heritage Site, the legal requirements for conducting the following activities are covered by existing legislation:

- The legal aspects specific to the operation of commercial show caves and commercial adventure caving.
- The laws pertaining to access, trespass, public and third party liability, operator responsibility and the responsible behaviour by participants in activities on the karst and in the caves.
- Rescue practices, resources and accountability and compliance with the Occupational Health and Safety Act.

- The legal requirements to operate any commercial venture (excluding farming) on all property within the COH WHS.
- The legal requirements for the management and control of all farming activities.
- The legal requirements for land and housing developments.
- The legal requirements for the operation of private nature reserves and conservancies.
- The legal considerations regarding the effects of fire damage to the fauna and flora in the COH WHS.
- The legal considerations relating to the effects of surface activities such as horse riding, hiking trails, 4x4 trails, mountain bike trails, team-building activities, etc.
- The laws pertaining to the harvesting of karst and cave material.
- The laws regarding the utilisation of wetlands within the COH WHS.

Consequently it is therefore felt that there is no need for further legislation. However, there is a great need for further guidelines relating to all activities taking place within the Cradle. It is always better to educate and encourage people to behave voluntarily within the law rather than to have to apply the law in a prescriptive way.

In considering these requirements and relating them to the current situation within the COH WHS it is apparent that there is a major requirement for the education of the landowners and operators within the Cradle with regard to the law. However this needs to be done with sensitivity as many of the landowners have owned property or have resided in the area for many years. As it is a requirement for the COH WHS to be operating as a partnership between the state and the private sector, the need for a cooperative approach becomes even more essential.

12.5 Proposals

12.5.1 The current state of the law

12.5.1.1 KARST

National legislation relating specifically to the karst is non-existent in South Africa although there are numerous laws that affect the karst purely because the subject or area of application happens to be situated on the karst. This is specifically pertinent when applying The Protected Areas Bill, The National Environmental Management Act, The Biodiversity Act, The World Heritage Convention Act, The National Water Act, The Mineral and Petroleum Resources Development Act and others. It may be possible that are provincial laws or even local government by-laws relating to karst, but an information search has not revealed any.

12.5.1.2 CAVES

The only laws in South Africa which specifically apply to caves are the Nature Conservation Ordinance 1983 Chapter IX: Trading in and Preservation of Cave-formations and the Limpopo Environmental Management Act 2003 Chapter 10: Preservation of Caves and Cave Formations.

The original Transvaal Provincial Authority Law of 1983, which was a first valiant attempt at introducing some form of cave conservation legislation, came about as a consequence of the destruction of Jocks Cave in the Abel Erasmus Pass in Limpopo and the subsequent sale of speleothems from the cave. The law was primarily driven by the Cave Research Organisation of South Africa with input and support from the South African Spelaeological Association and although there are some clauses specific to conservation, the law tends to focus more on the transportation and sale of speleothems rather than on the preservation of the cave and its environment. The law falls far short in meeting today's needs and requires revision or to be replaced by a new law that conforms to international standards. It is understood that the law is still relevant in Gauteng, the North West Province and Mpumalanga while Mpumalanga authorities are engaged in drafting new legislation for that province.

The Limpopo Environmental Management Act is a virtual copy of the old Nature Conservation Ordinance but with some minor changes and rewording. With regard to the preservation of caves and cave formations, the most significant addition to the Act refers to access to caves. Here the law stipulates that no person without a permit may enter or inhabit a cave. Furthermore, the law also states that the MEC has the authority to allow limited access, partial access or no access to visitors. It is presumed that the Act is referring to all caves whether they are known by the authorities or not, or whether the caves exist on state property or on private property. Typically, the law has again been formulated without the involvement of interested parties and landowners. It is consequently impractical and impossible to apply and uphold.

12.5.2 Guidelines

There are however a number of guidelines which apply specifically to the karst (generally identified as dolomite). These guideline documents are very good but they are only guidelines and guidelines remain discretionary except when they are supported by the law.

A document such as the Department of Public Works: Appropriate Development of Infrastructure on Dolomite: Guidelines for Consultants, is excellent, however it is aimed at the principal agents and consultants contracted by the Department to ensure best operating practices and to protect the Department from recourse through a number of avenues including the Occupational Health and Safety Act. This is all very well, but in the opinion of the authors the guidelines should apply to all developments on dolomite, whether private or State-owned, and should be supported by the appropriate legislation.

Another guideline that is in the process of being written is the Department of Water Affairs and Forestry: Guideline for the Assessment, Planning and

Management of Groundwater Resources within Dolomitic Areas in South Africa, (known as The Dolomite Guideline). Undoubtedly it will be an excellent document but again, they remain only *guidelines* that should be followed when undertaking the assessment, planning and management of the water resources of South Africa. These Guidelines also need to be supported by legislation if they are to succeed.

There are however, no official guidelines for the management and administration of caves in South Africa. A few sets of rules have been drafted by private cave owners and by the owners/administrators of Show Caves. There are also Caving Codes of Conduct which the caving clubs aspire to adhere to but these are only followed by their members and have never been included in general publications. A few commercial adventure caving operators claim to operate within a code of conduct but this has not been substantiated.

Other guidelines, which have an impact on the karst and caves are The South African Water Quality Guidelines, The National Water Quality Guidelines for the Protection of Freshwater Ecosystems, The National Water Quality Guidelines for Domestic, Industrial, Agricultural and Recreational Use, Policy and Strategy for Groundwater Quality Management in South Africa and others.

Guidelines on karst and caves from other countries abound. In some countries the subject has been well researched and much of it is relevant to South African conditions. Consequently instead of re-inventing the wheel, good international practices have also been considered and included in this paper. Some of these publications are listed in the bibliography.

12.5.3 Proposals for the protection of the karst environment

12.5.3.1 PROTECTION OF THE SURFACE OF THE KARST

COH WHS Proposed Karst Management Guidelines (Appendix 1)

There is a need for more practical guidelines relating specifically to the karst in order to manage the processes and influences that may impact on the karst. Furthermore, there can never be sufficient good advice and consequently both the national and provincial governments are encouraged to continue with the good work they have started.

The process to formulate good environmental practices starts with the drafting of relevant guidelines. Without appropriate guidelines and the means to educate the public to understand and apply them, any accompanying legislation becomes less effective and more difficult to apply. Consequently, guidelines play a very important role and it is with this need in mind that the accompanying proposed guidelines have been drafted.

Proposals regarding karst conservation laws

As our understanding of the importance of the karst has grown to the point that these formations are now identified as being a national asset, it is imperative that we nurture and preserve them for the future. However it is the opinion of the authors that there is probably no need to promulgate new laws specifically relating to karst. Reference, for example, to the National Environmental Management: Protected Areas Bill and the National Environmental Management: Biodiversity Act, will show that the protection of the karst is well provided for as long as karst areas are covered by these laws. What is therefore proposed is that all karst areas should be protected under the Protected Areas Bill by declaring them Protected Environments. Once this has been achieved all national and complementary provincial legislation will be directly applicable to the karst. It is recommended that this should apply to all legislation countrywide.

Proposals related to quarrying and mining in karst areas

The law pertaining to mining and quarrying is contained in the Mineral and Petroleum Resources Development Act. If the law is respected by mining companies and upheld by the authorities, then the law will be equally effective in karst areas as in any other area. However it is again important that this law resides under the umbrella of the National Environmental Management Act with special reference to the Protected Areas Bill and Biodiversity Act. Only then will the karst hopefully remain protected.

Proposed guidelines and legislation for building on karst areas

The document: Appropriate Development of Infrastructure on Dolomite: Guidelines for Consultants published by the Department of Public Works is an excellent document but needs to be extended to apply to all construction on dolomite, including private building projects as well as mining operations. It is also important that these guidelines complement the National Building Regulations and Building Standards Act. Consideration should also be given to extending this Act to contain a section specifically relevant to karst.

12.5.3.2 PROTECTION OF THE SUB-SURFACE OF KARST

COH WHS Proposed Cave Conservation Guidelines (Appendix 2)

The proposed cave conservation guidelines for the COH WHS are based upon guidelines from Canada and New Zealand but also conform to standards set by most international countries with extensive cave systems. The guidelines have been tailored to local conditions and are representative of the real situation pertaining to the caves of the COH WHS and to caves in other karst areas across South Africa.

COH WHS Proposed Cave Conservation Legislation (Appendix 3)

There are many examples of cave conservation laws available from all over the world, the majority being from the United States of America, but also from Canada, Australia, New Zealand, Great Britain and some European countries. Most of the laws are almost identical, making provision for practical legislation that could be applied in the protection of caves. The proposed cave conservation law as drafted for the COH WHS (Appendix 3) is a compilation of the best elements from international laws structured to suit South African conditions. The proposed law should be read in context with existing South African environmental law and needs to be drafted in legal terminology.

12.6 Further Recommendations

12.6.1 Protection of all karst areas in South Africa

After discussions with authoritative sources in other South African provinces where karst areas occur, it became clear that there is a need for karst and cave conservation laws and guidelines to be extended to provide for all of these regions. In Mpumalanga new legislation is under consideration and it is recommended that these authorities adopt the lessons and proposals from the Karst Working Group and that the other provinces, i.e. the Northern Cape, Eastern Cape, Western Cape, North West and Limpopo, follow suit. It is also recommended that all karst areas across the country be declared *protected environments* in terms of the Protected Areas Act thereby providing the best opportunity for the preservation of the karst and caves for the future. It is further recommended that caves situated in protected areas which are of specific interest or of a highly sensitive nature, are included in the management plans for the area or have plans specifically drafted for them.

12.6.2 Permits and permissions

Permitting systems are seldom successful unless the particular karst area is fenced off and under direct control of some authority. This is mainly due to the fact that:

- Many people are not aware that a permit is required.
- The landowner believes it is he, and not the government, that owns the right to grant permission.
- The areas and caves are so widely dispersed that it is impossible to monitor and police the area.
- Permits only control law-abiding citizens and not those who really need to be controlled.
- A permit cannot be issued for an unknown and undiscovered asset.
- The application for permits is a tedious, frustrating and time-consuming process and simply not worth the effort.
- People prefer to ignore the requirements and take chances rather than to face the inconvenience of applying.

It is therefore recommended that permits should only be required for specific sites and caves which have been identified as being particularly sensitive and fall under governmental control. For karst areas and caves in the private domain it is recommended that landowners be educated in good karst management principles and cave access control and be held responsible for granting permission to bona fide cavers and visitors entering caves on their properties. It is further recommended that authorities and landowners engage leading caving clubs to assist in controlling access to the caves. It is common practice overseas for authorities and landowners to place access control to specific caves under the direct stewardship of appointed caving clubs.

12.6.3 Show Caves

In the distant past the development of a cave to become a Show Cave required no specific assessment or permission nor did it require any environmental knowledge or skill on the part of the owner/operator to manage the cave. In more recent times, however, impact and viability assessments are required and operational procedures need to be approved before permission is granted. Unfortunately, after opening, no further control is exercised over the facility. To quote one example: in the recent past, parts of the Echo Caves were destructed to create additional entrances into the caves – an unjustifiable need! Coupled with a lack of professional planning of routes and pathways, the latest actions have now reduced the cave to a ruin.

It is therefore recommended that specific legislation should apply to show caves, and that show cave owners/operators will be required to submit detailed management plans to the COH WHS authorities for approval. It is also recommended that cave owners/operators have to become members of an internationally recognised institute and that their activities are audited on an ongoing basis to ensure that the caves are managed in a professional way.

12.6.4 Caving lights

Cave explorers have used different sources of light since the advent of cave exploration. From candles to early carbide lamps, from electric hand torches to miners caplamps and finally to today's modern Petzel carbide generators and LED headlamps. International practices vary, but the generally accepted standards today allow for the use of the miners sealed cell caplamp, the loose battery powered Petzel caplamp and LED headlamp and the Petzel carbide generator/lamp.

Miner's caplamps are in common use although they cannot be charged underground and are cumbersome. They are however acceptable in all environments. The loose battery powered Petzel caplamp and LED headlamps are very popular and are light and easy to carry. Spare batteries are also portable. However the loose batteries can be poisonous to the cave environment if they are left to corrode in the cave.

The modern Petzl carbide generator/lamp is still widely used worldwide by thousands of cavers. The new design of generator ensures cleaner burning when compared to the old carbide lamps, but still requires close attention. Carbide lamps are particularly popular on remote caving expeditions and exploring of extensive cave systems because they burn for many hours and carbide is easy to carry. However, spent carbide has to be removed from the cave and cavers are required to be particularly cautious and not allow the flame to deposit soot on the roof, walls and cave formations. Certain caving clubs have banned the use of carbide completely while others still accept its use on expeditions and for exploration purposes, and rather declare certain caves as being carbide-free.

The use of carbide lamps has been the subject of an intensive debate among local cavers (SASA: The Carbide Debate) and there has been a call for the banning of carbide by a number of adversaries to its use but without much foundation. Only a few cavers in South Africa still use carbide lamps and those who do are well aware of the need for strict control. The claims that carbide lamps are soiling the caves and polluting the cave atmosphere are generally unfounded. A clean-burning carbide lamp emits very little fume or soot and all cavers remove the spent carbide when leaving the caves. The burning of waste and rubbish in cave entrances or the fumes from the annual veld fire have a far more detrimental effect on the cave environment and ecology than two or three carbide lamps used in the cave for a few hours once or twice a year. It is therefore recommended that instead of imposing an unmanageable blanket ban on the use of carbide lamps, that certain sensitive caves should be declared carbide-free and that all cavers using carbide should be regularly reminded of the need to manage their lamps well.

12.6.5 Gating of caves

Since caves in the COH WHS are vulnerable and exposed to uncontrolled and illegal access, it is recommended that selected caves be gated in accordance with international standards (NSS Cave Gating Guide). In assessing those caves to be gated it is further recommended that the COH WHS engage environmental experts to join hands with caving clubs and special interest groups in forming a task group to oversee the process.

12.6.6 Inventory, classification and grading of caves

An inventory of known caves in the COH WHS should be compiled and classified according to their geological and ecological sensitivity and graded according to their difficulty and caving skills required. International criteria should be applied and the inventory should be compiled by GDACE and the COH WHS Management Authority in conjunction with scientists, cavers and members of special interest groups.

12.6.7 Access to karst areas and caves

Privileged access to caves should be granted to cavers, special interest groups and scientists. With regard to cavers, it has to be remembered that the majority of caves were discovered and explored by members from caving clubs and consequently special recognition should be given to this fact. It also needs to be understood that the discovery and exploration of new caves in the COH WHS will most likely be the result of caving club activities and such club activities should therefore be encouraged.

12.6.8 Archaeology and palaeontology

It is safe to say that discoveries made by archaeologists and palaeontologists led to the ultimate development of the COH WHS. Today, however, it has become important to move away from the insensitive way in which these activities were undertaken in the past. It is therefore recommended that all concerned parties should be included an invited to participate when sites are selected for inclusion in the cave inventory. Such a joint effort will help to minimise the physical impact and damage to the ecology of the site and allow for appropriate action to be taken when needed. Obviously, such discussions will take into account the interests of landowners, the local community, cavers, other scientists as well as other specialist interest groups and will consider steps to restrict access to the site.

12.6.9 Participative relationships

The success of the COH WHS will be best served through establishing participative relationships. This requires that GDACE and the MA interact with all stakeholders and interested parties. It is particularly important that GDACE and the MA interact closely with the landowners and operators within the COH WHS but also that GDACE and the MA bring together a core of independent experts and specialists to assist in managing the COH WHS. The Karst Working Group is an essential part of that process and it is recommended that the KWG continue as an entity to serve the interests of the Cradle. It is also important that the members of the KWG work closely with one another in order to put forward a collective opinion on aspects critical to the COH WHS. Members of the KWG can also assist other groups in their fieldwork and investigations. For example, it is essential that any scientific studies undertaken in the caves of the COH WHS will involve the caving clubs. Members of caving clubs are the only people with the knowledge of caves, the expertise and experience in caving as well as the equipment to enter and negotiate the caves.

12.6.10 The existing establishment

Many of the activities taking place in the Cradle have been ongoing for years and old habits die hard. In order to change things for the better, it is recommended that an audit of all activities should be undertaken and where necessary, recommendations made to improve the situation. However, to ensure a smooth transition and overcome prejudices and resistance to change, it is recommended that a Management of Change Process should be introduced to overcome any sensitive issues.

12.6.11 Commercial adventure caving

Commercial adventure caving is a popular activity in the COH WHS and one which attracts visitors and generates income for the area. Consequently this activity needs to be encouraged. However, due to the size and nature of the caves within the COH WHS and the buffer zone, commercial adventure caving needs to be operating under strict controls and should be restricted to one or two specific caves.

The majority of the caves of the COH WHS are of the sack type (i.e. having only one entrance) with sensitive environments that cannot support large and regular groups of people moving through them. There are however, caves within the COH WHS area which are less sensitive and which can sustain greater human impact.

It is therefore recommended that the COH WHS management authority along with the KWG, identify suitable caves for this specific purpose. If the caves are on private property it is important to negotiate the utilisation of the caves and associated terms with the owners. It is also recommended that specific rules and guidelines should apply to commercial adventure caving and that the operators need to comply with certain requirements when applying for permits to operate their business. It is important that operators are registered as legal enterprises and conform to all legal requirements. It is also important that once selected as adventure caves, caves are inspected and that dedicated routes are identified. Regular monitoring and audits are essential.

12.6.12 Applying the law

Having appropriate legislation in place is wonderful - identifying transgressors and applying the law is unfortunately problematic. One of the biggest problems facing South Africa is the lack of officials appointed to apply the law – from the application of traffic laws on the one end to the application of environmental legislation on the other. If officials were available to apply existing legislation, illegal activities currently taking place in the COH WHS and the buffer zone would not have been tolerated. Consequently it is recommended that members from certain organisations and special interest groups be accredited and appointed as rangers/wardens to identify and report on illegal activities. Thereafter it depends on the authorities to take firm and positive action against transgressors.

12.7 Conclusion

It is quite clear that although the existing laws of the country adequately provide for the majority of issues relating to the COH WHS and its environs, there is a need for specific legislation applicable to the karst in order to bring this unique environment under closer scrutiny and control. This however needs to be done without the law being too prescriptive as the success of the COH WHS ultimately depends on a close working relationship between private landowners and the government. As the Cradle needs to be economically viable it is also essential that legislation makes provision for this fact and does not alienate private landowners or hinder local enterprise and development.

The situation is different however with regard to the caves of the area. The economy of the area is not depending solely on the utilisation of the caves and at present there are enough caves available for tourism. Consequently, legislation to protect the caves should now focus more on protecting the geology and ecology of the caves and controlling access and activities inside the caves. To this end it is important that the existing legislation needs to be revised and expanded.

Almost as a prelude to imposing any law it is necessary to educate the people who will be affected directly by such legislation. To this end it is imperative that the local community living within the COH WHS understands what the Cradle is all about and why the laws need to apply. Education is the key and a concerted effort needs to be made by the authorities to enlighten the local residents and to encourage them to take ownership of and develop a sense of pride for the important role that they play in ensuring the success of the Cradle. It is therefore important that people understand the impact that their activities may have on the karst and caves and the reasons why these activities need to be managed. A three-tier educational process needs to be applied. Level one should be directed at people at grass roots level and should primarily explain the reasons behind the establishment of the Cradle and the benefits that the local community can expect. The second level of education should be directed at farmers, landowners, residents and business operators to encourage them to participate and to develop a sense of ownership. At this level it is hoped that a form of community policing could evolve which would be self-propagating. The third level should be directed at the general public who visit the Cradle and at the educational institutions in order to educate future generations.

To assist in this process it is important that karst and cave management guidelines be introduced to give direction to stakeholders and to pre-empt any need to have recourse to the law. The old saying that "ignorance has no place in the law" certainly applies here and guidelines are a means to educate residents and the general public alike in what to do and how to behave. Many other guidelines for specific activities in the Cradle ranging from farming to candle making need to be drawn up and the authorities are encouraged to develop best operating practices to set the required standards.

REFERENCES

BUCHANAN M and MAGUIRE J (2002) The Management of Karst Landscapes and Caves – Cradle of Humankind WHS Cultural Heritage Resources Management Project prepared by Mahube Consortium. (Not in the text).

CRAVEN SA (2004) The world's first attempt to legislate for cave conservation: Cango Caves in 1820, *Bulletin of the National Library of South Africa.* (Not in the text).

GLAZEWSKI J (2005) *Environmental Law in South Africa. (*Not in the text).

GROENEWALD J (this report) The impacts of agriculture on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site. In: *The Karst System of the Cradle of Humankind World Heritage Site*, Issue Paper 11, WRC Consultancy Project No. K8/624, pp. 217-257.

HOLLAND M, WITTHÜSER KT and JAMISON AA (this report) Hydrology of the Cradle of of Humankind World Heritage Site: Geology, surface- and groundwater. In: *The Karst System of the Cradle of Humankind World Heritage Site* , Issue Paper 6, WRC Consultancy Project No. K8/624, pp. 113-127.

KRIGE WG (this report) The impact of urbanisation on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site. In: *The Karst System of the Cradle of Humankind World Heritage Site*, Issue Paper 10, WRC Consultancy Project No. K8/624, pp. 189-216.

KRIGE WG and VAN BILJON M (this report) The impact of mining on the water resources and water-based ecosystems of the Cradle of Humankind World Heritage Site. In: *The Karst System of the Cradle of Humankind World Heritage Site*, Issue Paper 9, WRC Consultancy Project No. K8/624, pp. 160-188.

Select National Legislature:

National Environmental Management Act (Act No 107 of 1998)

National Environmental Management: Protected Areas Bill

National Environmental Management: Biodiversity Act 2004

Nature Conservation Ordinance (No12 of 1983) Chapter IX

Department of Public Works: Appropriate Development of Infrastructure on Dolomite: Guidelines for Consultants

Select International Legislature

United States of America:

Federal Cave Resources Protection Act of 1988.

Alabama Cave Protection Law (1988).

Arkansas Cave Protection Law (1989).

Arizona Cave Protection Law (1978).

California Cave Protection Act.

Florida Cave Protection Law.

Georgia Cave Protection Act (1977).

Hawaii Cave Protection Law (2002)

Idaho Cave Protection Law (1982).

Illinois Cave Protection Act.

Kentucky Cave Laws.

Maine Cave Protection Act (2001).

Maryland Cave Law.

Missouri Cave Resources Act.

Montana Cave Conservation Act (1993).

Nevada Cave Protection Laws (1959).

New Mexico Cave Conservation Laws (1981)

North Carolina Cave Protection Law (1987).

Ohio Cave Laws.

Oklahoma Cave Protection Law (1967).

Pennsylvania Cave Protection Act (1990).

Tennessee Cave Law.

Vermont Cave Protection Law (1975).

Virginia Cave Law.

West Virginia Cave Law.

Wisconsin Cave Law (1977).

Canada:

Karst Management Handbook for British Columbia.

Belgium:

Land Use of Karstic Areas in Belgium. Jean-Pierre Bartholeyns and Georges Michel.

Sustainable Development of Show Caves and Protection of Common Heritage. Jean- Pierre Bartholeyns

New Zealand:

Department of Conservation: Karst Management Guidelines: Policies and Actions.

New Zealand Speleological Society Handbook: Third Edition 1995.

General:

IUCN World Commission on Protected Areas: Guidelines for Cave and Karst Protection.

APPENDIX 12.1

Cradle of Humankind World Heritage Site

PROPOSED KARST MANAGEMENT GUIDELINES

POLICIES AND ACTIONS

CONTENTS

1.0 INTRODUCTION

The karst and caves of the COH WHS are well known examples of landforms collectively referred to as "karst". Karst include a variety of distinctive and often spectacular surface and underground features, formed predominantly by the dissolving action of water, which are much valued by residents and sought-after by visitors and tourists.

Karst areas usually also include distinctive soils, micro-climates, flora, fauna and hydrological patterns.

Karst is widely distributed throughout the region. Karst areas or features are often fragile and require special management to minimise adverse effects. It is therefore important that there are well understood guidelines to help to manage them in order to conserve their unique character.

1.1 Purpose

These guidelines have been prepared to help COH WHS staff and all stakeholders to more effectively manage the karst. They will be used to assist in making management decisions about specific sites and in the implementation of conservation management strategies. They should also be incorporated in other specific karst management planning programmes and documents.

The policies and actions described in these guidelines should be applied at individual sites in consultation with relevant stakeholders with a special interest in the sites, such as farmers, landowners, recreationalists, researchers, caving clubs, etc. In some cases, such consultation may result in modifications to the policies and actions described in this document, in order to help to continue to conserve karst and meet all desired outcomes in a way that is agreeable to all parties.

This document is not intended as a detailed description of karst. Readers who wish to obtain further details are recommended to consult the wide range of local and international papers on the subject.

1.2 Relationship to landowners, authorities, legislation and planners

The purpose of these guidelines is to present general policies and actions for the management of the karst, in order to achieve common goals ensuring that:

1.2.1 All private and public land identified under the Protected Areas Act is preserved and protected.
1.2.2 The nationally important, outstanding, distinctive and rare ecosystems, landforms, geological features and scenery of the COH WHS are preserved, protected, restored and sustainably managed.
1.2.3 The network of riverbank zones, wetlands, dams, ponds, rivers and riverbeds are conserved and the natural functioning and character of bodies of water are maintained.
1.2.4 Soil and water resources are protected and maintained in their natural state.
1.2.5 Public and management access to all protected areas and waters are secured.
1.2.6 A wide range of outdoor recreational, educational and heritage appreciation opportunities are provided.
1.2.7 Significant historic and cultural heritage sites are protected, preserved and conserved.
1.2.8 The *in-situ* genetic diversity of indigenous species is maintained.

These guidelines are however not statutory.

2.0 DESCRIPTION OF KARST

2.1 Definition

Typical karst topography consists of a type of topography formed in dolomite, limestone or marble areas, comprising depressions and holes, and with underground drainage in conjunction with surface streams. Karst areas therefore comprise two landscapes interconnected through a series of structures and dynamic processes.

The relatively accessible and visible surface landscape is characterised by closed depressions or sinkholes (known as dolines) formed either by solution of the surface bedrock or by collapse of underlying caves; elongate depressions formed by the coalescence of several dolines (known as uvala or karst valleys); stream sinks; prominent features such as pinnacles; kranzes; fissures (grikes) and gorges; natural bridges; blind or dry valleys and rock outcrops with furrows ranging in depth from a few millimetres to more than a metre formed as a result of solution of bedrock by rain or from subsoil moisture interaction with bedrock (karren).

The subsurface cave landscape is often unexplored or inaccessible, comprising natural cavities in the earth which act, or have acted in the past, as a conduit for water flow from stream sinks and percolation through cracks to springs or seeps or outgoing streams. Cave systems can be very complex, varying from single rooms, passages, and open shafts to intricate three-dimensional interconnected cavities. Some caves are completely dry and inactive, others totally filled with water; some are periodically flooded, and others permanently contain streams or lakes.

Although each of the surface and underground landscapes may have its own catchment and drainage areas, very often the one bears little relationship to the other. Subsurface streams may cross drainage divides and flow in a direction opposite to the general topographic slope.

The distinctive relief and hydrology of karst arise primarily from the greater solubility of certain rock types in natural waters. Karst is usually found in hard, non-porous rocks composed of relatively pure calcium carbonate such as dolomite, limestone and marble (recrystallised or metamorphosed limestone), which are dissolved away by rain and streams carrying carbon dioxide in solution. Other natural physical processes, such as uplift and mass movement, also play a part.

In addition, karst-like landforms and caves not derived from the dissolution of rock may occur in other rock types, e.g. those formed in quartzite and sandstone. These are known as pseudokarst.

Karst areas usually include distinctive soils, microclimates, flora and fauna, and hydrological patterns.

2.2 Location and extent

Although relevant to all karst areas, this guideline is focused on the COH WHS, which is situated to the northwest of Johannesburg in Gauteng and is applicable to the area encompassed within the boundaries of the Site and the adjacent buffer zone. The COH WHS covers approximately 8000 square metres of which the majority overlies the dolomite.

There are numerous other dolomite and limestone areas situated around the country, all of which are exposed to the same or similar threats as the COH WHS and it is recommended that these guidelines should be extended to provide a measure of protection for them.

3.0 VALUES OF KARST

Karst is a unique non-renewable resource with significant biological, hydrological, mineralogical, scientific, cultural, recreational, and economic values. The karst of the COH WHS has regional, national and international significance and is valued for its:

- Association with indigenous cultures.
- Unique attributes of natural heritage.
- Importance for natural history research.
- Utility for recreation and tourism.
- Role in the supply of water.
- Farming, business and development opportunities.

3.1 Cultural value

There are many sites and caves scattered across the karst areas in South Africa that are of cultural, spiritual and historical value to many of South Africa's peoples. It is therefore important in today's society that these values are understood and taken into sympathetic account when considering activities, developments and controls that impact on the relevant areas.

Equally, when applying guidelines and legislation to any karst area it is important that the beliefs of the local indigenous peoples are considered and that these communities become part of the process so that they understand the significance of the proposals and have a say in the development of the area.

3.2 Natural heritage value

Some surface plants and invertebrate animals are restricted to areas where limestone, dolomite and/or marble abound, and are known as calcicolous species. Many of these favour such calcareous habitats independently whether any karst formation is present or not. Karst surface landforms provide a variety of habitats to plant species that are restricted to or favour growing on calcareous soils. They also provide refuge to species previously spread widely throughout the landscape. Caves provide habitats or shelter for a wide range of animal species with varying degrees of reliance on or adaptation to dark, cool, moist conditions with low daily variability. Of particular interest are the "troglobites", species which are wholly adapted to subterranean environments and which cannot survive anywhere else. Research indicates that the primary habitat for many of these species may actually be the numerous smaller cracks and voids which penetrate the dolomite/limestone beyond the limits of human size caves. Caves may therefore be imperfect "windows" through which these ecosystems may be glimpsed.

3.3 Research value

Parts of certain cave systems are not as prone to the deteriorative effects of climate and erosion as the surface and in combination with their cool and relatively stable temperatures, have provided irreplaceable evidence of South Africa's environmental history which should be preserved. The structure, form and age of these sites and the fragments that they contain (such as sediments, fossils and human artifacts) can be related to such phenomena as past sea levels, earth movements and erosion cycles. These "time vaults" are important sites for geological, geomorphological, palaeontological and climatological studies.

Bones of bats, birds, amphibians and reptiles are commonly found in caves. The relatively high calcium content and constant microclimatic conditions of caves make them ideal repositories for the long-term preservation of vertebrate bones. Some caves also contain remains of fossil invertebrates, often of previously unknown or locally extinct species.

On the other hand, in some caves the natural processes of erosion of the limestone or dolomite sometimes expose fine examples of fossils that would otherwise have been hidden. The naturally exposed bone breccias in the COH WHS bear witness to this process.

Caves may also have well-defined boundaries, zones or habitats which make them excellent natural laboratories for studying and analysing processes such as adaptation, the structure and functioning of ecosystems, the reactions of ecosystems to induced changes and microclimatological studies.

Caves contain many types of secondary mineral deposits, known as speleothems (for example stalactites and stalagmites). Speleothems are one of the major terrestrial sources of palaeoclimatic information. Most speleothems are formed mainly from calcite, the most common crystalline form of calcium carbonate, which is the main chemical component of limestone, dolomite and marble. Aragonite and gypsum speleothems are also common. However, there are also occurrences of rare and obscure mineral forms seldom found in nature and the wealth of minerals found in MboboMkulu Cave in Mpumalanga is a good example.

3.4 Recreational and tourism values

Karst areas are highly valued for recreation and tourism by many South African and overseas visitors. For some people, this also includes valuing them for spiritual and other cultural reasons.

Probably the primary recreational and tourist use is to simply be there to enjoy and appreciate the often striking karst surface landscapes. Scenic drives, heritage trails, short walks and roadside amenities all facilitate and contribute to the enjoyment derived from being in these environments. Large numbers of people also visit caves each year, appreciating their awe-inspiring size while marveling at the stalactites and stalagmites and other rock formations. Tourism in caves such as Sterkfontein Cave and the Wonder Cave is significant with annual visitation levels of around 80 000 and 40 000 respectively.

Other recreational activities include hiking, horse riding, go-karting, 4x4 trails and fishing. All these activities are increasing in popularity and placing additional pressure on the karst and caves. Commercial adventure caving through “wild” or relatively undeveloped caves is also increasing in popularity. This activity demands a professional approach to safety standards, conservation and other codes of practice.

The largest collective group of *bona fide* cavers in South Africa are members of the South African Spelaeological Association (SASA) with four member clubs, and the independent Cave Research Organization of South Africa (CROSA). However, only the Speleological Exploration Club (SEC) and CROSA are active in the COH WHS. These clubs have played a significant role in cave discovery and exploration in the COH WHS and in developing caving ethics and conservation awareness as well as promoting the need for appropriate management.

3.5 Water supply

In some karst areas the water issuing from caves and springs is an extremely important local resource. The integrity and sustainability of water supplies depend on knowledge and appropriate management of surface sources and associated subterranean drainage patterns.

4.0 VULNERABILITY OF KARST AND MANAGEMENT OBJECTIVES

4.1 Surface features

The main activities that may have adverse effects on karst are various forms of farming, quarrying and mining, together with urbanisation, recreation, excessive water use, water pollution and waste disposal. Karst surface landscapes are also vulnerable to insensitive practices of recreational activities, such as trampling of vegetation, especially where people congregate (e.g. hikers and tour groups meeting in specific locations), the harvesting of rock forms and fauna and the dumping of rubbish.

Management Objectives:

- To protect significant surface karst features from physical damage.
- To maintain any site-specific microclimatic conditions and/or habitat/biodiversity characteristics associated with significant surface karst features.
- In the case of sinkholes and cave entrances, to prevent soil erosion and sediment transfer into subsurface openings and cave systems.
- To provide a measure of the aesthetics/recreational experience that may be achieved at surface karst features with high recreational value.

4.2 Sub-surface features

Sub-surface features are especially vulnerable to careless recreational use, some of which may be essentially irreversible, particularly in areas that had previously been in relatively undisturbed isolation. Just as such areas accumulate evidence of the past, so too do they accumulate evidence of human impact. Potential impacts include: disturbance of the cave passageways by trampling and erosion which could remain for hundreds of years in a dry passage; broken speleothems and fossils which may take thousands of years to re-form; the removal of speleothems and fossils; and the disturbance of sediment, subsequently coating speleothems and other floor deposits. Waste left inside caves will decompose at a substantially lower rate compared to waste left on the outside

Management Objectives:

- To maintain stable conditions for karst processes above and inside significant caves (e.g. temperature, humidity, infiltration rates, and drip water chemistry).
- To prevent the migration of surface fines/sediment into significant caves through fissures or cavities in the overlying epikarst.
- To protect delicate cave features, cave fauna, or other cave valuables against potentially damaging vibrations associated with road construction, quarrying and construction.
- To maintain the microclimate around significant cave entrances to ensure that water flow, air flow, air temperature, relative humidity, and level of shading remain constant to ensure that conditions for air and water exchange, subsurface habitats (e.g. bats, invertebrates), and cave formation processes, etc. are not altered beyond the range of natural variability.
- To maintain stable habitat conditions for flora inhabiting the cave entrance, and/or cave dwelling organisms (e.g., spiders, crickets, etc.) foraging in the cave entrance or relying on organic matter from the cave entrance falling into the cave as food source.
- To prevent silt, rubbish, dead animals and building and construction debris from being dumped in sinkholes and entering significant cave entrances.
- To provide a measure of the aesthetics/recreational experience that may be achieved at cave entrances with high recreational value.

4.3 Total catchment management

Karst is vulnerable to activities in other (non-karst) parts of surface catchments. It is, therefore, preferable to manage the entire catchment rather than just those portions containing karst. However, subsurface catchments may be difficult to identify because they frequently do not match the apparent catchment boundaries at the surface (e.g. cave streams frequently pass beneath both valleys and ridges on the ground surface). The relationship between surface conditions and subsurface processes and features is important and needs to be appreciated. For example, road construction and agriculture can greatly accelerate the natural erosion level of karst soils, and can dump large quantities of silt into cave entrances. These actions could destroy the habitats of cave fauna and may impact on the cave ecosystems. In addition, such activities often increase surface runoff of water, thereby increasing the frequency and size of flooding events in cave systems. Silt deposition and flooding may reach areas of the cave that have been unaffected for centuries, impacting on features preserved there. In the longer term, altering surface land uses may alter soil through-flow rates and chemistry of percolation waters, affecting processes such as the deposition of speleothems.

Management Objectives:

- To maintain water quality and quantity, and to limit the introduction of sediment, fine organic material and woody debris into subsurface environments to levels not exceeding those found under natural conditions. **Rationale:** Woody debris (large and small), sediment, and organic material can be transported downstream where it accumulates and clogs recipient karst features such as swallets (swallow holes) or cave entrances. This can restrict water from entering the subsurface and/or redirect flows to other subsurface openings or to the surface. Of particular concern is the introduction of fine sediment (e.g. silt, sand, clay) and fine organic material (e.g. needles, twigs, leaves) into subsurface cavities, including caves. These materials may cover underground surfaces, thereby impacting subsurface habitats and other valuable cave resources (e.g. mineral formations). The slow decay rate associated with the underground environment leads to the accumulation of organic material, remaining there over long periods of time.
- Sinking watercourses are considered to be less of a management concern than sinking streams because of their lower potential for impacting significant recipient karst features (i.e. sinking watercourses would typically exhibit low-energy water flows, lower transport potential, intermittent or ephemeral flows, etc.). Nevertheless, sinking watercourses have the potential to transport sediment, fine organic material, and small woody debris into the subsurface. For this reason, the management objectives for sinking watercourses are the same as those for sinking streams.

- To maintain water quality and quantity (within the range of natural variations), wildlife habitat, and visual quality, especially where sites with recreational potential have been identified.

4.4 Unique karst fauna/flora habitats

Karst ecosystems often support unusual or rare plant and animal species, both on surface and underground environments. For example, certain species of ferns and mosses prefer, or in some cases, require a dolomite/limestone substrate to grow on. Other fern species have adapted to growing in the cool, moist twilight conditions of cave entrances.

Many wildlife species use various karst features as habitat. Caves are used intermittently by carnivores for shelter or resting. Birds and small mammals often nest or live in caves and other cavities. Antelope and baboon commonly bed down in the vicinity of cave entrances during summer when the air from caves is cooler, and during winter when cave air is generally warmer than outside temperatures. Caves, and their stable environments, can be critically important habitat for bat species which depend on caves for roosting and hibernation. Karst springs often create favorable environmental conditions (microclimates) and/or habitats for rare flora and fauna and aquatic life forms.

Management Objective:
- To maintain a potentially critical habitat for unique or unusual karst flora/fauna.

4.5 Summary

A karst area is, therefore, best protected by maintaining the intact surface vegetation, soils and hydrological systems over the whole catchment affecting the area. In many instances, this will require cooperative management between many landowners and local authorities.

The critical factors that need to be understood and addressed for the conservation of karst areas are: water quality, soils, vegetation cover, hydrology, underground climates and air flows, inputs to underground systems (of water, organic debris, silt and chemical wastes), cave deposits (sedimentary and mineral), and cultural uses. The key to reducing the vulnerability of karst areas to adverse activities lies in educating the public and resource managers about the value of karst and caves, the critical factors that contribute to their vulnerability, the ways in which these areas may be damaged by thoughtless actions, and the management options to conserve them.

5.0 COH WHS BEST MANAGEMENT POLICIES FOR KARST

Management of karst areas should be based on the following principles:

5.1 To protect sites with cultural, heritage or research value by maintaining natural flow as well as air, water, and energy cycles.
5.2 To foster a range of educational, recreational and tourism activities in karst areas for the safe enjoyment and appreciation of suitable and exploitable karst features according to national goals.
5.3 To promote appropriate protection for internationally, nationally and regionally significant karst features which are not under its management.
5.4 To establish a viable network of representative areas of karst ecosystems, landforms and landscapes that originally contributed to South Africa's own natural character.
5.5 To promote understanding of the attributes, values, vulnerability and management of karst areas among departmental staff, external agencies, the public and associates.
5.6 To work cooperatively with other interested parties to minimise any adverse impacts that activities undertaken both inside and outside of the COH WHS may have, as well as all processes that may affect the karst.

6.0 ACTIONS TO CONSERVE KARST AREAS

The following actions are deemed necessary to effectively manage the karst. Many of these action plans are drawn from the IUCN Guidelines for Cave and Karst Protection (Watson *et al.* 1997).

The actions are grouped into those related to:
- Overall actions to conserve the natural karst heritage of the COH WHS.
- Planning the management of protected natural karst areas administered by GDACE and the COH WHS MA.
- Protection of karst areas from visitor impacts.
- Concessions in karst areas.
- Non-routine activities in karst areas.

- Protection of karst on private land and other public land.
- Staff training and capacity.

6.1 Overall actions to conserve the natural karst heritage of the COH WHS

- Formally protect the area as a Protected Environment in terms of the Protected Areas Act.
- Identify a representative selection of specific sites as restricted natural areas.
- Assess the potential effects of current and proposed activities on karst areas.
- Protect karst areas from the interference with rocks, soils, vegetation, and water resources where such interference will interrupt or alter the processes that generate and maintain them.
- Safeguard the quantity and quality of water inputs into karst systems (through formal protection of an entire catchment and/or environmental management and control of water resources).
- Minimise the erosion of soils and alteration of soil properties (such as aeration, aggregate stability, organic matter content, and a healthy soil biota), which may affect karst areas.
- Encourage residents and visitors to report the discovery of new cultural or natural features.
- Promote a healthy karst management approach among all stakeholders.

6.2 Plan the management of protected natural karst areas administered by the MA

GDACE should, through the COH WHS MA and by utilising the skills and services of the Karst Working Group (KWG), undertake the following actions as point of departure in the management of karst areas in the COH WHS:

- Undertake a basic karst inventory study to identify the extent, nature and value (including cultural value) of the area. Focus on the three-dimensional integrated nature of karst areas, i.e. rock, water, soil, vegetation, atmosphere elements and cave energy levels.
- Identify threats (including threatened species) and opportunities, and formulate appropriate management responses.
- Prioritise actions to: ensure that a representative selection of karst sites are declared as protected natural areas, remove or mitigate threats, restore damaged features (as much as is practicable), and provide a range of recreational and educational opportunities for the safe enjoyment and appreciation of suitable karst features and other valuable resources.
- Develop monitoring programmes.
- Liaise with karst user groups and stakeholders

6.3 Protection of karst areas from visitor impact

Management planning and controls should seek to match visitor numbers, use patterns and behaviour to the nature of the karst resource.

The COH WHS management authority should:

- Liaise with tourism operators, local caving clubs and other user groups, educational organisations, police and cave search and rescue coordinators as well as their national bodies, to ensure that they are aware of and adhere to accepted guidelines.
- Avoid releasing information that will encourage or facilitate people to search for karst features (including fossil deposits) which may be at risk from inappropriate or uniformed use.
- Monitor the condition of much-frequented and vulnerable karst sites, in order to assess and improve the effectiveness of current management practice(s).
- Minimise the vulnerability of significant karst features to visitor impacts by educating visitors about the fragility of karst areas and about the appropriate behaviour when visiting such areas. The use of on-site and visitor centre information and interpretation panels as well as associated publications are good media for education and promotion of safety.
- Restore damaged karst features for tourism purposes rather than opening new areas (where appropriate).
- Investigate new mechanisms to restrict access to karst sites that are sensitive to or currently being damaged by visitors. Options include:
  - Categorise areas and issue permits to only allow entry to restricted areas (e.g. nature reserve or scientific reserve).
  - Establish a system that only allows permit holders of accredited institutions and clubs into specific areas.
- Limit public access to vulnerable karst features (e.g. by using physical structures or notices) where visitor impact cannot be adequately reduced by user education or other

measures.

6.4 Concessions in karst areas

It is recommended that GDACE in collaboration with the MA, process all applications for concessions in karst and cave areas in accordance with the relevant legislation, conservation management strategy, any relevant conservation management plan, and the Department's standard operating procedures:

- Consider whether there are less vulnerable or already modified features where the concession would be more appropriately located.
- Limit the effects of concession activities on karst and cave areas by restricting licenses to appropriately qualified concessionaires, so as to ensure adequate protection of the area's natural, cultural, and historic resources.
- Consider, and where appropriate, invite applications for the provision of facilities and services currently provided by the Department but which may be better provided by a concessionaire.
- Where possible, provide information to concessionaires about the values of a karst site, its fragility, and restrictions on visitor behaviour at the site in order to conserve it.
- Ensure that concessionaires provide appropriate interpretation to their clients, particularly about the fragility of a site and restrictions on visitor behaviour at the site in order to conserve it.
- Identify areas where concessionaires may be able to assist by raising public awareness of conservation in karst and cave areas.
- Monitor all concessions to make sure that conditions are adhered to.
- Monitor all concessions for direct, indirect, and cumulative effects of their operations. In cases where the effects of a concession are considered unacceptable, the operating conditions of the concession agreement may be varied to mitigate them, or the concession agreement may be terminated.
- Investigate reports of unauthorised commercial activities on land administered by the COH WHS management authority. Appropriate action to authorise as a concession, to prosecute or prohibit the activity should then be taken.

The COH WHS management authority will ensure the adequate protection of the natural, cultural, and historic resources of karst and cave areas by setting concession operating conditions that address (but are not limited to):

- Group sizes and guide/client ratios.
- Leadership requirements such as guide training and/or qualifications.
- Access routes and interpretation techniques.
- Requirements for the protection of specific sites, e.g. route-marking in certain areas.
- Waste removal and disposal requirements (e.g. food scraps and wrappers).
- The type of lighting system to be used, i.e. electric (preferable where practical) or carbide.
- Monitoring by the concessionaire of relevant activities and impacts.

6.5 Non-routine activities in karst areas

When considering requests for non-routine activities such as search and rescue training exercises, army exercises, filming, weddings, or any other activity in karst areas, the COH WHS management authority will:

- Consider the appropriateness of the proposed activity and the impact that such an activity may have on the area.
- Consider whether there are less vulnerable areas, or already modified features, where the activity could be more appropriately located.
- Assess the costs involved or the benefits that the proposed activity may have to other users of the karst area.
- Assess any safety issues with regard to obligations under the Occupational Health and Safety Act.
- Establish formal links with the South African Spelaeological Association and Cave Research Organisation of South Africa, the police and search and rescue organisations.

6.6 Protection of karst on private land and other public land

The following factors should be considered when evaluating whether to seek the protection of karst on private land and public land managed by other agencies:

- Degree of representativeness of existing protected natural areas containing karst, and geographical and environmental location.
- Geological, hydrological and biological attributes and significance.
- Overall scientific significance.
- Cultural and historic attributes and significance.
- Scenic, educational, recreational and tourism attributes and significance.

- Type and level of threat and degree of urgency of response.

Protection mechanisms that may be considered include:

- Acquisition
- Covenant, with associated contributions to the management costs by GDACE and/or the MA (e.g. fencing, tracks, interpretation signs)
- Voluntary management actions by landowner
- Resource Management Act controls.

Appendix 5 provides information on legal ownership of caves.

6.7 Staff training and capacity

The COH WHS management authority should:

- Foster the development of appropriate karst management expertise and capacity through staff training. This should include training for stakeholders in the COH WHS.
- Develop methods for conservation management (e.g. methods for determining acceptable impacts, and for monitoring) in accordance with the Integrated Environmental Management Policies and Procedures.
- Acquire specialist equipment to appropriately manage karst

7.0 GUIDELINES FOR VISITORS

The success of preserving the karst extends beyond attempts by the authorities to promote good management policies or to revert to the law for enforcement. The best tool is that of education directed at a level that any layman can interpret and relate to, i.e. the simpler, the better. The following guidelines for visitors to the karst using keywords are intended to do exactly that:

- **Permission** from **farmers** and **landowners** – always get permission before entering private or state property. If you don't, it may get you into trouble, you may be shot at and you will spoil future access for yourself and for others.

- **Gates** and **fences** – always leave gates in the position you find them, never leave closed gates open. Open gates may lead to stock loss, theft, very irate farmers and landowners and will spoil future access for yourself and for others.

- **Relationships** - always try and establish good cordial relationships with farmers and landowners. The better you know them, the easier it becomes to get access to their property and it will help you and others in the future.

- **Roads, farm tracks, routes, trails** and **driving** habits – if you are driving a vehicle, stick to the established roads and tracks as far as possible to prevent damage to vegetation, grasslands, and crops. Do not drive like a maniac or in an erratic fashion. Be on the lookout for animals and reptiles on the road or track and take evasive action. When you are walking stick to the beaten track or choose a route that will have the minimum impact on the environment. Be observant and avoid animals, insects and reptiles that you encounter.

- **Picnics** and **braais** – ask the farmer/landowner if you may have a picnic or braai. When having a braai, be absolutely sure that you choose an area that is clear from surrounding grass and do not braai on a windy day. Do not leave the fire unattended and when you leave make sure that the fire is fully out, leaving behind no other evidence of the braai or picnic. Fires that spread out of control destroy fauna and flora, destroy crops and livestock and can damage fences and buildings. Farmers and landowners will not be happy and you could face legal action.

- **Rubbish, bones** and **refuse –** always take away with you what you bring into an area. Rubbish, bones and refuse pollute the soil and water resources and may be poisonous to both domestic and wild animals. Never leave your litter lying around and never attempt to bury it. It may contaminate the soil and is usually dug up by baboons.

- **Noise, radios,** discharging **firearms,** revving **engines,** using **chain-saws, generators** - refrain from creating any loud noise, it will frighten domestic and wild animals and may upset other visitors. Any noise detracts from the tranquility of the area and is alien to the sounds of nature. Farmers and landowners may be upset and it can lead to unpleasantness. A good policy is that if you need to listen to the radio then do so in the confines of your vehicle so that other people do not hear it.

- **Group size, knowledge** and **experience** – keep the number of visitors in your group to a reasonable minimum. Large groups have a greater impact on the environment, cause more damage and have a tendency to make more noise. Farmers and landowners are intimidated by large numbers and are more inclined to deny access. Try and include members in your group that are experienced in your particular activity and who can share their knowledge with the other members.

- **Camping, washing** and **ablutions** – always ask for permission to camp. If granted, be sure to camp where directed or find an appropriate place where you will be screened and sheltered from the wind. Be sure to establish an ablutions area downwind and always bury your faeces. If you are camping next to a stream or a river, draw water for washing from the stream and do not wash directly in the stream. Make sure washing water does not enter the stream but rather dig a soak-away to dispense the water into. Close the soak-away when you leave.

- **Visitors, education, training** and **controls** – if you have first-time visitors to the karst with you, then make sure that you educate them in the rights and wrongs of such a visit. Train them in good karst practices and the reasons behind doing things the right way. Above all, make sure they behave responsibly and never get out of control.
- **Thanks, feedback** and **reports** – be sure to visit the farmer or landowner on the way out and to express your thanks and those of the group. Give feedback on your activities and if requested, agree to submit a report on your findings.
- **Farmers, landowners, education, advice** and **support** – should you observe an activity or condition having a negative impact on the karst, be sure to inform the farmer or landowner in a diplomatic way and to use the opportunity to educate and advise. Always offer support and volunteer assistance to overcome the problem.

8.0 ACKNOWLEDGEMENTS

These guidelines have been structured around the Canadian Karst Management Handbook for British Columbia and the Karst Management Guidelines initiated by the New Zealand Speleological Society and largely prepared by the New Zealand Department of Conservation staff and other people who value karst areas and who are experienced in managing them. The authors of this document have applied the principles to the South African context and more specifically to the COH WHS.

Further acknowledgement is given to the South African caving fraternity who, like their New Zealand counterparts, are passionate about the karst and caves of their country and who arguably know more about the surface and sub-surface of our karsts than anyone else. It is this fraternity that collectively have discovered and explored and documented so much about the karst and caves of our own country and those of our neighbours over the last 50 years.

Acknowledgement is also given to the IUCN with reference to the document: Guidelines for Cave and Karst Protection, which offers excellent advice on an international level.

9.0 APPENDICES

APPENDIX 1. IUCN Guidelines for Cave and Karst Protection (Watson *et al.* 1997)

1. Effective planning for karst regions demands a full appreciation of all their economic, scientific and human values, within the local cultural and political context.
2. 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.
3. 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.
4. The location and sites for destructive actions in karst, such as quarrying or dam construction, should be carefully selected to minimise conflict with other resources or sites of intrinsic values.
5. Pollution of groundwater poses special problems in karst and should always be minimised and monitored. This monitoring should be event-based rather than done at merely regular intervals, as it is during storms and floods that most pollutants are transported through the karst system.
6. All other human uses of karst areas should be carefully planned and implemented to minimise undesirable impacts, and monitored in order to provide information to assist in future decision-making.
7. 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.
8. 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.
9. Governments should ensure that a representative selection of karst sites is declared as protected areas (especially as [IUCN] category I - IV...) under legislation which provides secure tenure and active management.
10. Priority in protection should be given to areas or sites with particular natural, social or cultural value, possessing a wide range of values within the one site, sites which have suffered minimal environmental degradation; and/or of a type not already represented in the protected areas system of their country.
11. Where possible, a protected area should cover the total catchment area of the karst.
12. Where such coverage is not possible, all legislation providing for environmental controls or total

catchment management should be used to safeguard the quantity and quality of water entering the karst system.

13. 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, programmes of public education, heritage agreements or covenants.
14. Management agencies should seek to develop their expertise and capacity for karst management.
15. Managers of karst areas and specific cave sites should recognise that these landscapes are complex, three-dimensional and integrated natural systems comprising of rock, water, soil, vegetation and atmospheric elements.
16. 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.
17. Managers should bear in mind that in karst areas, any surface activity may be sooner or later impact directly upon underground areas or further downstream.
18. 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.
19. The interchange of air and water between surface and underground environments is the vital mechanism in maintaining the desired carbon dioxide levels. Therefore, the management of both air and water quality as well as quantity forms the keystone of effective management of karst areas at regional, local and site-specific scales. All developments planned for karst surfaces should take the infiltration pathways of water into account.
20. Catchment boundaries normally extend beyond the limits of the rock units in which the karst has formed. The whole karst drainage network should be traced and mapped using water tracing experiments and cave mapping techniques. It should be appreciated that the boundary of these extended catchments may fluctuate dramatically according to weather conditions, and that relict cave passages may be reactivated following bouts of heavy rain.
21. 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.
22. Soil management strategies should be drafted in order to minimise erosive loss and alteration of soil properties such as aeration, aggregate stability, organic matter content and a healthy soil biota.
23. Stable natural vegetation cover should be maintained, as this is pivotal to the prevention of erosion and maintenance of critical soil properties.
24. The establishment and maintenance of karst protected areas may 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. However, activities inside caves may have detrimental effects on regional groundwater quality.
25. Management strategies should be developed in order to maintain the natural transfer rates and quality of fluids (including gases), through the integrated network of cracks, fissures and caves in the karst. All materials introduced into the system should be carefully evaluated to avoid adverse impacts on air and water quality.
26. The extraction of rocks, soil, vegetation and water will clearly interrupt the processes that produce and maintain karst, and therefore such activities should be carefully planned and executed in order to minimise the environmental impact. Even the small-scale removal of limestone pavement or other karren for ornamental decoration of gardens or buildings has a drastic impact and should be subject to the same control measures applied for any major extractive industry.
27. Imposed fire regimes on karst should as far as is practicable, mimic those occurring naturally.
28. While it is desirable that the public should be able to visit and appreciate karst features such as caves, the significance and extreme vulnerability of many such features mean that great care should be taken to minimise damage to such features, particularly when such damage has a cumulative effect over time. Management planning should recognise this fact and management controls should seek to match the visitor population to the nature of the resource.
29. International, regional and national organisations concerned with aspects of karst protection and management should appreciate the importance of international cooperation and do their best to disseminate and share expertise.
30. The documentation of cave and karst protection/management policies should be encouraged and such policies should be made available to other management authorities.
31. Data bases should be prepared listing cave and karst areas located inside protected areas, while also identifying major unprotected areas which deserve recognition. Karst values of existing and potential World Heritage sites should be similarly recorded.

APPENDIX 12.2

Cradle of Humankind World Heritage Site

PROPOSED CAVE CONSERVATION GUIDELINES

POLICIES AND ACTIONS

CONTENTS

1.0 INTRODUCTION

The karst and caves of the COH WHS are well known examples of landforms collectively referred to as “karst”. Karst include a variety of distinctive and often spectacular surface and underground features, formed predominantly by the dissolving action of water, which are much prized by local people and sought-after by visitors and tourists.

Karst areas usually also include distinctive soils, microclimates, flora, fauna and patterns of hydrology.

Karst is widely distributed throughout the region. Karst areas or features are often fragile, and require special management to minimise adverse effects. It is, therefore, important that there are well understood guidelines to help to manage them, in order to conserve their unique character.

1.1 Purpose

These guidelines have been prepared to help COH WHS staff and all stakeholders to more effectively manage the karst. They will be used to help to make management decisions about specific sites and implement conservation management strategies. They should also be incorporated in other specific karst management planning programmes and documents.

The policies and actions described in these guidelines should be applied at individual sites in consultation with relevant stakeholders with a special interest in the sites, such as farmers, landowners, recreationalists, researchers, caving clubs, etc. In some cases, such consultation may result in modifications to the policies and actions in this document, in order to help to continue to conserve karst and meet all desired outcomes in a manner that is agreeable to all parties.

This document is not intended as a detailed description of karst. Readers who wish to obtain further details are recommended to consult the wide range of local and international papers on the subject.

1.2 Relationship to landowners, authorities, legislation and planners

The purpose of these guidelines is to present general policies and actions for the management of the karst, in order to achieve common goals ensuring that:

- All private and public land identified as Protected Environments under the Protected Areas Act is preserved and protected.
- The nationally important, outstanding, distinctive and rare ecosystems, landforms, geological features and scenery of the COH WHS are preserved, protected, restored and sustainably managed.
- The network of riverbank zones, wetlands, dams, ponds, rivers and riverbeds are conserved and the natural functioning and character of bodies of water are maintained.
- Soil and water resources are protected and maintained in their natural state.
- Public and management access to all protected areas and waters are secured.
- A wide range of outdoor recreational, educational and heritage appreciation opportunities are provided.
- Significant historic and cultural heritage sites are protected, preserved and conserved.
- The *in-situ* genetic diversity of indigenous species is maintained.

These guidelines are however not statutory.

2.0 DESCRIPTION OF KARST

2.1 Definition

Typical karst topography consists of a type of topography formed in dolomite, limestone or marble areas, comprising depressions and holes, and with underground drainage in conjunction with surface streams. Karst areas, therefore, comprise two landscapes interconnected through a series of structures and dynamic processes.

The relatively accessible and visible surface landscape is characterised by closed depressions or sinkholes (known as dolines) formed either by solution of the surface bedrock or by collapse of underlying caves; elongate depressions formed by the coalescence of several dolines (known as uvala or karst valleys); stream sinks; prominent features such as pinnacles; kranzes; fissures (grikes) and gorges; natural bridges; blind or dry valleys; and rock outcrops with furrows ranging in depth from a few millimetres to more than a metre, formed as a result of solution of bedrock by rain or from subsoil moisture interaction with bedrock (karren).

The subsurface cave landscape is often unexplored or inaccessible, comprising natural cavities in the earth which act, or have acted in the past, as a conduit for water flow from stream sinks and percolation through cracks to springs or seeps or outgoing streams. Cave systems can be very complex, varying from single rooms, passages, and open shafts to intricate three-dimensional interconnected cavities. Some caves are completely dry and inactive, others totally filled with water; some are periodically flooded, and others permanently contain streams or lakes.

Although each of the surface and underground landscapes may have its own catchment and drainage areas, very often the one bears little relationship to the other. Subsurface streams may cross drainage divides and flow in a direction opposite to the general topographic slope.

The distinctive relief and hydrology of karst arise primarily from the greater solubility of certain rock types in natural waters. Karst is usually found in hard, non-porous rocks composed of relatively pure calcium carbonate such as dolomite, limestone and marble (recrystallised or metamorphosed limestone), which are dissolved away by rain and streams carrying carbon dioxide in solution. Other natural physical processes, such as uplift and mass movement, also play a part.

In addition, karst-like landforms and caves not derived from the dissolution of rock may occur in other rock types, e.g. those formed in quartzite and sandstone. These are known as pseudokarst.

Karst areas usually include distinctive soils, microclimates, flora and fauna, and hydrological patterns.

2.2 Location and extent

Although relevant to all karst areas, this guideline is focused on the COH WHS, which is situated to the northwest of Johannesburg in Gauteng and is applicable to the area encompassed within the boundaries of the Site and the adjacent buffer zone. The COH WHS covers approximately 8000 square metres of which the majority overlies the dolomite.

There are numerous other dolomite and limestone areas situated around the country, all of which are exposed to the same or similar threats as the COH WHS and it is recommended that these guidelines should be extended to provide a measure of protection for them.

3.0 VALUE OF CAVES

Caves are a resource of regional, national and international significance. They are valued for their:

- Association with indigenous cultures
- Unique attributes of natural heritage
- Importance for natural history research
- Utility for recreation and tourism
- Role in the supply of water

3.1 Cultural value

There are many caves scattered across the karst areas in South Africa that are of cultural, spiritual and historical value to many of South Africa's peoples. It is therefore important in today's society that these values are understood and taken into sympathetic account when considering activities, developments and controls that impact on the relevant areas.

Equally when applying guidelines and legislation to any cave it is important that the beliefs of the local indigenous people are considered and that these communities become part of the process so that they understand the significance of the proposals and have a say in the development of the area.

3.2 Natural heritage value

Caves provide habitats or shelter for a wide range of animal species with varying degrees of reliance on or adaptation to dark, cool, moist conditions with low daily variability. Of particular interest are the "troglobites", species which are wholly adapted to subterranean environments and cannot survive elsewhere. Research indicates that the primary habitat for many of these species may actually be the numerous smaller cracks and voids which penetrate the dolomite, limestone/marble beyond the limits of human size caves. Caves may therefore be imperfect "windows" through which these ecosystems may be glimpsed.

3.3 Research value

Parts of certain cave systems are not as prone to the deteriorative effects of climate and erosion as the surface and in combination with their cool relatively stable temperatures, have provided irreplaceable evidence of South Africa's environmental history which should be preserved. The structure, form and age of these sites and the fragments that they contain (such as sediments, fossils and human artifacts) can be related to such phenomena as past sea levels, earth movements, and erosion cycles. These "time vaults" are important sites for geological, geomorphological, palaeontological and climatological studies.

Bones of bats, birds, amphibians and reptiles are commonly found in caves. The relatively high calcium content and constant microclimatic conditions of caves make them ideal repositories for the long-term preservation of vertebrate bones. Some caves also contain remains of fossil invertebrates, often of previously unknown or locally extinct species.

On the other hand, in some caves the natural processes of erosion of the limestone or dolomite sometimes expose fine examples of fossils that would otherwise be hidden. The naturally exposed bone breccias in the COH WHS bear witness to this process.

Caves may also have well defined boundaries, zones or habitats which make them excellent natural laboratories for studying and analyzing processes such as adaptation, the structure and function of ecosystems, the reactions of ecosystems to induced changes, and microclimatological studies.

Caves contain many types of secondary mineral deposits, known as speleothems (for example stalactites and stalagmites). Speleothems are one of the major terrestrial sources of palaeoclimate information. Most speleothems are formed mainly from calcite, the most common crystalline form of calcium carbonate, which is the main chemical component of limestone, dolomite and marble. Aragonite and gypsum speleothems are also common. However, there are also occurrences of rare and obscure mineral forms seldom found in nature and the wealth of minerals found in MboboMkulu Cave in Mpumalanga is a good example.

3.4 Recreational and tourism value

Caves are highly valued for recreation and tourism by many South African and overseas visitors. For some people, this also includes valuing them for spiritual and other cultural reasons.

Large numbers of people also visit caves each year, appreciating their awe-inspiring size while marveling at the stalactites and stalagmites and other rock formations. Tourism in caves such as Sterkfontein and the Wonder Cave are significant with annual visitation levels of around 80 000 and 40 000 respectively.

Commercial adventure caving through "wild" or relatively undeveloped caves is also increasing in popularity. This activity demands a professional approach to safety standards, conservation and other codes of practice.

The largest collective group of *bona fide* cavers in South Africa are members of the South African Spelaeological Association (SASA) with four member clubs, and the independent Cave Research Organization of South Africa (CROSA). However, only the Speleological Exploration Club (SEC) and CROSA are active in the COH WHS. These clubs have played a significant role in cave discovery and exploration in the COH WHS and in developing caving ethics and conservation awareness as well as promoting the need for appropriate management.

3.5 Water supply

In some karst areas the water issuing from caves and springs is an extremely important local resource. The integrity and sustainability of water supplies depend on knowledge and appropriate management of surface sources and associated subterranean drainage patterns.

4.0 VULNERABILITY OF CAVES AND MANAGEMENT OBJECTIVES

4.1 General

The main activities that may have adverse effects on the caves are various forms of farming, quarrying and mining, together with urbanisation, recreation and rubbish and waste disposal. Subsurface features are especially vulnerable to careless recreational use, some of which may be essentially irreversible, particularly in areas that had previously been in relatively undisturbed isolation. Just as such areas accumulate evidence of palaeontological interest, so too they accumulate evidence of recent human impact. Such impacts include: disturbance of the cave passageways by trampling and erosion, which could remain for hundreds of years in a dry passage; broken speleothems and fossils which may take thousands of years to re-form; the removal of speleothems and fossils; and the disturbance of sediment, subsequently coating speleothems and other floor deposits. Waste left inside caves will decompose at a substantially lower rate compared to waste left on the outside.

The critical factors that need to be understood and addressed for the conservation of caves are: water quality, soils, vegetation cover, hydrology, underground climates and air flows, inputs to underground systems (of water, organic debris, silt and chemical wastes), cave deposits (sedimentary and mineral) and the use of caves for cultural, scientific, recreational and exploratory purposes. The key to reducing the vulnerability of caves to adverse activities lies in educating the public and resource managers about the value of caves, the critical factors that contribute to their vulnerability, the ways in which caves may be damaged by thoughtless actions, and the management options to conserve them.

4.2 Cave environments

It is helpful to consider cave energy levels when assessing the potential effects that visitors may have on caves and cave environments. High-energy cave passages are those prone to high-energy events (such as flooding) on a regular basis, causing such caves and underground passages to be regularly modified by rock falls or other effects of the flooding event. Speleothem formations are rare in these caves because any that may form are rapidly scoured away or damaged. The impacts that visitors may have under these conditions will generally be minimal. In moderate-energy cave passages, conditions such as running water, persistent wind or animal activities represent forces with lower energy levels impacting on the cave environment. These caves often contain the most abundant speleothem formations, indicating an abundance of saturated water. Compared to high-energy caves, the effects that visitors may have on moderate-energy caves may become more evident over a longer period of time, although such effects may be masked by occasional flooding and sediment rearrangement. In low-energy cave passages a major energy event may be characterised by falling droplets of water. Speleothems in such low-energy caves are characterised by small and delicate formations resulting from the very low crystal growth rate. The presence of visitors in a low-energy cave may have serious effects on the cave environment, as the amount of energy released by visitors even during a short visit, may be many times more than what the cave has experienced in hundreds of years.

In general, individual caves will probably contain components of all three different types of energy level.

Many caves are moderate or low-energy environments, with essentially little input of energy from humans over the centuries. A small group of cavers entering a cave will change the energy regime (through the way that people behave and move in caves, as well as slightly affecting the heat, light and nutrient levels) but will generally have little effect on the rock formation itself. However, when visitor numbers are large, the picture changes dramatically. The effects of visitors are generally cumulative, possibly synergistic (i.e. the total is more than the sum of the individual components). In other words, the effects of a single party of ten cavers will be greater than the effects of two parties of five cavers each in the same cave. However, the actual effects also depend on the management and behaviour of the group, and a party of ten well-managed and guided cavers will cause far less damage than two parties of five inexperienced cavers. Correspondingly, a cave that has been "hardened" to carry guided tourist traffic may be far more stable and sustainable than an unmanaged but accessible "wild" cave.

Changes to airflow and humidity in cave systems, which may result from either natural or human activities (e.g. digging through sediment-filled passages for recreational exploration), can have major effects. Cave-dwelling species and growing speleothems often rely on temperature-stable humid microclimates.

4.3 Total catchment management

Caves are vulnerable to activities in other (non-karst) parts of surface catchments. It is, therefore, preferable to manage the entire catchment rather than just those portions containing karst. However, subsurface catchments may be difficult to identify because they frequently do not match the apparent catchment boundaries at the surface (e.g. cave streams frequently pass beneath both valleys and ridges on the ground surface). The relationship between surface conditions and subsurface processes and features is important and needs to be appreciated. For example, road construction and agriculture can greatly accelerate the natural erosion level of karst soils, and can dump large quantities of silt into cave entrances. These actions could destroy the habitats of cave fauna and impact on the cave ecosystems. In addition, such activities often increase surface runoff of water, thereby increasing the frequency and size of flooding events in cave systems. Silt deposition and flooding may reach areas of the cave which have been unaffected for centuries, impacting on features preserved there. In the longer term, altering surface land uses may alter soil through-flow rates and chemistry of percolation waters, affecting processes such as the deposition of speleothems.

Caves are therefore best protected by maintaining the intact surface vegetation, soils and hydrological systems over the whole catchment affecting the area. In many instances, this will require cooperative management between many landowners.

5.0 COH WHS MANAGEMENT POLICIES FOR CAVES

Management of karst areas should be based on the following principles:

5.1 To protect sites with cultural, heritage or research value by maintaining natural flow as well as air, water, and energy cycles.
5.2 To foster a range of educational, recreational and tourism activities in specific caves for the safe enjoyment and appreciation of suitable and exploitable cave features and values according to national goals.
5.3 To promote appropriate protection for internationally, nationally and regionally significant cave features which are not under its management.
5.4 To establish a viable network of representative areas of karst ecosystems, landforms and landscapes that originally contributed to South Africa's own natural character.
5.5 To promote understanding of the attributes, values, vulnerability and management of caves among departmental staff, external agencies, the public and associates.
5.6 To work cooperatively with other interested parties to minimise any adverse impacts that activities undertaken both inside and outside of the COH WHS may have, as well as all processes that may affect caves.

6.0 ACTIONS TO CONSERVE THE CAVES IN THE COH WHS

The following actions are deemed necessary to effectively manage the caves in the COH WHS. Many of these actions are drawn from the IUCN Guidelines for Cave and Karst Protection (Watson *et al.* 1997), the South African Spelaeological Association Caving Code of Conduct and the New Zealand

Speleological Society Handbook.

The actions are grouped into those related to:

- Overall actions to conserve the natural caves of the COH WHS.
- Planning the management of protected wild caves in areas administered by the COH WHS.
- Protection of caves from visitor impacts
- Concessions in caves
- Non-routine activities in caves
- Protection of caves on private land and other public land
- Staff training and capacity

6.1 Overall actions to conserve the natural caves of the COH WHS:

- Formally protect a representative selection of specific caves as protected natural sites.
- Assess the potential effects of current and proposed activities on caves.
- Protect caves from the interference with rocks, soils, vegetation, and water resources where such interference will interrupt or alter the processes that generate and maintain the caves.
- Safeguard the quantity and quality of water inputs to cave systems (through formal protection of an entire catchment and/or environmental management and control of water resources).
- Minimise the erosion of soils and alteration of soil properties (such as aeration, aggregate stability, organic matter content, and a healthy soil biota), which may affect the caves.
- Promote a healthy cave management approach among all stakeholders

6.2 Plan the management of protected natural caves administered by the COH WHS:

The COH WHS in conjunction with selected stakeholders and the Karst Working Group should undertake the following actions as point of departure in the management of caves falling under its jurisdiction:

- Undertake a basic inventory study to identify the number of caves, the extent of the caves, the nature of (energy level) and sensitivity of the caves and their cultural value, if any.
- Emphasise the three-dimensional integrated nature of the caves: i.e. rock, water, atmosphere elements, and cave energy levels.
- Identify threats to the caves (including threatened species) and opportunities, and formulate appropriate management responses.
- Prioritise actions to: ensure that a representative selection of caves are declared as protected natural features, remove or mitigate threats, restore damaged features (as much as is practicable), and provide a range of recreational and educational opportunities for the safe enjoyment and appreciation of suitable caves as tourist attractions.
- Develop monitoring programmes.
- Liaise with wild cave user groups, landowners and stakeholders.

6.3 Protection of caves from visitor impact

Management planning and control should strive to allow visitor numbers, user patterns and behaviour to be in accordance with the nature and sensitivity of the caves.

The MA should:

- Liaise with tourism operators, local caving clubs and other user groups, educational organisations, police and cave search and rescue coordinators as well as their national bodies, to ensure they are aware of and adhere to accepted guidelines.
- Avoid releasing information that will encourage or facilitate people to search for caves and cave features (including fossil deposits) which may be at risk from inappropriate or uninformed use.
- Monitor the condition of much-frequented and vulnerable cave sites, in order to assess and improve the effectiveness of current management practice(s).
- Minimise the vulnerability of significant caves to visitor impacts by educating visitors about the fragility of cave systems and about the appropriate behaviour when visiting such areas. The use of on-site and visitor centre information and interpretation panels as well as associated publications are good media for education and promotion of safety.
- Restore damaged cave features (where appropriate) in caves used for adventure tourism rather than opening new wild caves.
- Investigate new mechanisms to restrict access to wild caves that are sensitive to or currently being damaged by visitors. Options include:

  Categorise areas and issue permits to only allow entry to restricted areas (e.g. nature reserve or scientific reserve).

  Establish a system that only allows permit holders of accredited institutions and clubs into specific areas.
- Limit public access to vulnerable or significant cave features (e.g. using physical structures or

notices) where visitor impact cannot be adequately reduced by user education or other measures.

6.4 Concessions in caves

It is recommended that GDACE, in collaboration with the MA, process all applications for concessions in caves in accordance with the relevant legislation, conservation management strategy, any relevant conservation management plan, and the Department's standard operating procedures:

- Consider whether there are less vulnerable or already modified features where the concession would be more appropriately located.
- Limit the effects of concession activities on cave areas by restricting access to appropriately qualified concessionaires, so as to ensure adequate protection of the area's natural, cultural, and historic resources.
- Consider, and where appropriate, invite, applications for the provision of facilities and services currently provided by the Department but which may be better provided by a concessionaire.
- Where possible, provide information to concessionaires about the value of sensitive caves and restrictions on the number of visitors in order to conserve the caves.
- Ensure that concessionaires provide appropriate interpretation to their clients, particularly about the fragility of caves and the restrictions on visitor behaviour inside the caves in order to conserve them.
- Identify areas where concessionaires may be able to assist by raising public awareness of conservation in caves.
- Monitor all concessions to make sure that conditions are adhered to.
- Monitor all concessions for direct, indirect, and cumulative effects of their operations.
- In cases where the effects of a concession are considered to be unacceptable, the operating conditions of the concession agreement may be varied to mitigate them, or the concession agreement may be terminated.
- Investigate reports of unauthorised commercial activities in caves administered by the COH WHS. Appropriate action to authorise such activities as a concession, to prosecute, or prohibit the activity should then be taken.

The COH WHS management authority will ensure the adequate protection of the natural, cultural, and historic resources of caves by setting concession operating conditions that address (but are not limited to):

- Group sizes and guide/client ratios.
- Leadership requirements such as guide training and/or qualifications.
- Access routes and interpretation techniques.
- Requirements for the protection of specific sites, e.g. route-marking in certain areas.
- Waste removal and disposal requirements (e.g. food scraps, and wrappers).
- The type of lighting system to be used; i.e. electric (preferable where practical) or carbide.
- Monitoring by the concessionaire of relevant activities and impacts on the cave environment.

6.5 Non-routine activities in caves

When considering requests for non-routine activities such as search and rescue training exercises, filming, weddings, or any other activity in the caves the COH WHS management authority will:

- Consider the appropriateness of the proposed activity and the impact that such an activity may have on the cave or cave system.
- Consider whether there are less vulnerable caves where the activity could be more appropriately located.
- Assess the costs involved or the benefits that the proposed activity may offer to other users of the cave.
- Assess any safety issues with regard to obligations under the Occupational Health and Safety Act.
- Establish formal links with the South African Spelaeological Association and Cave Research Organisation of South Africa, the police and search and rescue organizations.
- Consult with the South African Spelaeological Association and the Cave Research Organisation of South Africa on all cave-related matters, activities and proposals.

6.6 Protection of caves on private land and other public land

The following factors should be considered when evaluating whether to seek the protection of caves on private land and public land managed by other agencies:

- Degree of representativeness of existing natural caves.

- Geological, hydrological and biological attributes and significance.
- Overall scientific significance.
- Cultural and historic attributes and significance.
- Scenic, educational, recreational and tourism attributes and significance.
- Type and level of threat and degree of urgency of response.

Protection mechanisms that may be considered include:

- Acquisition
- Covenant, with associated contributions to the management costs the COH WHS (e.g. fencing, tracks, interpretation signs)
- Voluntary management actions by landowner
- Resource Management Act controls.

Appendix 5 provides information on legal ownership of caves.

6.7 Staff training and capacity

The COH WHS should:

- Foster the development of appropriate cave management expertise and capacity through staff training. This should also include training for stakeholders in the COH WHS.
- Develop methods for conservation management (e.g. methods for determining acceptable impacts, and for monitoring) in accordance with the Integrated Environmental Management Policies and Procedures.
- Acquire specialist equipment to appropriately monitor the caves.

6.8 A Caving Code of Ethics Guideline

The following Caving Code of Ethics will help to guide the actions of all cavers visiting the COH WHS' underground heritage and promote an ethical approach to caving among all other cave users. Visitors participating in commercial adventure caving trips are generally only interested in the experience as such and are therefore only given a brief insight into the world of caves. However, it is recommended that visitors who find the experience stimulating and wish to learn more or who take a real interest in the karst and caves join an accredited caving club where the appropriate training and education will be provided.

Conservation and protection of caves:

1.0 Take care to avoid destruction or disfiguration of cave decorations (speleothems) or any other natural feature of caves.
2.0 During exploration, tape off sensitive areas and mark routes for future use.
3.0 In sensitive areas, rigidly adhere to tracks and where applicable, follow route markers.
4.0 Do not disfigure caves by unnecessary markings. Survey marks should be small, inconspicuous and removable.
5.0 In areas of clean flowstone floors, remove muddy clothing or boots.
6.0 Do not leave any rubbish in caves, even when wastes were carelessly disposed of by previous visitors. Flash-bulbs, batteries, wrappings, and other refuse should be removed from the cave.
7.0 Carry spent carbide out of the cave in a strong, unsealed plastic bag loosely tied at the top to prevent spillage. Where appropriate, encourage the use of battery-operated lights
8.0 Discourage camping in caves except where absolutely necessary.
9.0 Discourage the practice of urinating or leaving faeces in caves.
10.0 Where no other alternative is available, remove all faeces from the cave when leaving the cave.
11.0 Use only tracing agents that present no danger to cave flora and fauna when undertaking water tracing tests.
12.0 Ensure that water supplies are not adversely affected by tracing agents and before starting any experiments, obtain the required permission from the applicable catchment authority.
13.0 Do not install a gate or a barrier in a cave without first obtaining approval of the South African Spelaeological Association or Cave Research Association of South Africa, as well as the landowner or administrating authority. Only install cave gates or barriers constructed according to internationally approved standards.
14.0 Do not install a gate in a cave without an accompanying sign explaining the reason for restricting access, and the circumstances under which authorised visits may be possible.
15.0 Do not interfere with, force, or damage a legitimately erected gate or barrier.
16.0 Use only natural anchors where possible. Bolts for rigging in caves should only be used as a last resort.
17.0 Under no circumstances should modifications be made to a cave, or cave entrance, other

than to gain access.

18.0 Do not remove any deposit, speleothem, sub-fossil remains, flora or fauna, or any other naturally-occurring object from a cave or karst area without first obtaining permission from the administering authority.

19.0 Anything removed from a cave or karst area (where permission has been granted to enter the area) should, where appropriate, be lodged with an accredited museum or scientific organisation.

20.0 The classification of caves and karst areas for the purpose of conservation and preservation has to be in accordance with international codes of practice.

21.0 Honour the classification of caves and karst areas determined by government agencies e.g. the COH WHS

22.0 Consult government agencies to assist them in preparing classifications for caves and karst areas.

23.0 Respect all cultural and historical sites and do not enter them without prior permission. No photographs should be taken without obtaining permission.

24.0 Observe the established Minimum Impact Code and rules of good camping when camping in natural areas or on farmland, especially in the lighting and extinguishing of fires and the removal of rubbish. Bury faeces when camping.

25.0 In order to conserve and protect cave and karst resources, encourage other organisations or groups that use caves to adopt these guidelines.

Cavers and landowners:

26.0 Seek and confirm specific approval in advance from the owner before entering a cave or private property. On no account take access for granted.

27.0 Respect the privacy of landowners.

28.0 Respect restrictions placed on access to caves, for example, during the bat hibernating season.

29.0 Take care to avoid interference with crops or livestock, and ensure that all gates are left as found.

30.0 Where a cave entrance has been blocked by the landowner, re-block the entrance when leaving the cave. Liaise with the owner to erect a fence or other appropriate barrier to secure the entrance.

31.0 Do not conduct any substantial dig or use explosives on or below the surface without the permission of the landowner (or administering authority). Secure or cover any hole that has occurred as a result of any explosion.

32.0 Dogs or firearms are not allowed when visiting caves, unless prior consent has been granted by the landowner (or administering authority).

33.0 Carry a valid caving club or membership card from an accredited organisation on caving expeditions.

34.0 Inform the farmer or landowner (or administering authority) after exiting the cave and thank them for the opportunity to visit the cave.

Public relations:

35.0 Always obtain permission from the farmer, landowner or managing authority *before* entering a tourist cave. Treat guides and other officials courteously.

36.0 When planning a visit to the area or cave falling under the jurisdiction of another group or club, cooperate and liaise with that group/club *before* the intended visit.

Publishing information:

37.0 Be very discreet in disseminating information that might endanger caves or karst areas. In particular, do not reveal the location of cave entrances in newspapers or magazine articles.

38.0 Do not publish or draw media attention to scientifically, ecologically, or physically sensitive caves or karst areas without prior consultation with the COHWH and the South African Spelaeological Association.

39.0When reporting the results and outcomes of caving activities, (particularly to the media), avoid and discourage sensationalism, exaggeration and unwarranted statements.

40.0When publishing the results of any investigation, take particular care to acknowledge the contributions (e.g. publications, personal communication, etc.) of any other parties involved (e.g. clubs, groups, individuals, etc.) in the investigation.

7.0 ACKNOWLEDGEMENTS

These guidelines have been structured around the Karst Management Guidelines initiated by the New Zealand Speleological Society and largely prepared by the New Zealand Department of Conservation staff and other people who value karst areas and who are experienced in managing them. The authors of this document have applied the principles to the South African context and more specifically to the COH WHS.

Further acknowledgement is given to the South African caving fraternity who, like their New Zealand

counterparts are passionate about the karst and caves of their country and who arguably know more about the surface and sub-surface of our karsts than anyone else. It is this fraternity that collectively have discovered and explored and documented so much about the karst and caves of our own country and those of our neighbours over the last 50 years.

Acknowledgement is also given to the IUCN with reference to the document: Guidelines for Cave and Karst Protection, which offers excellent advice on an international level and to the SA Spelaeological Association for their input.

8.0 APPENDICES

APPENDIX 1. IUCN Guidelines for Cave and Karst Protection (Watson *et al.* 1997)

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

2.0 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.

3.0 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.

4.0 The location and sites for destructive actions in karst, such as quarrying or dam construction, should be carefully selected to minimise conflict with other resources or sites of intrinsic value.

5.0 Pollution of groundwater poses special problems in karst and should always be minimised and monitored. This monitoring should be event-based rather than done merely at regular intervals, as it is during storms and floods that most pollutants are transported through the karst system.

6.0 All other human uses of karst areas should be carefully planned and implemented to minimise undesirable impacts and monitored in order to provide information to assist in future decision-making.

7.0 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.

8.0 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.

9.0 Governments should ensure that a representative selection of karst sites is declared as protected areas (especially as [IUCN] category I - IV...) under legislation which provides secure tenure and active management.

10.0 Priority in protection should be given to areas or sites with particular natural, social or cultural value, possessing a wide range of values within the one site, sites which have suffered minimal environmental degradation and/or of a type not already represented in the protected areas system of the country.

11.0 Where possible, a protected area should cover the total catchment area of the karst.

12.0 Where such coverage is not possible, all legislation providing for environmental controls or total catchment management should be used to safeguard the quantity and quality of water entering the karst system.

13.0 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, programmes of public education, heritage agreements or covenants.

14.0 Management agencies should seek to develop their expertise and capacity for cave and karst management.

15.0 Managers of karst areas and specific cave sites should recognise that these landscapes are complex, three-dimensional and integrated natural systems comprising of rock, water, soil, vegetation and atmospheric elements.

16.0 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.

17.0 Managers should bear in mind that in karst areas, any surface activity may sooner or later impact directly upon underground areas or further downstream.

18.0 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.

19.0 The interchange of air and water between surface and underground environments is the vital mechanism in maintaining the desired carbon dioxide levels. Therefore, the management of both air and water quality as well as quantity forms the keystone of effective management of karst areas at regional, local and site-specific scales. All developments planned for karst surfaces should take the infiltration pathways of water into account.

20.0 Catchment boundaries normally extend beyond the limits of the rock units in which the karst has formed. The whole karst drainage network should be traced and mapped using water tracing experiments and other cave mapping techniques. It should be appreciated that the boundary of these extended catchments may fluctuate dramatically according to weather conditions, and that relict cave passages may be reactivated following bouts of heavy rain.

21.0 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.

22.0 Soil management strategies should be drafted in order to minimise erosive loss and alteration of soil properties such as aeration, aggregate stability, organic matter content and a healthy soil biota.

23.0 Stable natural vegetation cover should be maintained, as this is pivotal to the prevention of erosion and maintenance of critical soil properties.

24.0 The establishment and maintenance of karst protected areas may 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. However, activities inside caves may have detrimental effects on regional groundwater quality.

25.0 Management strategies should be developed in order to maintain the natural transfer rates and quality of fluids (including gases), through the integrated network of cracks, fissures and caves in the karst. All materials introduced into the system should be carefully evaluated to avoid adverse impacts on air and water quality.

26.0 The extraction of rocks, soil, vegetation and water will clearly interrupt the processes that produce and maintain karst, and therefore such activities should be carefully planned and executed in order to minimise the environmental impact. Even the small-scale removal of limestone pavement or other karren for ornamental decoration of gardens or buildings has a drastic impact and should be subject to the same control measures applied for any major extractive industry.

27.0 Imposed fire regimes on karst should as far as is practicable, mimic those occurring naturally.

28.0 While it is desirable that the public should be able to visit and appreciate karst features such as caves, the significance and extreme vulnerability of many such features mean that great care should be taken to minimise damage to these features, particularly when such damage has a cumulative effect over time. Management planning should recognise this fact and management controls should seek to match the visitor population to the nature of the resource.

29.0 International, regional and national organisations concerned with aspects of karst protection and management should appreciate the importance of international cooperation and do their best to disseminate and share expertise.

30.0 The documentation of cave and karst protection/management policies should be encouraged and such policies should be made available to other management authorities.

31.0 Data bases should be prepared listing cave and karst areas located inside protected areas, while also identifying major unprotected areas which deserve recognition. Karst values of existing and potential World Heritage sites should be similarly recorded.

APPENDIX 2. Ownership of Caves

Ownership of caves is broadly based on the old common law that suggests that whoever owns the land on which the entrance lies, also owns that which lies below it. Therefore legal definition may be drawn by defining the area on the surface. The above doctrine has some exclusions, particularly in relation to statutes reserving mineral rights of private land to the State.

Nevertheless, the ownership of caves (or more precisely the walls thereof) generally lies with whoever owns the land on top of or surrounding the caves. A surface survey of the land below which a cave is located is acceptable to lay claim to ownership. However, problems may arise where such a survey indicates that the entrance lies on one property but the cave extends below a neighbouring property.

It is imperative that an accurate cave survey should be undertaken before land covering a cave is declared as a reserve. The British Cave Research Association Grade 5 Survey (a system adopted by the South African Spelaeological Association) has been proved to be accurate enough for this purpose. An accurate cave survey will ensure that adequate attention has been given to the location of entrances and the extent of passages.

APPENDIX 3. The South African Spelaeological Association Caving Code of Conduct.

Members of this Section should at all times adhere to the following during each and every visit to a cave or caving area, irrespective of whether the trip is an official club trip or not. The Executive of this Section shall be answerable for the conduct of each member regarding all the aspects of this Code of Conduct, morally if not legally.

1.0 Landowner relations

1.1 The Landowner's permission must always be obtained before traversing property or visiting a cave.
1.2 The Landowner's property and possessions must at all times be respected and protected.
1.3 Wherever possible, Landowners should be informed of work being undertaken, and be involved in the conservation of their caves.
1.4 Wherever practical the best Landowner and Caver relationships should be maintained at all times.

2.0 Conduct of meets

2.1 Parties should not visit a cave unless someone on the surface has been informed of the cave location, of the number of members in the party, and their anticipated return time.
2.2 Caving parties should have a Leader capable of handling the conditions related to the cave to be visited.
2.3 A 2:3 ratio of experienced to in-experienced members should be maintained in accordance with the cave conditions and the number in the party.
2.4 The highest possible standard of safety must be maintained throughout each caving meet.
2.5 Meet Leaders have a personal responsibility for the conduct and safety of all party members.
2.6 The maximum possible instruction in the procedures and science of spelaeology shall be provided for all new members wherever practical.

3.0 Conservation

3.1 The absolute minimum possible damage is to be caused to cave formations, growths, and items of geological, archaeological, palaeontological or biological significance.
3.2 No item taken into a cave by a party is to be left in that cave unless Committee approval has been obtained for a specific purpose.
3.3 The cave environment and ecological systems are to be subjected to the minimum possible disruption.
3.4 Nothing, whether living or inanimate, should be removed from a cave unless Committee approval has been obtained for a specific purpose.
3.5 Wherever possible, members shall remove from a cave any foreign matter found during a meet, except items clearly serving some specific purpose.
3.6 Cave locations may not be supplied to persons whose bona fides have not been verified.
3.7 The Executive of this Section will, where necessary, negotiate with Land-owners for some measure of control of access to a cave for conservation purposes.
3.8 Cavers should at all times actively promote and encourage cave conservation both amongst themselves and non-caving parties.
3.9 On the surface, members will respect and adhere to general conservation principles and ideals with equal force.

4.0 Scientific projects

4.1 Detailed records to the best of all members' abilities will be kept of all activities. These records will be made available for the furtherance of any scientific aim or project, but not to the detriment of caves or caving.
4.2 All possible assistance should be rendered to any person or group in the furtherance of a scientific or educational aim or project.
4.3 The Executive of the Section shall actively encourage and assist members in initiating and/or participating in projects of a scientific and/or educational nature.

5.0 Other caving bodies

5.1 Wherever possible, assistance shall be given to other caving bodies in the furtherance of their aims and objectives.
5.2 The rights of other caving bodies shall not be infringed upon by the members and Executive of this Section.
5.3 Inter-club cooperation and freedom of movement shall be encouraged by the Executive and members.
5.4 Similarly, cooperation and friendship should be encouraged with other organisations of a similar, but not necessarily, of a caving nature in this and other countries.
5.5 Matters of contention shall be dealt with fairly, honestly and timeously between the Section Executive and the bodies concerned.

The Executive of this Association affirms that the above principles shall at all times form the activities of this group.

APPENDIX 12.3

Cradle of Humankind World Heritage Site

PROPOSED CAVE CONSERVATION LEGISLATION

POLICIES AND ACTIONS

CONTENTS

SECTION 1,0 Physical damage to karst and caves

No person or owner of a cave may willfully or knowingly:

1.1 Break, break-off, crack, carve upon, write, burn, or otherwise mark upon, remove, or in any manner destroy, disfigure, disturb, deface, mar, or harm any speleothem, whether attached or broken.

1.2 In any manner disturb or alter the entrance and surrounding environment, natural condition, surface, speleogen or sedimentary deposit of any cave, other than the minimal disturbance necessary for:

a) Exploration,

b) Conducting legitimate scientific research, and then only when authorised by the Cave Advisory Committee (Refer to Section 6).

c) Recreational and educational purposes.

d) Rescuing injured persons from the cave.

1.3 Break, force, tamper with or otherwise disturb a lock, gate, door, fence, sign or other obstruction designed to control or prevent access to any cave, unless when authorised by the Cave Advisory Committee (Refer to Section 6).

1.4 Remove, disfigure, kill, harm, disturb, keep or restrain any cave life form or in any manner alter, disturb or destroy the natural condition of any environment relating to such life.

SECTION 2.0 Pollution of caves

2.1 No person, organisation, firm, corporation, municipality, metropolitan structure or other such entity shall dispose of, dump, store, or otherwise introduce into any cave, sinkhole, or natural subterranean drainage system any litter, refuse, dead animals, sewage, wreckage, garbage or any chemical or biological contaminant. All these substances are potentially dangerous to humans and cave life and may be hazardous to the quality of the water entering a cave, aquifer or the water table.

No person shall burn within a cave or sinkhole any material which produces any smoke or gas which is harmful to any cave life or which may have a negative impact upon the natural beauty of the cave or sinkhole and which may be drawn into the natural atmosphere of the cave through barometric process.

2.3 No person, organisation, firm, corporation, municipality, metropolitan structure or other such entity shall design, give permission for build, erect, construct or cause to have constructed any temporary or permanent structure or earthworks, dam, dyke, road or other excavation work that will negatively impact on any cave entrance, sinkhole or natural drainage channel without due recourse to environmental law and without permission of the Cave Advisory Committee.

2.4 No person shall take within the environment of a cave an aerosol container or other container containing paint, dye or other colouring agent.

2.5 No person shall leave within the environment of a cave any container, food, clothing, battery or other equipment other than that required to allow access to the cave, for scientific research or for continued exploration of the cave system.

SECTION 3.0 Collections and removal from caves

3.1 No person or cave owner may remove from a cave any cave life or natural cave material which may be found therein, whether attached or broken, including speleothems, speleogens and rock samples.

3.2 No person or owner of a cave may sell or offer for trade any speleothems or any other cave material in the Province of Gauteng or to export or import such material for trade within or outside the Province.

3.3 Notwithstanding the provision of this legislation, permits for scientific collection may be obtained from the Cave Advisory Committee (Refer to section 7.0).

SECTION 4.0 Entering and utilisation of caves

4.1 No person shall enter or remain in a cave for purposes other than cave exploration or scientific research unless by permission of the Cave Advisory Committee. Any non-conformance shall constitute a violation of this legislation.

4.2 Any cave required to be used for whatever purpose not defined in 1.2 shall require the permission of the Cave Advisory Committee.

4.3 No cave shall be used for any commercial activity without permission from the Cave Advisory Committee.

SECTION 5.0 Altering caves

5.1 Any alteration to a natural or constructed entrance to a cave shall ensure that the original passage or air, water and cave lift forms are maintained.

5.2 Gates employed at the entrance to or at any position within a cave shall be of appropriate construction to facilitate the original and unimpeded passage of air, water and cave life forms and shall be approved by the Cave Advisory Committee prior to construction.

SECTION 6.0 Management of caves

6.1 Prior to the development of any cave for tourism or for any other use including, but not limited to mining or quarrying, an Environmental Impact Assessment shall be undertaken by an independent body in conjunction with the Cave Advisory Committee, who shall also be responsible for establishing a Cave Monitoring and Management Plan.

6.2 A Register of Significant Caves shall be kept by the Gauteng Directorate of Nature Conservation and shall reflect caves which are of a particularly sensitive nature or which are under significant threat in terms of this legislation.

6.3 The Register shall be compiled by the Cave Advisory Committee, who shall periodically sit to consider applications for the inclusion of caves on the register.

6.4 The Register shall be periodically updated by the Cave Advisory Committee.

6.5 Each cave that is recommended to the Cave Advisory Committee for inclusion in the Register shall be considered by the Committee on its individual merits and shall be added to the register if that cave meets the criteria for significance as defined in this legislation.

6.6 The Directorate of Nature Conservation in consultation with the Cave Advisory Committee shall implement management measures to assure that caves on the register are protected during the period of consideration.

6.7 The Cave Advisory Committee shall be the only authority to recommend management measures for the protection of Significant Caves and shall decide on the most practical means to implement and control such measures.

6.8 Information concerning the specific location and nature of any significant cave may not be made available to the public unless it is considered by the Cave Advisory Committee that to do so would further the aims of this Legislation and would not create a risk of harm, theft from or destruction of such cave.

SECTION 7.0 Permits

7.1 The Cave Advisory Committee shall be the only authority empowered to issue permits for the removal of an obstruction designed to control or prevent access to a cave.

7.2 The Cave Advisory Committee shall be the only authority empowered to issue permits for the erection of any lock, gate, door, fence, sign or other obstruction designed to control or prevent access to any cave.

7.3 The Cave Advisory Committee shall be the only authority empowered to issue permits for the collection and removal, for whatever purpose, of any cave life or material including but not limited to speleothems, speleogen and other cave material.

7.4 The Cave Advisory Committee shall be the only authority empowered to issue permits to enter caves for exploration, recreation, scientific research, education and monitoring purposes.

7.5 The Cave Advisory Committee shall be the only authority empowered to issue permits for any mining, quarrying or excavation work.

SECTION 8.0 Related sciences

8.1 Laws including, but not limited to environmental issues, archaeology, palaeontology and national monuments should be referred to in this legislation or included if they are not encompassed in other acts, if such acts don't contradict the cave legislation.

SECTION 9.0 Liabilities

9.1 Neither the owner of a cave nor his authorised agents acting within the scope of their authority are liable for injuries sustained by any person using the cave for recreational or scientific purposes, if no charge has been made for the use of the cave.

SECTION 10.0 Enforcement of legislation

All law enforcement agencies shall be empowered to enforce the law in accordance with this legislation.

Cave Protection Wardens shall be appointed by the Gauteng Directorate of Nature Conservation in consultation with the Cave Advisory Committee, from the scientific and recreational caving community. Such Wardens shall receive official recognition and shall be empowered to access private property and to inspect any cave and report perpetrators who contravene any part of this legislation.

SECTION 11.0 Penalties

Any person who contravenes or fails to comply with this legislation shall be guilty of an offence and liable on conviction to a fine not exceeding an amount decided upon by the Cave Advisory Committee, e.g. (R10 000.00) or imprisonment of a period not exceeding (24 months) or both such fine and imprisonment.

SECTION 12.0 Provisions of the Act

12.1 The provisions of this act are severable. If any part of the act is declared invalid or unconstitutional, such declaration shall not affect the remaining parts.

SECTION 13.0 Approval of the Act

This act shall become effective immediately upon its passage and approval by the Provincial Legislator or upon its otherwise becoming a law.

SECTION 14.0 Criteria for assessing cave significance

Provision for categorising caves/sections of caves.

Specifications for assessment profiles.

(It is recommended that the detail be established by the Cave Advisory Committee).

SECTION 15.0 The structure of the Cave Advisory Committee

The Cave Advisory Committee shall include Provincial Authorities and Conservation agencies, plus caving bodies i.e. South African Spelaeological Association, Spelaeological Exploration Club, Cave Exploration Rescue and Adventure Club, Cave Research Organisation of South Africa and The Potch Potholers.

(Details of the structure and modus operandi of the Cave Advisory Committee to be established by the relevant representatives).

SECTION 16.0 The World Conservation Union (IUCN)

It is recommended that this act be linked to the IUCN Guidelines for Cave and Karst Protection and that the Provincial Authorities enter into a partnership with the IUCN to promote cave conservation.

ISSUE PAPER 13 SYNOPSIS PAPER

I.M. Macgregor

ABSTRACT

The Cradle of Humankind World Heritage Site (COH WHS) with associated hominid and other fossil-bearing deposits represents sites of significant scientific interest and importance, both nationally and internationally. These fossil deposits are however not the only attribute of this site and often overlooked is the fact that the karst system in which the said fossil deposits occur are the oldest extensive shelf carbonates in the world and also contain important Precambrian fossil assemblages (stromatolites and microfossils) which remain largely un-researched.

The commissioning of this publication and the results emanating from it have indicated that much work and research remains to be undertaken in the formulation of an Integrated Environmental Management Plan (IEMP) for the COH WHS karst ecosystem and caves. The current knowledge base is insufficient to this end. The implementation of such an IEMP is deemed essential for the sustainable management and long term integrity of the COH WHS.

This paper presents an integrated synthesis of the relevant papers comprising the publication including a framework and the findings/recommendations and responses for each of the said papers as presented by the authors.

The future of the IUCN-SA Karst Working Group and the “road ahead” is also briefly discussed. It is recommended that the Management Authority (GDACE) and the Karst Working Group (KWG) convene a post-publication workshop to prioritise further research requirements necessary in the compilation of an Integrated Environmental Management Plan (IEMP) for the COH WHS. The long term sustainability and integrity of this World Heritage Site lies in the development and implementation of such an IEMP.

13.1 Introduction

The main purpose of this Synopsis or Integrative Paper is not to present a summary of the previous papers in the publication but rather to address the following in respect of the appropriate papers, namely Papers 2 to 12:

i) Present a synopsis of the important and relevant issues arising out of the said papers.

ii) To identify "gaps" and issues requiring further attention.

The above are to be considered in respect of input(s) into the future management strategies of karst environments in South Africa and in particular the COH WHS.

For the non-technical/scientific reader some of the papers may appear to be highly academic and scientific and this paper attempts to (as largely as possible) concentrate on the key issues arising from the papers in a non-technical manner. To assist the "lay reader", a Glossary of Terms has been provided at the start of the publication.

Some of the papers do not contain a *Table of Contents* and hence a short section entitled "Structure and Contents" of each of the papers is briefly presented to facilitate a quick reference to issues covered in each paper. This is followed by the more important issues as presented in i and ii above. The contents of the papers are not referred to in detail and an appropriate understanding of this paper necessitates background information contained in the said papers.

As indicated in Paper 1, the future of the South African Karst Working Group (KWG) has relevance and some comment and suggestions pertaining to the importance of the KWG, it's future sustainability and management based on inputs from various members and I&APs (Interested and Affected Parties) is briefly discussed.

Issue Paper 2: Describing the Social, Environmental and Financial Significance of the Cradle of Humankind World Heritage Site

C. Bradley and J. Tholin

STRUCTURE AND CONTENTS OF PAPER

This paper includes the following sections: Abstract; Introduction; a section on Social, Environmental and Financial Motivations for Preserving the COH WHS; Conclusion and Bibliography.

FINDINGS OF THE PAPER AND RECOMMENDED RESPONSE(S)

1. Social Motivation for Preserving the COH WHS:

The authors make reference to the cultural significance of the COH WHS and its exceptional universal value in respect of well preserved hominid fossils dating as far back as 3.5 million years. Although many other cave deposits in southern and eastern Africa have yielded hominid remains the COH WHS is unusual in that it has yielded over 500 hominid fossils, thousands of fossilized animal remains, 9000 stone tools and other. The Sterkfontein Cave is the richest region in terms of Australopithecus fossils and to date is the longest sustained excavation of ancient hominid remains in the world.

On the granting of World Heritage status the World Heritage Committee stated that the fossil sites at the Cradle "throw light on the earliest ancestors of humankind" and that "they constitute a vast reserve of scientific information, the potential of which is enormous". The South African government as a signatory to the ratification of the Cradle of Humankind as a World Heritage Site has effectively made a declaration to the people of the world that it will enable the protection and preservation of this site and surrounding environment. There is a degree of social responsibility that South African holds to the rest of humanity to protect and preserve places such as the COH WHS for present and future generations.

2. Environmental Motivations for Preserving the COH WHS:

The authors refer to the importance of karst and associated cave systems and the specialised environments in these systems. Mention is made of the ecological significance of cave environments with reference to some rare and endangered cave dwelling bats and the importance of such caves for the survival of these species.

The sensitivity and fragility of cave environments is also raised and the importance of appropriate management thereof emphasised.

Hydrological aspects are also mentioned with reference to the importance of karst aquifers and the potential impact on such aquifers by various human activities such as mining. The contamination of the aquifer cannot only result in harmful human side effects but AMD (Acid Mine Drainage) has stability ramifications as well. It is indicated that an estimated 14,600 people live within the COH WHS with roughly an equivalent amount in the environs, equalling approximately 30,000 people who depend on this karst system for their daily water supply.

The authors also raise the issue of the importance of the preservation of the COH WHS as well as the conservation of the natural resources in the region in terms of social importance due to the social issue of environmental justice. In Section 24 of the Bill of Rights it states that everyone has a right "to an environment that is not harmful to their health or well being" and "to have the environment protected, for the benefit of present and future generations". With a high number of people dependent on the aquifer of the karst system of the COH WHS, any contamination of this aquifer may compromise their rights in terms of the Bill of Rights of the Constitution of South Africa.

Finally it is important to note that the karst systems provide a valuable source of carbon sequestration which aids in the reduction of greenhouse gases affecting the earth. The destruction of karst environments could facilitate the release of carbon dioxide into the atmosphere and further add to the effects of global warming.

3. Financial Motivation for Preserving the COH WHS:

The most significant aspect raised by the authors in terms of financial issues is that related to the revenue derived from tourism. Tourism has been recognised as an extremely important element of the South African economy and currently contributes about 7.4% of the GDP and it is estimated that by 2010 tourism will provide (directly or indirectly) 1.2 million jobs within the country. It is also estimated that tourism now surpasses gold as the leading foreign exchange generator with a value of R5.3 billion.

The COH WHS is in itself a significant tourism destination within South Africa and with the recent opening of the R163 million Interpretation Centre Complex in the region it is estimated that R65 million will be generated in the first year of operations. These changes will make the COH WHS a more desirable tourist destination and visitor numbers are envisaged to exceed 50 000/year.

The activity of commercial caving is mentioned in terms of income generation in the region but the associated negative impacts associated with this activity are also cited.

The financial significance of the prudent management of the hydrological system and aquifer of the COH WHS and its future integrity are also briefly discussed.

Issue Paper 3: Policy and Legislative Overview: Management of Karst and Cave in the Cradle of Humankind World Heritage Site

J. Cross

STRUCTURE AND CONTENTS OF PAPER

This paper includes a comprehensive Abstract; an Introduction and Purpose; Literature Review – Environmental Legal Framework for Karst and Cave encompassing both International Perspectives (Status of International Law in South Africa; International Conventions) as well as National Perspectives (Constitutional Considerations; and Legislation in respect of Biodiversity, Protected Areas, Water, Air, Land Use, Heritage Resources, Mining, Agricultural and Genetically Modified Organisms and Environmental Management Legislation in respect of statutory mechanisms to manage and protect karst and cave.

The paper also addresses Common Law Liability and sections on Policy Review, Problem Statement as well as Towards Integrated Legal Management and Protection of Karst and Cave in the COH WHS and Conclusions and Recommendations.

FINDINGS OF THE PAPER AND RECOMMENDED RESPONSE(S)

There is no single dedicated body of legislation concerned with the management and protection of karst and cave in an integrated manner. The diversity of legislation by necessary implication results in fragmentation and a proliferation of management structures and management tools, such as management plans and frameworks. As such, there appears to be a need for a coordinated approach to the planning of management measures and protection in respect of karst and caves within the COH WHS.

There are no guidelines which are specifically concerned with the management and protection of karst and caves. The development of these guidelines are essential to facilitate decision making with regard to the management and protection of karst and caves as well as enforcement for non-compliance with operational rules, regulations and other statutory provisions.

There is no immediate need for additional statutory measures dedicated to the management and protection of karst within the COH WHS in view of the fact that existing available statutory management measures appear to be adequate.

The capacity to enforce the current statutory framework is a matter of concern.

A recommendation is made that resources be allocated to focus on the development of guidelines on karst and caves to be incorporated into planning (i.e. Integrated Management Plans), operational rules (i.e. to be applied within the COH WHS in terms of the statutory regulations), statutory enforcement mechanisms and resources (i.e. authority officials and environmental management inspectors) and training (i.e. community, property owners, economic sectors and enforcement), before specific legislation is developed to manage karst and caves in the COH WHS.

RESPONSE(S)

In regard to the current legislation it is concluded and recommended that the following response/actions be considered:

- Firstly, by way of a management response, it is recommended that the Karst Working Group (KWG) produce, as soon as possible, a Guideline Document in respect of the management and protection of karst and caves in order to form an Integrated Management Plan to be developed by an Authority.
- Secondly, following the formal declaration in the Government Gazette of the Gauteng Member of the Executive Council as the Management Authority responsible for the Fossil Hominid Sites of Sterkfontein, Swartkrans, Kromdraai and Environs World Heritage Site, it is recommended that the Authority should, commence with the coordination of all the management measures undertaken by GDACE and SAHRA inter alia in terms of the National Heritage Resources Act and incorporate it into the Integrated Management Plan to be developed in terms of the World Heritage Convention Act for the COH WHS.

- Thirdly, the Authority should assess its role within the context of the environmental legal framework referred to in this legal paper. The regulatory systems of indirect intervention (monitoring) and direct management and enforcement (World Heritage Site Administrative Regulations) should be established as a priority. Thereafter, consideration could be given to undertaking of a feasibility study to determine whether the development of dedicated sub-ordinate legislation (i.e. regulations) are required in order to manage and protect karst and cave specifically.
- Fourthly, based on the observations above, it is recommended that the Authority proceed to establish a monitoring system to identify applications for all types of authorisations requiring an environmental assessment before a decision is taken, impacting on the environment, within the COH WHS. A Memorandum of Understanding (MoU) could serve as legal vehicle whereby inter-governmental duties to communicate regarding applications for authorisation within the COH WHS could be formalised. In addition, communication by landowners or communities within the COH WHS to the Authority on the undertaking of activities should be promoted.
- In the fifth instance, the designated Authority should proceed to implement and enforce the regulations in terms of the National Environmental Management Protected Areas Act. The relevant Authority must ensure that authorised officials and environmental management inspectors operating within the COH WHS receive training to apply the regulations with regard to the protection of karst and cave in particular.
- Finally, this legal paper serves as a legal baseline from where further action should be identified and recommended. It is recommended that further detailed legal assessment be given with regard to the development of an Integrated Environmental Management Plan in order to ensure coordination with the legislation referred to in this paper, specialist legal advice on the Authority's power of enforcement and legal training of authorised officials (being Authority employees) as referred to in the administration regulations issued under the National Environmental Management: Protected Areas Act as well as environmental management inspectors appointed in terms of the National Environmental Management Act. Training should in particular refer to the environmental legal framework for the management and protection of karst and cave referred to in this paper.

Issue Paper 4: The State of Karst Ecology Research in the Cradle of Humankind World Heritage Site

J.F. Durand and D. Peinke

STRUCTURE AND CONTENTS OF PAPER:

This paper commences with an Abstract and an Introduction (with some background on the 2.2 billion year old Transvaal Supergroup karst rocks and some aspects of the fossils and fauna associated with cave deposits within this system). It also presents a "Problem Statement" including perspectives related to impacts associated with Tourism, Mining, Agriculture, Urbanisation and other. Of significance is the issue that very little research has been undertaken on karst ecology in South Africa and without the necessary knowledge of karst ecology and an effective management plan for karst systems, one risks the ignominy of allowing part of South Africa's unique biodiversity to disappear.

The paper also presents a section on the current knowledge of troglobitic organisms in the COH WHS including: a Literature Review (mainly focussing on bats and Arthropods); information pertaining to the food web and energy flow within the karst system (including bat faeces, allochthonous epigean food sources, bacteria and fungi).

The paper also presents some perspectives emanating from unpublished information on cave ecology in the COH WHS and in closure includes a Summary and Recommendations and a Reference List.

FINDING/S OF THE PAPER AND THE RECOMMENDED RESPONSE/S

The fragility of karst environments and ecosystems was highlighted in Paper 1 and is endorsed in both this paper as well as Paper 5.

Some of the most important issues arising from this paper are contained in the section entitled "Problem Statement". In short these include the following:

- The threats and impact on karst ecosystems are from various sources and include tourism, educational, research, mining, agricultural and industrial activities and urbanisation. The impacts may be direct or indirect and the sources may be both from within the boundary of the COH WHS and peripheral to it. Many of the preceding issues are dealt with in more detail in the following papers but some reference to specific issues impacting on cave ecology is of relevance.
- Poor farming practices pose a major threat to karst ecology. Water in caves is essential for the survival of water-dependent organisms and bats which require a certain level of humidity in caves. Intensive agriculture is often accompanied by excessive utilisation of groundwater resources impacting on groundwater in caves. The existence of bats has a positive impact on farming practices as they remove high numbers of insects often detrimental to such farming practices. For instance, the use of insecticides and fertilisers in the horticultural industry in the Krugersdorp District and grain farms in the east of the North West Province are accumulating and pose a direct and indirect impact on the karst ecology by infiltration into the groundwater of the COH WHS.

- Urbanisation is perhaps one of the greatest threats to the karst ecology of the COH WHS. In recent times there has been unprecedented development westward from Johannesburg towards the COH WHS and these include new housing complexes (predominantly of high density) and informal housing/settlements. Impacts of the encroaching urbanisation include, but are not limited to the hydrological system (both in terms of water quality and quantity) but more potentially may have insidious impacts on the bat populations in the COH WHS. For instance, the ecologically insensitive urbanisation has the potential of changing the bat population dynamics where larger numbers of the house-dwelling bats such as the Cape serotine (Eptesicus capensis) and the Yellow house bat (Scotophilus dingani) are now considered to be competing with cave-dwelling species such as Rhinolophus clivosus, Miniopterus schreibersii, Myotis tricolor and Nycteris thebaica in the region. The ambient lighting associated with urban development is known to favour the existence of house-dwelling bats and enhance the competition between these bats. Surveys undertaken in the nearby Walter Sisulu Botanical Gardens have confirmed this fact (personal communication D. Peinke).
- Of concern is the lack of knowledge of the ecological constituents and interaction and interdependence between different biotic and abiotic components of South African karst systems. A lack of knowledge also exists in respect to the physiological parameters necessary for their survival. There is however knowledge of a few more noticeable cave organisms, but ignorance about the systematics, distribution and behaviour of the majority of the rest of cave organisms (many of which are endemic).
- Also of relevance is the matter of the food web and energy flow within karst systems. Subsequent to the abandonment of the caves by mammalian predators and cave-dwelling hominids, bats have become the most important active importers of organic matter into caves. Bats are therefore the most important links between photosynthetic processes outside the cave and troglobitic end consumers within caves. The "health" of the food web is therefore directly linked to a healthy bat population. The success and survival of bats is dependent on the vegetation types which support the insects they feed on. Loss of bat habitat due to human interference resulting from farming practices, urbanisation or other activities, will clearly lead to their demise which will have a direct impact on the subterranean ecology in caves.
- Another important aspect pertaining to bats is that preferred habitats and food of difference species of bats in the COH WHS differ slightly allowing for overlapping of roosting and feeding ranges. Different species of bats are active at different times of night and use different hunting strategies and the presence of colonies of bats in a cave may be seasonable. Disturbance of roosting colonies by human activity during such periods has the potential of seriously

impacting on the sustainability of such populations and the entire ecosystem of cave systems.

RESPONSE(S) REQUIRED

The recommended responses from this paper include the following:

- There is a pressing need to compile an inventory of karst dependent organisms and to undertake a thorough systematic description of all the organisms living in caves, fountains, surface streams and aquifers and their distribution within the COH WHS. One of the major gaps in knowledge concerns the diverse invertebrate communities within caves.
- On establishment of this baseline information it is important to determine the ecological needs and physiological parameters of cave organisms as well as the interaction, inter-specific relationships between subterranean organisms within the karst system and between troglophiles and species outside caves.
- The energy flow of the karst ecosystems should also be studied in order to understand extra and intra-karst nutrient relationships.
- The primary producers within the karst ecosystems should be identified and studied, including studies on the fungi and bacteria.
- It is important to draw up a responsible management plan for the conservation of the karst ecosystem and the utilisation of the karst system for tourism, scientific and educational purposes. An ecologically responsible solution has to be found in order to protect the extremely sensitive bat populations, which are in turn crucially important for the unique and vulnerable troglobitic invertebrate and fungi populations.

Issue Paper 5: Threats to the Karst Ecology of the Cradle of Humankind World Heritage Site

J.F. Durand

STRUCTURE AND CONTENTS OF PAPER:

This paper commences with an Abstract and an Introduction which in brief deals with the importance of karst systems, both nationally and locally in the context of the COH WHS (this also being the only World Heritage Site in Gauteng), and mentions in brief some of the activities threatening the karst system of the COH WHS.

The above-mentioned threats are dealt with in more detail in the Discussion section forming the main body of the paper and include the following: Mining (Limestone and Dolomite; Gold mining and the activities of abstraction and discharge of water from these mines. Other problems associated with gold mining include AMD (acid mine drainage) and impacts associated with pollution or effluents containing cyanide (having been used in the gold extraction process) and other metals such as manganese, aluminium, iron, nickel, copper, lead, uranium, thorium and radium; Agriculture or Farming (including impacts associated with irrigation practices, use of pesticides and fertilisers); Urbanisation (habitat loss, alien species, habitat for competitive species, pollution and waste management); Caving Tourism and Palaeontological excavations; and use of caves as dumpsites.

The paper further continues with a section on Recommendations (including Regulatory, Management and Monitoring responses required), a Summary and a Reference List.

FINDING/S OF THE PAPER AND RECOMMENDED RESPONSE/S

Issues pertaining to the threats to the karst ecology of the COH WHS as presented above are covered comprehensively and are not further discussed in detail here (reference should be made to the content of the paper for this purpose).

Of relevance are the recommendations and responses required in mitigation of the threats identified which are as follows:

REGULATORY RESPONSES REQUIRED:

Bat-related Issues:

The first of the issues identified here concerns the bat populations within the COH WHS. The author indicates that the phasing-out of the use of insecticides in and around the COH WHS would be one of the most important steps towards the conservation of the biodiversity within the area. Insecticides have a detrimental effect on the breeding efficiency and survival of bat populations. It is of great concern that there are many agricultural practices utilising insecticides within and in the vicinity of the COH WHS, all well within the feeding range of cave-dwelling bats. Although dosages ingested by bats may be sub-lethal, the toxins are passed on to the nursing young with fatal results and cause massive mortality.

The issue of competition between cave-dwelling bats and house bats associated with encroaching urbanisation around the COH WHS was mentioned in more detail in the previous paper and will not be discussed in detail here. The author proposes that house bats be excluded from buildings in the vicinity of the COH WHS in order to minimise numbers and avoid detrimental competition for limited food resources with cave-roosting bats. Simple and non-lethal methods are available to this end.

A further recommendation by the author in respect of bats is that caving, tourist activities and palaeontological excavations in caves which are used by the Miniopterus schreibersii, Rhinolopus clivosus and Myotis tricolor as hibernacula or maternity roosts, should be regulated.

Hydrological-related Issues:

In terms of hydrological issues reference is made to the lack of knowledge of groundwater, aquifers and karst systems in South Africa as well as the lack of adequate guidelines for better management and enforcement of existing policies concerning these natural resources. Furthermore, there is a lack of knowledge about the role of groundwater in supporting the ecology, linking the ecosystems and interacting with the surrounding environment. This leads to the uncontrolled abstraction, over-exploitation, pollution and deterioration of groundwater resources.

With the above in mind, it is therefore crucial that an "Integrated Groundwater Plan" be drafted and implemented. It is also noted that at this stage there is also a lack of a multi-disciplinary approach to groundwater management and a tendency to approach the different components of the hydrological cycle in isolation rather than in an integrated and holistic manner.

Water Quality, Legislative and Enforcement Issues:

The author raises the issue of impacts associated with mining operations and rehabilitation of mines. The effectiveness of the mining regulations (Mineral and Petroleum Resources Development Act of 2002) is also queried. This legislation holds liable the registered holder of a mining permit for compliance with the above Act until an unconditional closure certificate has been issued by the DME (Department of Minerals and Energy). The author refers to the limited number of active mines in Gauteng and the North West Province and draws attention to the effluents emanating from over 30 mines, most of which have been abandoned. The inability of active mines to control and responsibly manage their current effluents and other associated ecological impacts, places in question the ability of these mines to qualify for closure certificates in the foreseeable future. With the preceding in mind a scenario may develop where State institutions may have to assume responsibility for the ecological ramifications (including the pollution of the main water resource of tens of millions of people) thereof if appropriate measures are not adopted and enforced timeously. At the same time, mining companies could cry bankruptcy and point fingers at industry and informal settlements around them.

MANAGEMENT RESPONSE(S) REQUIRED

Water Quality Issues:

In addition to the National Water Quality Guidelines for domestic, industrial, agricultural and recreational use developed by the DWAF (Department of Water Affairs and Forestry) the said department has also determined the substance-specific National Water Quality Guidelines for the protection of freshwater ecosystems. These guidelines determine the maximum concentrations for a host of metals and substances such as aluminium, lead, mercury, molybdenum, selenium, vanadium, ammonia, arsenic, chlorine, etc. The threshold levels of each toxic substance at which chronic and acute toxicity occurs in aquatic biota are tabled in these guidelines. The DWAF also set limits of pH and suspended solids in water. It is proposed that these above mentioned criteria should be used in water quality evaluation, impact assessment and during the drafting of conditions pertaining to discharge permits for mines, industry and municipalities.

The DWAF in terms of the National Water Act of 1998 is responsible for the regulation, protection, use, development, conservation and control of the freshwater resources of South Africa and in respect of the Policy and Strategy for Groundwater Quality Management in

South Africa of 2000 to ensure an adequate supply and acceptable quality of freshwater. Unfortunately, the effectiveness of the legislation is only as good as the ability to implement the regulations by monitoring the quality of the resource and possible threats to the resource and it depends on the willingness and ability to enforce the legislation.

Issues Pertaining to the Classification of Caves:

The matter of the classification of caves is also raised as an issue. Caves in South Africa should be classified according to their ecological and geological sensitivity as has been done in other countries. It is recommended that GDACE should, with the assistance of scientists and cavers, undertake an assessment of the caves in the COH WHS and compile an inventory and classify caves according to their sensitivity. It is suggested that open caves possessing few sensitive features could be opened for recreational purposes with the permission of the owners. Caves and entrances to caves, having important attributes in respect of geological, palaeontological and other significance, those housing endangered species or sensitive habitats should be restricted or closed off. A permit could be issued by the management authority (GDACE in the case of the COH WHS) to enter caves for scientific or conservation purposes.

The importance of the classification of caves for management purposes has also been cited by M. Buchanan & J. Maguire (2002) and I. M. Macgregor (2005) as well as other authors in this publication.

Issues Related to Cave Entrances and Accessibility:

A conflict in priorities often arises where cavers or scientists block up passages or place grills or gates across cave entrances to restrict or prevent access. Unfortunately, these often block or restrict access of passage by cave-dwelling bats. If the necessity arises for the installation of such structures, the design should include horizontal bars of an appropriate size and spacing so as not to impede free passage of bats into and out of caves.

Possible Linkage between Aquifers of the COH WHS and the NW Province, Catchment Issues and Activities Peripheral to Karst Areas:

The author indicates that, at this stage, the negative effects of mine effluent released in the North West Province have as yet not been detected in the karst of the COH WHS. However, occurrence of the same amphipods in the Potchefstroom area as well as in the COH WHS would indicate that there may be an interconnection between the aquifers. The implication of this is that pollutants originating outside the COH WHS may end up in this area and hence pose a serious threat to the karst ecology of the COH WHS. The breaching of dykes during mining operations has in all likelihood enhanced the existence of such connections. It is implied that the connectivity of such aquifers requires further investigation.

It is also pertinent to note that the survival of karst-dependent species such as bats and amphipods depends on the conservation of areas much larger than the caves and karst area themselves. Water from the entire catchment feeding into the karst system will have an impact on ecological processes in the karst. Appropriate management practices would by necessity often have to include peripheral areas to karst as also indicated by J. Watson et al (1997) in Issue Paper 1. The release of mine, industrial and other effluents as well as treated sewage into rivers forming part of the karst catchment must be prohibited. In addition, the author proposes that waste and rock dumps, slimes dams, tailings, and low grade ore piles should be removed from the catchment.

Agricultural Perspectives and Alien Vegetation:

The potential impacts of agriculture on the COH WHS are discussed in the current paper, in Paper 4 and are also comprehensively addressed in Paper 11.

The author considers the existence of commercial farming in the core area of the COH WHS to be problematic from a conservation point of view. The farming practices (including the use of agrochemicals and abstraction of water) and feedlots are considered to degrade the karst environment. In respect of pesticides, it is recommended that these substances should be phased out in an area of at least 10 km radius from any caves that are inhabited by bats to ensure the restoration of bat populations to their original numbers.

Various species of alien vegetation occur within the COH WHS and these pose a threat to the biodiversity of the area. Management intervention is urgently required in this regard and mitigation measures must include peripheral areas in order to limit re-infestation.

Encroachment of Urbanisation:

The ecological problems associated with encroaching urbanisation have been previously discussed and are further comprehensively discussed in Paper 10.

The above-mentioned problems include changes to the hydrological system (including drainage patterns), nutrient and moisture patterns, the generation of waste and pollution, the introduction of alien species and habitat loss. In mitigation of these it is imperative that urbanisation is limited on the periphery of the COH WHS. In mitigation of impacts associated with urbanisation, directives on the introduction of open spaces, banning of exotics, bat–proofing buildings and the erection of bat- friendly street lights must be considered for the urban edge on the periphery of the COH WHS.

Palaeontological Excavations:

The author of this paper also raises the matter of palaeontological excavations which need to be carried out in a sensitive manner. Reference is made to the two palaeontological sites of Makopane's Valley (Limpopo Province) and Gladysvale in the COH WHS both of which house the Red Data species Schreiber's long-fingered bat or Natal cling bat (Miniopterus schreibersii natalensis) at different times of the year (used as hibernacularium in the case of Gladysvale and in the case of Makopane's Valley, as maternity roosts in summer). Excavation activities during those times of the year have the potential of seriously disrupting these populations of bats.

BASELINES STUDIES AND FURTHER RESEARCH

The matter of lack of baseline information has been previously mentioned in this paper and is also discussed elsewhere in this publication.

In order to conserve the karst ecosystem it is deemed necessary to undertake baseline studies to determine the composition, distribution and population densities of karst-dependent species. Monitoring programmes should also be implemented to establish the waxing and waning of population numbers as well as to determine the general well-being of the populations and their direct environment. The interaction and dependency between the groundwater resources and the cave ecosystems needs to be determined and monitored as the karst ecology forms an ecotone between groundwater and surface habitats where an intricate food web comprising microfauna, bacteria and fungi exists. If any of these ecological links disappears it will create a domino effect on the rest of the system and have serious implications in respect of endemic species.

MONITORING REQUIRED

Groundwater:

The matter of the hydrology of the COH WHS is a recurring issue raised in respect to threats to the karst system and are dealt with in more detail elsewhere in this publication. The ground and surface water quality should be constantly monitored, especially in the light of the recent influx of mine effluent into the COH WHS. The monitoring of agrochemicals and metals should also be undertaken on a regular basis.

Monitoring of Karst Ecosystems:

As indicated in the previous section, baseline surveys and further research is required to determine the constituents of the karst ecology (including troglodytes, troglophiles, stygobites and stygophiles in both epigean and hypogean habitats) in the COH WHS. Once this is established it will be important to monitor these on a regular basis. It is considered that stygobites such as amphipods can be used for hypogean water health monitoring in a similar way that epigean invertebrates are used in the SASS4 scoring in surface water health monitoring programs.

In terms of bat populations it is imperative to monitor bat roosts to determine whether the conservation strategies or practices are sound within Gauteng, North West and Limpopo Provinces. This should include the migration and roosting habits of bats in the COH WHS and caves in the Makopane's Valley. The survival of Schreiber's long fingered bat in the sub-region depends on the success of its annual migration to the colder caves in Gladysvale (COH WHS) to hibernate in winter and to warmer caves in the Makopane's Valley in spring to pup. Both these sites are of palaeontological interest and research and in order to limit disturbance of the bat populations, access to these sites should be restricted to appropriate times.

In conclusion the author of this paper makes reference to the following:

Urbanisation and the resulting habitat loss and pollution from industry and mining activities are the greatest threats to karst ecology in Gauteng. Mining poses the main threat to karst in the North West while farming practices in the North West and Limpopo Provinces are of some concern. Of all the anthropogenic impacts mining and agriculture are considered to be the greatest danger to karst ecology due to their irreversible effects, scale of destruction and long-term pollution. At this stage it seems as if the cost to inhibit present, remedy past and prevent future anthropogenic damage to soil, ground and surface water and karst ecology will cost more than the wealth ever generated by mines and industries in the areas concerned.

Issue Paper 6: Hydrology of the Cradle of Humankind World Heritage Site: Geology, Surface and Groundwater

M. Holland, K.T. Witthüser and A.A. Jamison

STRUCTURE AND CONTENTS OF PAPER

This paper commences with an Abstract followed by an Introduction, a Conceptual Framework of the karst aquifer, the Geological Setting of the COH WHS, the Water Resources of the COH WHS (including surface and groundwater), Management Issues and Strategy and finally, Conclusions and Recommendations as well as a comprehensive Reference List.

FINDING(S) OF THE PAPER AND RECOMMENDED RESPONSE(S)

Complexity of the Geology and Lack of Detailed Information:

Compared to the classic karst areas in Europe and America, the karst system of the COH WHS is very different and possibly unique. The Malmani Dolomite (Transvaal Supergroup) as mentioned in Paper 1 is very old and has been subjected to deep burial, tectonization, folding, uplifting and prolonged episodes of natural loss of soil and erosion. Another important and well documented characteristic of the regional karst of the Malmani dolomite is its subdivision into hydrological “compartments” isolated from each other by impervious dykes and silicified faults.

Two major compartments have been identified in the COH WHS by various researchers but the bulk of the COH WHS dolomites have not been investigated and a deficiency of data exists. Recent work by A.A. Jamison has indicated many more fracture zones and dykes than were previously reported while considerable deformation (pre-Bushveld Complex folding and late Bushveld bedding sub-parallel ductile deformation mylonites) in the COH WHS was identified, indicating to a more complex system of karst in the area.

The heterogeneity of karst aquifers also makes it difficult to quantify and predict the movement of groundwater and contaminants through and/or between different aquifer zones. It is also difficult in many instances to quantify a sustainable water balance that would prevent over-use of the groundwater resource. This is significant as many towns, rural areas and farming practices in South Africa rely on water from the Transvaal Supergroup dolomites.

Issues Pertaining to the Reserve and Groundwater Recharge:

Given the heterogenity of the system, it is widely accepted that no single estimation technique can successfully determine groundwater recharge. The reliability of water balance methods such as the Cumulative Rainfall Departure Method and Darcian methods like saturated flow volume or numerical flow models depend on availability of data which is often lacking. Groundwater tracers provide a supplementary way to assess and compare characteristics of groundwater recharge.

To comprehend the dynamics of the karst aquifer it is necessary to understand the recharge processes and the hydrodynamic flow systems that are controlled by the permeability of the aquifer and exchange of water between the different layers and compartments. Yet to describe the hydrology of the karst system effectively a sound geological and conceptual hydrogeological model verified by tracer tests is essential.

With the above in mind it is considered that the groundwater resource units have not been delineated and require further investigation. This would also imply that the dynamics of the hydrological system are not fully understood and also require further investigation before appropriate management practices can be implemented.

MONITORING OF SURFACE AND GROUNDWATER:

Surface Water

The dolomitic formations underlain by the COH WHS generate little surface runoff creating an area virtually devoid of surface drainage channels. Furthermore it is considered that the hydrology of the catchment has been significantly influenced by man. Abstraction of water occurs for agricultural, and to a lesser extent, for urban, domestic, mining and industrial uses while natural runoff is increased through effluent return flows from industries, mines, municipal sewage works (Randfontein and Krugersdorp) and increased runoff from urbanised areas. Both the aforementioned sewage works account for approximately 35% of the total mean annual runoff at the downstream gauging station on the Bloubankspruit. The impacts of these return effluents on water quality in the COH WHS is not completely understood but discussed elsewhere in this publication.

Various surface water monitoring points from the Institute of Water Quality Studies (DWAF) are found along the Bloubankspruit, Magalies and Krokodil (Crocodile) Rivers and certain chemical data exist for these gauging stations but no catchment management, river health programme or monitoring programme exists.

In order to determine the trends in changes in surface water quality and quantity, a more comprehensive monitoring programme including additional and more data feed and a much denser array of surface water monitoring points, is indicated and required.

Groundwater:

It is reported that the dissolution process in the dolomite karstification has been more active in the chert-rich dolomite due to higher porosity developing in the brittle, fragmented, cherty horizons being accessed by deeper penetrating fractures and fissures. In the absence of surface drainage channels, recharge from runoff is not a dominant factor in the COH WHS. Recharge according to the 1995 National Scale Map of recharge is reported to vary from 13% of MAP (Mean Annual Precipitation) in the southern part to 10% in the northern part of the COH WHS.

There is a significant lack of groundwater chemistry data in the COH WHS and where data is available (Directorate of Geohydrology – DWAF) only a few boreholes have continuous groundwater chemical data. It should be noted that alternative monitoring points such as springs, cave streams and seeps are often more appropriate monitoring points in karst terrains as they often intercept flow from a larger area than boreholes. There are however reportedly few of these natural features in the study area. Therefore the extent to which the groundwater monitoring stations adequately represent response to the aquifer to many controlling factors has to be evaluated with the view to determine if and where additional monitoring points have to be established.

MANAGEMENT ISSUES AND STRATEGY

The important issues arising out of management issues and strategy in this paper include the following: Due to the complexity and heterogeneity of the karst system it is now accepted that no single approach can successfully determine the dynamics of the system. An integrated approach is therefore required in which a variety of methods are utilised to explore and study aquifers in order to describe their functioning and structure. These include: Characterisation of the structure by geological and morphological analyses; Delineation of the karst system by means of geological mapping, tracing tests and water balance; Characterisation of their lump functioning by use of spring hydrographs or time series analyses and by using hydrogeochemical and isotope methods for analysing natural tracing; Characterisation of their local functioning by artificial tracing tests and pump testing.

In response to the provisions of the National Water Act (No 36 of 1998) the GRDM (Groundwater Resource Directed Measures) was developed which consists of three important aspects namely: Classification; the Reserve and Resource Quality Objectives. The adoption of these GRDM principles provides a sequential process to ensure that groundwater resources are protected and to ensure sustainable management and development in the future.

With reference to the above it is recommended that a comprehensive GRDM for the study area is required which would require extensive field studies and data collection by various specialists.

In further liaison with the authors of this paper the following issues are presented as warranting further research:

- The most important and overall goal is the inception of a conceptual hydrological model, i.e. a working description of the characteristics and dynamics of the physical hydrological system including the solutes of concern that consolidates site water quality data into a set of assumptions and concepts that can be evaluated quantitatively (ASTM 1995).

An improved understanding of the following factors is necessary to initiate the conceptual model:

- Continuous monitoring of accessible boreholes in the area before a final monitoring network (water quality and quantity) is designed. These data should be consolidated in a public accessible database of available information (e.g. water samples and levels by DWAF (Department of Water Affairs & Forestry), CGS (Council for Geosciences), UP (University of Pretoria) meteorological information, etc.) to promote open information data integrity and exchange.
- Delineation of groundwater resource units within the area – thorough characterisation of the geology including the occurrence of dissolution channels (preferential flow paths), caves as well as the occurrence and role of bounding dykes, faults and formation contacts on the groundwater flow.
- Determination of the Reserve – Recharge, hydro-census addressing especially abstraction and discharge rates from and to surface or groundwater resources, ecological reserve and the water balance.

Issue Paper 7: The Use of Caves and Karst in the Cradle of Humankind World Heritage Site

P. Kenyon and R. Ellis

STRUCTURE AND CONTENTS OF PAPER

This paper includes the following major sections:

Abstract; Introduction; The Problems of Sustainability within the COH WHS; Commercial Activity Relating to the Caves of the COH WHS; Proposed Actions Regarding the Sustainability of the COH WHS Karst and Caves (***Surface Activities***: such as cattle farming; removal of rock formations and flora; coordination of Interested & Affected Parties; legislation, policy and verification; tourist guides; archaeological diggings; ***Sub-Surface Activities*** : such as casual use of caves; radon gas; *Histoplasmosis capsulatum*; lighting and lampenflora; use of sinkholes and caves as dumpsites; environmental impact studies of caves and the low energy description of a cave; commercial adventure caving.

The paper further considers the following: Best Practices

Worldwide; Some Recommendations on Cave and Karst Management and Proposed Actions; Specific Recommendations; Conclusion and Reference List.

FINDING(S) OF THE PAPER AND RECOMMENDED RESPONSE(S)

The topics and issues covered in the paper have been summarised in the previous section but the most salient points arising from this paper include the following:

The authors of this paper draw attention to the sensitivity of cave environments and consider the largest impact leading to the degradation of these environments to be associated with human activity and access. Reference is also made to other human activities including those related to tourism and others which are considered to place emphasis on the question of the sustainability of the COH WHS. These have been divided into four categories namely: a) Tourist Residential (hotels, guest house related facilities and restaurants). b) Tourist or Commercial Land-based (activities such as game farming, chicken farming, horse breeding and farming practices). c) Tourist Specific (activities such as show caves, adventure caving, archaeological tours, quad biking, fishing, hiking, horse riding and others). d) Assorted Economic (activities such as petrol stations, truck repair shops, brick builders, local builder's yards and others). The question is posed if these are degrading the karst and where applicable, the caves and whether they are sustainable and if so, can they be expanded upon.

The caves of the COH WHS are mainly what are referred to as "low energy" caves as they typically have a single entrance with minimal air flow, fragile crystal and rock formations and bat populations. The principle of tourism or cave carrying capacity, is argued, does not exist – that is that every visitor to a cave has an impact and that such impacts are cumulative. Impacts that occur include polishing of rock structures, changes in humidity and temperature, compaction of floor sediments, disturbance of fauna and flora, destruction of rock crystal formations and speleothems, graffiti - to mention but a few. It is suggested however that some caves can sustain a degree of visitation due to the already dirty appearance, lack of water passages and robust rock formations. It is also considered that non-specialist visitors have the greatest impact.

The issues arising out of the commercial activity related to caves in the COH WHS include the following: the two major tourist caves are the Wonder and Sterkfontein Caves and these and the remaining archaeological and palaeontological caves are considered to be generally well protected against casual access and the implications of commercial activity. The same cannot be said of other caves where little security other than landowner vigilance is in place to prevent unauthorised access.

The existing cave legislation is contained in Section 99 of the Gauteng Nature Conservation Ordinance and contains no reference to permits being required for the construction of barriers to prevent access to caves.

With respect to caves, activity can be divided into archaeological or palaeontological significant caves, show caves and wild caves. Wild caves are further divided into those being utilised by caving clubs and commercial operators. It is reported that there has been an increase in numbers of persons visiting such caves in the last 4 years and that the increase in numbers is largely attributed to the commercial ventures. Further details pertaining to cave utilisation (including financial aspects and numbers of visitors, etc.) are presented in the paper. Of significance is that the authors consider that commercial adventure caving, taking all considerations into account, is not felt to be further sustainable and is already showing an impact on the caves being utilised.

1. The paper, as indicated above, considers further proposed actions or topics regarding the sustainability of the karst and caves of the COH WHS. These are divided into Surface and Subsurface Activities and not considered in detail here (the reader should refer to the relevant sections in the said paper). It is however deemed appropriate that the following be briefly mentioned:

    - Cattle Farming – the impact of such operations is seen as requiring investigation and documentation. Specialist agricultural knowledge would be required to confirm the actuality of over-use and the implications of its continuation.

    - Removal of Rock Formations and Flora in General – the removal of "Pelindaba" rock for various purposes as well as the removal of sensitive rock structure (speleothems) needs to be assessed and monitored and preventative measures explored and enforced.

    - The Coordination of I&APs (Interested and Affected Parties) – it is considered that the sustainability of the COH WHS will revolve around all I&APs working towards a common goal. There is a need to involve landowners and local parties in a coordinated manner which currently does not appear to be the case (there are numerous anecdotal comments by local residents being uncertain as to what is happening within the COH WHS and the issue has been raised in other papers of this publication and at the IUCN KWG workshop held at Sterkfontein in the latter part of January 2006). The authors propose the development of a Cave and Karst Management Authority comprising cavers, scientists, management experts, I&APs and landowners or where such an authority may currently exist, then better coordination is required. This authority should, apart from addressing degradation of the caves, also consider the sustainability of tourism ventures which is considered to be one of the major activities responsible for such degradation.

    - Legislation, Policing and Verification – a common problem related to illegal activities in karst areas is the inability to implement and enforce legislation. However, there would appear to be no single legislative format one can learn from by studying international comparisons. A review is required and a framework of cave and karst conservation legislation needs to be built. Proposals have been developed by such groups as CROSA and SASA and these need to be considered. The authors also propose the formation of a group that is prepared to take accountability and responsibility for the caves and karst including scientists, cavers, management experts as well as landowners and I&APs. - (NOTE: Aspects pertaining to legislative issues have been further considered in Papers 3 and 12).

- Tourist Guides - the importance of appropriately trained tourist guides is deemed an important aspect to ensure sustainability of karst and caves. There is therefore a need to create and maintain standards and train such tourist guides.
- Archaeological Diggings – An aspect which has not been investigated previously is the impact of the excavation of what is often the entrance to caves for archaeological and scientific research. The effect of such activities on the cave atmosphere, the need for extensive excavation, the disposal of the diggings and the associated impacts of frequent occupation of the vicinity, are all areas that require investigation.
- Casual Use of Caves by Visitors – many landowners allow visitors to access caves on their properties without any supervision. Such activities are known to result in various impacts including littering, disposal of old batteries, etc. Education and vigilance by landowners could assist in mitigation of the negative impacts associated with this activity.
- Radon Gas – This gas arises following the radioactive decay of uranium and thorium found naturally in rocks. Such radiation can be detrimental to health leading to lung cancer and work done by Dr F. Gamble indicated a low but variable level of exposure risk in caves of Gauteng and Mpumalanga of between 0.003 and 0.6 WL (typical acceptable working levels in the United Kingdom are 0.05 WL). This was a baseline study and more extensive research in this regard is suggested.
- Histoplasmosis capsulatum – this is the condition known as “Cave Disease” which is caused by inhaled fungal spores germinating in the lung tissue. The fungi commonly grow on bat guano and there are a number of caves in the COH WHS which are notorious for its presence. If an individual’s immune system is weakened they are at an increased risk of serious side effects to Histoplasmosis. It is now a generally accepted philosophy to approach all caves within the region as potentially having “histo”. It is recommended that persons who have never caved before and are visiting a known “histo” cave for the

first time, limit the duration of their stay underground, as the length of the stay is proportional to the severity of the dose. It is also recommended that children under 12 years of age do not enter such caves.

- Lighting and Lampenflora – Lampenflora are biological growths which occur in caves as a result of a permanent lighting system. Its development is proportional to the level of heat, wavelength of light radiation and proximity to rock surface. The effects of such lighting can be reduced by the use of low energy and narrow wavelength lights. Surface lighting has been discussed in brief previously in the context of the effects of encroachment of urbanisation on the COH WHS, such as on bat populations. This issue however requires further investigation.
- Use of sinkholes and Caves as Waste Disposal Sites – in certain areas it has been and still is common practice to utilise caves and sinkholes as waste disposal sites. The potential negative impacts of such activities are enormous. Improved education on the implications of such dumping as well as improved access to waste disposal sites could go a long way in reducing the incidence of such practices.
- Environmental Impact Studies of Caves and the Low Energy Description of Caves – the equilibrium of any ecosystem such as a cave is driven by the exchange of energy within the system. In the cave situation this energy can be a pyramid driven by bats and their guano, an inflow and outflow of water and air and even thermal pulse through rock as seasons change. The majority of caves in the COH WHS are what are referred to as “sack caves”, virtually closed with a single or limited access to surface with little flow of air and water and declining bat populations. Any variable or variation in the energy balance can be significant in proportion to the absolute value of the initial effect. For this reason it is inevitable that the flow of visitors within a cave will impact the cave and the return to equilibrium can be lengthy. The smaller the cave, the lower the energy balance and the greater the impact. Stemming from the above the following suggestions are made: - a) To establish key indicators of the “health” of caves which can be structured into an impact study and recommendations made on the basis of the results. Such a study could then be used to indicate the much abused term of “carrying capacity” of a cave or perhaps more appropriately termed “the limit of acceptable change”. b) It is suggested that caving organisations such as CROSA and SASA and local interest groups in agreement with the management authority and specialists, discuss with specific landowners a

checklist of regularly monitored and appropriate parameters (such as temperature, carbon dioxide, humidity, water table levels, droplet counts, lampenflora where applicable, water quality, visitor numbers, dust levels on speleothems and others). Once such a system is established it should be applied to selected caves (see list in the said paper) and monitored on a quarterly basis. The data obtained from such an ongoing exercise should lead to establishing the degradation proportional to the numbers of visitors.

It is further recommended that the following be considered as sustainable ways of protecting caves: a) Reduce the awareness and demand for cave adventures and rather replace it with an emphasis on cave ecology and respect. b) Harden the environment in commercial caves by utilising tracks and routes (only applicable to regular tourist caves). c) Provide alternative activities such as other tourist facilities and d) Restrict access to caves by gating, using the appropriate conservation standards and raise public and landowner awareness and education.

- Commercial Adventure Caving – This activity is limited to a few operators who use it as a marketing tool advertising caving as part of a package of activities ranging from team building, abseiling and adventure caving. The authors of this paper (as previously indicated) consider commercial adventure caving not to be sustainable. The impacts of such activities can be seen in the permanent fixtures left behind to aid the climbing of muddy walls, the compaction of cave floors and other physically visible impacts. The effects of increased temperature, altered humidity, as well as the impacts of such activity on the bat population, have not been quantified but are none the less present. With the above in mind it is necessary to determine the impacts of such operations and, if necessary, limit them to specific venues.

Some of the recommendations on cave and karst management emanating from this paper are briefly discussed below. These include Proposed Actions and Specific Recommendations:

The sustainability of karst and caves is dependent on the interaction of abiotic and biotic factors including the interaction of water, soil vegetation and animal activity and the impact on these, mainly from human-related activities. The removal of surface vegetation, for instance, by harvesting or fire may not have an obvious effect on caves, however significant levels of carbon dioxide respiration takes place through vegetation roots. Seepage of carbon dioxide into a cave system can have a major effect on the atmosphere within a cave environment and changes in the mineral solution rates. The following proposals are aimed at long-term studies and achieving a short-term or immediate impact:

Proposed Actions:

1. The charting of the karst catchment area in a holistic

manner, taking into consideration the potential impact that any proposed activity may have on the area. It should be recognised that, second only to human entrance, any activity which may significantly impact on the flow or content of the surface water, will have the quickest impact on the caves.

2. Focus on specific immediate activities which may be of concern such as excessive mining of clay, high visitation levels in caves, unregulated building, etc.
3. As human visitation to caves have a high impact, certain caves should be immediately identified as being limited to only scientific or speleological interest and not for general access. Efforts need to be made to prevent unauthorised access to caves and the involvement of the landowner in this is deemed important.
4. It is proposed that caves which can withstand a greater degree of human traffic be identified (including those outside the COH WHS) and used for more frequent caving trips. The management objective should not be to prohibit caving activity but rather subject it to more control both by authorities and I&APs and that commercial caves outside the COH WHS should be promoted (subject to study) as opposed to more sensitive cave development within the COH WHS.
5. *(Note - Points 3 and 4 above equate to the classification of caves as previously discussed.)*
6. Available technical expertise should focus on determining the karst boundaries, in developing a plan of the water cycle, development of management plans for the area and key cave sites, coordinate I&APs, train educators and interact with the landowners.

Specific Recommendations:

1. Legislation – according to the authors legislation will address the protection of karst and caves but that this will be difficult to enforce and should be the last option when such areas are threatened.
2. Education – a formalised education programme designed to assist landowners in preventing abuse of the caves and karst, should be distributed. The distribution of the IUCN Guidelines for Cave and Karst Protection (J. Watson et al., 1997) and the Caving Code of Conduct of SASA will assist in this regard. Informed and educated landowners are considered as the primary method of protecting and sustainably managing karst and caves in the COH WHS. For this reason there is a need to develop a strong interest and awareness amongst landowners - such awareness would be underscored by the legislative requirements.
3. The establishment of an overseeing group for the implementation of "Best practices" as occurs overseas. Such a group would need to be supported by the Management Authority (GDACE) and the caving groups (CROSA and SASA) and others, and would implement the best operating

practices as researched amongst the various karst and cave bodies.

4. The following activities should also be undertaken: a) Removal of general waste from caves and sinkholes. b) A study of the effects of cattle farming and the subsequent runoff effluent. c) A study on the radon levels of caves. d) The impact on the bat populations by urbanisation and cave visitations. In further communication with the authors it was also indicated that further studies on the prevalence of *Histoplasmosis* are required.

5. Limitation on the expansion of Speleological Interest Groups and Commercial Caving: Such a limitation should be a voluntary code of conduct regarding access to caves based on "Limits of acceptable change", - these limits are as yet still to be determined. It is considered necessary to establish a list of caves which are under immediate threat and to reduce activity limits in such caves, pending the conducting of a cave impact assessment. The authors consider that an outright ban or rigorous permit system may simply perpetuate a lack of cooperation which has been historically seen to occur.

In conclusion the authors have made the following remarks:

1. The threat to caves is driven by the level of human interference.

2. The human impact on caves can be measured by the use of various criteria (i.e. floor compaction, damage to speleothems, changes in humidity and temperature, etc.), but few of these are currently being monitored and a coordinated assessment of the caves and karst of the COH WHS is still lacking.

3. There appears to be no systematic structure to get the many I&APs to adopt a unified approach and instead, many individual groups exist with little interaction or cooperation which is paralysing effective action.

4. There is a need for Cave Management Plans which should be compiled with the input of all I&APs and the Management Authority.

5. The caves and karst of the COH WHS are at a critical point in their continued existence. It is essential that a coordinated approach to measure the impact and supporting the rehabilitation and conservation of what remains, be implemented as soon as possible.

Issue Paper 8: Perceptions, Behavioural Change and Education around Karst

J.F. Durand

STRUCTURE AND CONTENTS OF PAPER

This paper includes the following sections: Abstract; Introduction; Problem Statement; Discussion (covering the following: The impact on the karst system and karst ecology inside the COH WHS that can be addressed by education, household impacts, farming activities within and adjacent to the COH WHS); The impact on the karst system and karst ecology from the larger geographical areas outside the COH WHS that can be addressed through education; Response and Actions Required; Regulatory Response Required; Research Required and Monitoring Required and References.

FINDING(S) OF THE PAPER AND RECOMMENDED RESPONSE(S)

This paper provides a good perspective on the threats and impacts on the karst of the COH WHS and categorises those which can be addressed by education – namely those within the boundary of the COH WHS and those peripheral to it. Responses to these are presented as well as required monitoring recommendations.

PRECEDING THE ABOVE IS A PROBLEM STATEMENT WHICH HIGHLIGHTS THE FOLLOWING

Misconceptions related to the water resources of the karst system and faecal pollution:

There appears to be a misconception that the dolomite-rich area of the COH WHS has an unlimited supply of water and that faeces will be broken down by bacteria and have little impact on the ground and surface water reserves. This has relevance in that there are estimated to be in the order of 700 farms or small holdings comprising the COH WHS, the majority of which rely on groundwater and dispose of human waste by way of septic tanks, French drains and pit latrines. In spite of the fact that there are municipal regulations for the distance between boreholes and septic tanks, French drains and pit latrines, these may often not be adhered to and the author is of the opinion that the groundwater will inevitably be contaminated with faecal coliforms. In support of this, the reported existence of these in the Sterkfontein and Koelenhof caves has been recorded.

The use of caves and sinkholes as waste disposal sites:

A relatively high incidence of this practice is reported from the COH WHS and the potential impacts associated with this in respect of the water reserves and other require little explanation.

Alien vegetation:

As previously mentioned, the high levels of alien vegetation in parts of the COH WHS have a potential impact on the biodiversity of the region in an addition to ground and surface water reserves as well as disruption of drainage patterns and habitat loss.

Removal of indigenous flora and the use of insecticides:

These practices have an impact on the cave-dwelling bats for instance and many landowners are ignorant of this fact.

In respect of the impacts inside the COH WHS that can be addressed by education, the author considers the most important to be those related to “Household” impacts and those associated with farming practices. The main household impacts include those above and are not discussed in any further detail here.

The impacts pertaining to farming practices include the following:

Types of Farming Practices:

Farming practices within and adjacent to the COH WHS include agriculture (including grains and vegetables) horticulture and animal husbandry. The accumulation of agrochemicals (fertilisers and insecticides) has a major or potentially major impact on the surface and groundwater and soil which inevitably leads to habitat loss and the extinction of organisms. Furthermore, the effluent from piggeries, dairy farms, chicken batteries and feedlots (all of which occur within the COH WHS) is flushed directly into rivers in the area. The author states that if the subdivision under 2 hectares is not permissible because of the impact of sewage, then neither should the practice of animal husbandry be allowed in the area.

Use of Insecticides:

The use of insecticides and the impact on cave-dwelling bats has been previously mentioned and will not be further discussed in detail here. It is however, relevant to mention that alternatives to these should be investigated and compost should replace fertilisers and biological control should phase out insecticides.

Over-Abstraction of Water:

Often large quantities of water are abstracted for agricultural purposes and these have an effect on two habitats namely the groundwater and the surface area and have negative impacts on karst systems and karst ecology. Dolines and sinkholes can develop and the mobilisation and subsequent deposition of salts in the soil leads to salinisation of the soil. Furthermore, a drop in the water table may result in a cave drying out which will be detrimental to humidity-dependent bats and other cave fauna and flora.

Clearance of Indigenous Vegetation and Alien Species:

Many farming practices inevitably involve land clearing and the destruction of natural ecosystems and is often accompanied by the introduction of alien species. These have various impacts on the environment, including changes in runoff patterns and surface permeability which can negatively impact on recharge of aquifers. Other aspects concerning this matter have been mentioned previously and not discussed further here.

The author of the paper considers the following to have relevance in respect of impacts on the karst system and ecology from the areas peripheral to the COH WHS that can be addressed through education:

1. The main threats to the karst system are pollution, habitat loss and the mismanagement of the catchment area on which the karst system of the COH WHS is dependent, including those associated with mining operations (Gauteng and North West Provinces), effluent from industries, agriculture practices and chemicals, landfills and loss of habitat due to urbanisation (these issues are discussed elsewhere in this publication and not dealt with in further detail here).

2. The author considers the most practical approach to affect the minimising or halting of negative impacts on the catchment area to be through constant and consistent application of legislation. High-level interaction between environmental officers of government departments and managers and environmental personnel from industries and mines may convince these businesses of the benefits of environmental economics. Applying this approach as an alternative would be more in line with the ideals of sustainable development and would therefore be a good option. Industry and mining may make ideal business partners for sponsoring environmental education programmes, clean-ups and conservation, if approached correctly.
3. Even though the national acts and municipal regulations conform to international best practice, and whereas there is not one conflicting regulation amongst the acts and by-laws regulating conservation, there are many practices in and around the COH WHS that are in conflict with the aims of these acts. Examples cited here include the Percy Stewart Water Care Works (PSWCW) which discharges into the tributary of the Bloubankspruit that runs into the dolomitic areas of the COH WHS and sludge from the Flip Human and PSWCW is disposed of by irrigating lawn farms which impact negatively on surface and groundwater in the karst system (according to the Mogale City Local Municipality State of Environment Report of 2003). The author also states that not only is the fact that orthodox farming practices are allowed in the ecologically sensitive karst region of the COH WHS in direct conflict with conservation principles, but that the presence of animal husbandry, French drains and pit latrines contradicts the municipal by-laws prohibiting the building of French drains and pit latrines.
4. An alternative indirect approach by means of which environmental education may play a positive role on the curtailment of negative mining, industrial and farming practices is to raise the environmental awareness of the general public. Workshops to explain the public’s environmental rights and to provide an introduction to the different governmental and municipal departments’ functions would benefit the community and ultimately contribute to the conservation of the karst environment and ecology in the COH WHS.

In the latter part of the paper, the author addresses the following: Actions (Response) Required; Regulatory Response Required; Research Required and Monitoring Required - a synopsis of which is presented as follows:

ACTIONS REQUIRED

1. Sanitation Awareness of Inhabitants of the COH WHS: It is important that the awareness of the inhabitants of the COH WHS in respect of sanitation issues be increased. There are furthermore certain mitigation factors which can be

implemented in respect of septic tanks, French drains and pit latrines.

2. Communication between the Management Authority and Landowners: The issue of a lack of or poor communication between the Management Authority and landowners has come to the fore both elsewhere in this publication, at the KWG Workshop in the latter part of January 2006 and from other sources. From interviews with landowners and tenants in the area, it seems as if there is a feeling that they are not been informed on issues within the COH WHS by GDACE and are not been included in decision-making processes. The majority of those approached were even unaware of which government department is responsible for developments within the COH WHS although GDACE has held several public meetings in the area.

3. Legislative Issues: Although adequate and laudable legislation exists to regulate activities that may impact on the COH WHS, the majority of respondents and landowners are unaware of the municipal regulations in respect of subdivision, sanitation and water quality, tourism development and other. An education programme in this regard is indicated.
Some legislation contains clauses that state that the public should be educated, or that public awareness should be promoted. The World Heritage Act (Act 49 of 1999), for instance, states ".. that community well–being and empowerment must be promoted through cultural and heritage education, the raising of cultural and natural heritage awareness, the sharing of knowledge and experience and other appropriate means". Similarly the Mogale City Local Municipality aims to disseminate information about sanitation and wastewater management.

4. Mogale City State of the Environment Report 2003: This report includes a section entitled "What can you do?" in each chapter. Some of the items are important to the COH WHS and specifically to karst systems, groundwater and karst ecology. These are not discussed in detail here (the reader is referred to the relevant section of this paper) but it is appropriate to mention the broad categories of relevance in this regard which are as follows: a) Conservation of Water b) Conservation of Rivers and Wetland c) Conservation in General d) Environmental Education and e) Nature Conservation Legislation and Public Participation.

5. The Department of Public Works Guidelines (2003): This department has published extensive guidelines for development on dolomites which include a list of practices that should be avoided when designing infrastructure on dolomitic land as well as stipulations on designs and materials used for construction.
Dissemination of Information: It is clear that the regulatory authorities that govern the karst, surface and groundwater, karst ecology and biodiversity within the COH WHS

unanimously agree on the importance of public education and participation in the conservation of the area. The challenge is how to achieve this. Various proposals and options are discussed by the author and include: a) The majority of respondents were in favour of a web site and flyers or a booklet informing them of the karst and karst ecology rather than workshops or government directives. It is therefore proposed that a website be established which should contain information on the conservation of karst and karst ecology, relevant applicable legislation, guidelines on rehabilitation of ecology within the COH WHS, guidelines on sanitation, health, construction on dolomite and farming on dolomite. b) For those not having access to the internet, flyers and workshops are recommended. c) Schools in the region should also assist in the education programme.

6. Establishment of a Community Forum: The author of this paper also proposes the establishment of a Community Forum where residents and workers within the area can communicate with each other and the decision makers and hence participate in the conservation of the karst environment. This body is considered an ideal mechanism to disseminate information and to allay and address fears and apprehension about conservation and development. This forum could raise funds and undertake educational programmes and clean-up's, etc. and could also benefit by working in close relationship with I&APs of the COH WHS but who are not necessarily resident in the area (i.e. Caving Clubs, Bat Interest Groups, etc.).

Further detailed aspects pertaining to this Community Forum are discussed in the body of the paper which is not considered here and to which the reader is referred.

REGULATORY RESPONSES REQUIRED

Legislation:

It is clear that there is adequate legislation to protect the various elements of the COH WHS (soil, water, biodiversity) and to control farming, mining and industrial activities within and peripheral to the site. Areas that could be added to, or referred specifically in future augmentations or addition of legislature include the classification and use of caves and the protection of karst ecology. The IDP (Integrated Development Plan) for Mogale City of 2002 (Environmental Stability) lists resource and pollution protection and ecological conservation as some of its key priorities. Provisions are therefore in place for the municipality to protect the natural resources such as the fauna and flora of the region as well as land and water by promoting and upholding sustainable development principles.

A problem however arises in respect of the prioritisation of legislation. Issues such as the following need to be prioritised: do property rights have precedence over biodiversity, should the use of insecticides be allowed in an area occupied by insectivorous Red Data species, should animal husbandry be allowed on karst areas where the majority of occupants rely on groundwater for

domestic purposes, do the rights of mining companies responsible for toxic effluents entering the COH WHS outweigh the rights of inhabitants to clean water, etc. There also appears to be dual standards applied in that just about every abode within the COH WHS dolomitic area has French drains and pit latrines and depends on groundwater although this is against the Department of Public Works and the Mogale City regulations. On the other hand, the same municipality releases waste water from the Percy Stewart Water Care Works into the catchment of the COH WHS.
A further problem arises in that the enforcement of the legislation is difficult if not impossible, and this with the conflict of interests requires URGENT resolution so as not to undermine the World Heritage Status of the Cradle of Humankind.

RESEARCH REQUIRED

The author lists the following under research requirements: a) The compilation of an inventory of waterborne diseases (human and animal) in the COH WHS. b) Continuous monitoring and research on water quality and pollution in the area. c) Alternative eco-friendly farming practices and methods in the COH WHS.

MONITORING REQUIRED

The following are presented as issues requiring monitoring: a) Pit latrines, septic tanks and French drains require monitoring and a census on these is required to this end. b) Microbial analyses of borehole water used for human consumption must be done on a regular basis. c) Water from the DWAF boreholes should be constantly tested for mine and industrial effluent and agrochemicals. d) Waste disposal in caves and sinkholes must be regularly monitored. e) Water quality must be measured downstream from piggeries, chicken batteries, feedlots and the trout farm. f) Monitoring and removal of exotic plants and animals from the COH WHS.

Issue Paper 9: The Impacts of Mining on the Water Resources and Water-based Ecosystems of the Cradle of Humankind World Heritage Site

W.G. Krige and M. Van Biljon

STRUCTURE AND CONTENTS OF PAPER

The contents of this paper include the following: Abstract; Introduction; The Surface Water Catchment of the COH; Urbanisation as a Direct Result of Gold Mining; Regional Geological Setting; Mineral Deposits and Mineral Geology; Some of the Minerals Mined within the COH or its Surface Water Catchment (gold mining and associated impacts); Lime and Metal Mining, Stone Aggregate, Shale, Slate, Building Brick, Clay and Asbestos operations; Conclusions and Responses and References.

FINDING(S) OF THE PAPER AND RECOMMENDED RESPONSE(S)

It is now commonly accepted that mining operations (and in particular past gold mining enterprises) constitute a major impact on the COH WHS. This paper (the full contents will not be discussed in detail here) presents a well-documented background to the impact of mining in the region. A brief background of this is presented to facilitate an understanding of the recommendations that follow.

Impacts Associated with Gold Mining Operations

Gold was discovered in the West Rand in 1887 and mining operations which continued for over 100 years reached their peak during World War 2. Currently all the mines have closed and only selected reworking of sand and tailings dams is taking place. The main mines concerned include Randfontein Estates Ltd (now owned by Harmony Gold Mining Ltd), West Rand Consolidated Mines Ltd (now owned by Durban Roodepoort Deep), Luipaards Vlei Estates Ltd (now owned by Mogale Gold) and East Champ D'Or GM Co Ltd (now owned by First Westgold). Although these mines occur outside the COH WHS, they are still very much in the zone of influence of the site.

The mining operations created a combined mined out interlinking void of 44 926 778 cubic metres which is now referred to as the Western Basin Mine Void. As gold reserves became depleted, the underground mines started closing down and the focus shifted to opencast mining which resulted in the creation of the West Wits pit now owned by DRD. As the mines became deeper, increased problems were experienced with water ingress and at the peak of mining operations, an average of 32 thousand cubic meters was pumped daily into both the Wonderfonteinspruit and the Tweelopiespruit. On cessation of mining operations the mine void began to flood and in 1998 a decision was made to cease pumping operations altogether. Finally in September 2002 poor quality water due to AMD (acid mine drainage) resulting from oxidation from sulphide minerals in the strata and aided by SOB (sulphur oxidising bacteria) from the mining operations, started decanting from a number of boreholes and an old shaft into the headwaters of the Tweelopiespruit East within the zone of influence of the COH WHS. In the order of 15.5 Mℓ/day is currently decanting and the water is of an extremely poor quality with high sulphate concentrations reaching levels of 4500 mg/ℓ.

A directive was issued by the DWAF to all mines responsible for creating the Western Basin Mine Void to come to an agreement as to a cost of apportionment for the treatment of the water to acceptable limits for subsequent discharge into the watershed. It is reported that to date only Harmony Gold Mining Ltd has complied with the DWAF directive.

For about two and a half years untreated and partially treated water flowed through the Krugersdorp Game Reserve and into the Zwartkrans dolomitic compartment. The low pH and high dissolved solids and oxygen-consuming chemical reactions taking place in the water resulted in the destruction of the entire faunal population of the Tweelopiespruit. Since the beginning of 2005, Harmony has been pumping most of the water via their treatment plant to the Wonderfonteinspruit but they are unable to contain the flow from the mine void at certain periods, such as during heavy storms.

With the above background in mind, the impact of the AMD requires some discussion. The most important effect that the mine water could have on the dolomitic aquifers of the COH WHS is to "poison" the groundwater of the region. As was previously indicated, the majority of the inhabitants of the COH WHS rely on borehole water for domestic purposes. The low pH also means that, under such acidic conditions, certain harmful metals are soluble and may be transported into the area with the mine water. In addition to this, the high acidity of the water has the potential of artificially enhancing the dissolution of the dolomite, leading to stability problems apart from others. It also has the potential to impact negatively on the karst and cave ecology.

With reference to the above, questions arise as to what the impact(s) on the Sterkfontein Caves will be, what is the future of the contaminated mine water and what monitoring and mitigation measures can be implemented? These are discussed in detail in the said paper and are only briefly discussed here.

As the water level in the Sterkfontein Caves is higher than that of the nearby Bloubankspruit as well as the groundwater table, the authors of this paper consider that the chances that the water from the stream or the regional groundwater would impact on the water in the caves are low. As far as the expected longevity of polluted water emanating from the mines is concerned, it can be said that this problem will remain for some time although short-term solutions are being implemented and medium and long-term solutions are under investigation. In actual time scales there is some speculation that this period of recovery could range from several decades to more than 100 years.

Further negative impacts associated with gold mining are the waste deposits (tailings dams, sand dumps and waste-rock dumps). Of these, tailings dams have the main potential impact. Tailings dams contain constituents of the host rock (including sulphide minerals) and residues of chemicals used in the gold extraction and processing procedures. For this reason they have the potential of AMD by way of seepage of leachates into the hydrological system. The fine particle size of this material poses a dust problem in which such material can be brought into the COH WHS with the resultant associated impacts. As it stands there is still no long-term solution to the tailings dams other than to mix it with cement and pump it back into the mine void.

Other Mining Operations

Economically exploitable minerals recorded within the COH WHS and in close proximity to it include the following: lime, manganese, lead, copper, gold, silver, shale, slate, banded ironstone, stone aggregate, chrysotile asbestos and clay. The majority of the mines concerned are no longer in operation. These are briefly discussed (the reader is referred to the said paper for further detail) as follows:

- Although overshadowed by the impact of gold mining, lime mining operations have probably had the second greatest impact on the COH WHS. These activities destroyed caves, flow stones and speleothems but also led to the discovery of the famous homonid and other fossiliferous remains of the COH WHS.

- One of the largest and most prominent mines within the COH WHS is the Sterkfontein Quarry which for years produced stone aggregate. During its lifespan many caves were destroyed or severely damaged. On a positive side, this quarry exposed some interesting geological features which can be used as a ***geological and palaeontological education centre where students could experience the geology and fossil sites at first hand.***

The impacts associated with the mining of above-mentioned minerals within the COH WHS are historical and localised. The most prominent of them all is the visual impact that these ceased operations have left on the landscape.

RECOMMENDATIONS AND RESPONSES

Until a final solution to the decanting of mine water has been implemented, the following responses are recommended to minimise future impacts:

1. A comprehensive monitoring system is recommended to detect changes in groundwater chemistry before any major damage can be incurred. Studies are currently underway to better understand the flow patterns within the dolomitic aquifers and these are necessary before qualitative statements can be made regarding the impact of the decant water (treated or untreated) on the COH WHS.
2. The authors mention the establishment of a Water Utility Company to treat and sell the mine water and this is apparently under review. This option is regarded as the only sustainable solution to the problem and should be viewed as such by the regulatory authorities. Only if this liability can be turned into a viable economic entity will it succeed.
3. There is also the matter of the minerals dissolved in the water currently regarded as pollutants. It is suggested that research be conducted to facilitate extraction of these minerals in a cost-effective manner and turn a problem into a resource.
4. Historically some of the water that is now decanting from the mine void flowed down the Tweelopiespruit (pre-mining) and it is therefore appropriate that this scenario be restored. Obviously the water must be of an acceptable quality. It is recommended that a needs analysis be undertaken to determine the requirements of the downstream users, current water usage and available treated decant water. It is the authors' opinion that such a survey will indicate whether there is an ample supply of treated d***ecant water to satisfy the needs of the downstream users***
5. The DWAF undertake monitoring of the groundwater table

and water quality on a regular basis. This data should be made available to a central database and used as an early warning system for any contamination and groundwater level fluctuations.

6. The last and probably most-asked question related to the decanting of mine water is what the impact will be on the Sterkfontein Caves. The authors' preliminary research findings indicate that the water in the Sterkfontein Caves pool is at a higher ***elevation than the water level in the*** Bloubankspruit adjacent to the caves and even higher still than the regional groundwater level. The chances that the caves will be impacted directly by the water in the s***tream or in the groundwater aquifer are therefore considered to be remote.***

Note: Investigations subsequent to the writing of this paper have indicated that the level of the water in the Sterkfontein Caves is in fact lower than indicated in Point 6 above and this places in question the inferred associated "remote" impact of the stream and groundwater aquifer on the said caves – further information is awaited in this regard.

Issue Paper 10: The Impact of Urbanisation on the Water Resources and Water-based Ecosystems of the Cradle of Humankind World Heritage Site

W.G. Krige

STRUCTURE AND CONTENTS OF PAPER

This paper includes the following sections: Abstract; The Background to Humankind's History in the Cradle of Humankind; Determining the Boundaries for the Study; Human Activities that Impact on the Groundwater Resources in the Cradle (Mining, Large Scale Municipal Sewage Disposal Works, Rural Sewage and Solid Waste Disposal, Agriculture, Industries Other than Agriculture and Mining, Drilling of Boreholes and the Destruction of, or Damage to Unknown Caves; The Alteration of the Karst Botanical Ecology by Man's Activities and the Subsequent Alteration to the Recharge of Groundwater, Transportation of Hazardous Substances Across the COHWH, Subdivision of Land, Change of Land Use and Alteration of Surface Runoff Coefficients, Tourism); Conclusions and Recommendations (Regulatory, Education, Monitoring and Research) and a list of References.

FINDINGS OF THE PAPER AND RECOMMENDED RESPONSE(S)

As in the previous paper, the author has presented a well-documented perspective of the topic in question but it should be noted that only the impacts of "urbanisation' on the water resources of the COH WHS are considered while other peripheral and internal non-water related issues were not included.

The contents of the paper are presented in the previous section and it will be noted that several of these are discussed elsewhere in the publication. To avoid duplication, certain of these are not discussed in detail here but the reader is strongly advised to refer to these sections in the paper for further detail.

Of particular note in this and the previous paper are the sections on the catchment or zone of influence of the COH WHS. The COH WHS comprises an area of approximately 47 000 ha of which approximately 22 890 ha consists of dolomite and chert horizons of the Transvaal Supergroup (Chuniespoort Group). The catchment or zone of influence is however substantially larger than this and the southern and southwest catchment of the Zwartkrans compartment for instance increases the surface catchment by an additional 24 845 square kilometres (i.e. 52.9%).

The author refers to the historical presence of man in the COH WHS and his impact on the area but considers the most important event of far-reaching impact on the area to be the discovery of gold in 1886 on the nearby Witwatersrand. The impacts of mining activities have been discussed in the previous paper and are not considered in any further detail here. It must however, be noted that mining operations were accompanied by urbanisation resulting in a number of associated impacts. Water had to be supplied and this was brought in from the Vaal River. The issue of the discharge from the Percy Stewart Sewage Works (PSSW) and the Randfontein Sewage Works has also been mentioned previously but requires some further explanation. Sewage effluents with a volume of 19.3 and 8.16 Mℓ/day respectively are discharged into the hydrological system, potentially impacting on the COH WHS. As indicated, much of this water is derived from the Vaal River and has a totally different chemistry compared to the groundwater of the dolomitic areas. The mixing of these two waters over a long period may produce unknown results within the dolomitic aquifers. Apart from the difference in water chemistry, an increased volume of water is being discharged and a number of sinkholes have formed in the streambed of the Tweelopiespruit. It is furthermore reported that the situation of the PSSW on the Rietfontein Wrench Fault has resulted in unknown volumes of untreated water entering the groundwater due to leaks from cracks in the infrastructure.

The author also addresses aspects of rural sewage and solid waste disposal as well as agriculture which have also been documented elsewhere in the publication. Industries other than mining and agriculture as well as the drilling of boreholes and destruction or damage to unknown caves are also raised as issues by the author.

The alteration of the botanical ecology of the karst by man's activities and the subsequent alteration to the recharge of groundwater are also interesting perspectives raised. Reference is made to the uniqueness and ecological importance of the grasslands of the area of the COH WHS and the historical importance of fire in this ecosystem. Unfortunately, as a result of urbanisation and the subsequent subdivision of the Cradle into smaller farms and small holdings, many occupants have been following a policy of non-burning or burning at inappropriate times. This has the potential of severely impacting on the natural ecological processes resulting in changes in species composition and biomass and may lead to bush encroachment. The alteration of vegetation within the COH WHS will ultimately lead to a gradual alteration in the hydrology (recharge and runoff) which could have an effect on the quality and quantity of the groundwater environments of the area.

The author also raises the issue of transportation of hazardous substance across the COH WHS. In the event of an accident and a spillage, rapid infiltration into the dolomite and dolomitic soil could be expected with resultant contamination of both groundwater and soils. The author considers that the local and district municipalities are ill-equipped to deal with any such spillage. The recent upgrading and tarring of the road through the COH WHS will in all likelihood result in an increased traffic load and possibly raise the probability of the occurrence of such a spillage. Also of relevance here is the fact that Petronet has an underground petroleum pipeline crossing the catchment of the COH WHS from which a similar spillage may occur, especially in the light of the fact that all dolomitic areas are considered potentially unstable due to sinkhole development.

The issues of subdivision of land, change in land use and alteration of surface run-off coefficients are also raised as potentially impacting on the COH WHS. Typical examples include the destruction of habitat as well as the canalisation of drainage lines, small streams and wetlands to make more land available for development. These activities have a pronounced effect on downstream users and riparian properties and also impact on the recharge of groundwater aquifers. Examples of problems associated with these matters are cited in the paper and an assessment of the impacts of such matters and urban encroachment requires urgent attention.

Impacts associated with tourism are further discussed in this paper. In recent times and since the Cradle has been declared a World Heritage Site, many restaurants, wedding venues and conference centres, shops and tourism-related activities have sprung up. In addition to more visitors to the area, this has resulted in more pressure on the COH WHS including the generation of more litter, sewage and waste, more water being pumped from the groundwater resource and more feet trampling the rocks and vegetation in the area. The higher volumes of visitors to commercial caves are also taking their toll. Other impacts associated with tourism facilities include the building of additional roads, grasslands being replaced by landscaped lawns, introduction of exotic species, construction of dams and water features to mention but a few - all of which alter the natural environment.

RECOMMENDATIONS AND RESPONSES

The author considers that there are two methods of protecting the environment: by regulation and by education and that the one should go hand-in-hand with the other and be supported by research and monitoring to enable identification and quantification of the impacts. In the case of the COH WHS this protection should not only be focused on the site itself but must be extended to encompass the entire catchment of the COH WHS which extends beyond its boundaries. The following main recommendations are hence made:

1. Regulatory Recommendations:

1. There are a number of authorities that regulate activities within and concerning the COH WHS as well as on matters pertaining to the environment. These include the DWAF, Department of Agriculture, Department of Minerals and Energy, GDACE as the Management Authority as well as district and local authorities. The author maintains that there is not always sufficient communication between the different authorities.
2. It is furthermore indicated (as by other authors in this publication) that there is sufficient legislation in place to cover virtually all aspects requiring regulation in the COH WHS. The problem lies in the lack of enforcement of the law and poor communications between the authorities having jurisdiction as indicated previously. The lack of enforcement is likened to lack of capacity.

Response:

1. A single regulatory authority needs to be established: It is recommended that there should be some sort of overall regulatory authority to coordinate all activities within the COH WHS. This body should have a coordinating function, not to create new regulations but rather to enforce the existing. This would facilitate a holistic approach as required as opposed to the existing situation where every authority operates in isolation.
2. A new set of effluent standards and/or guidelines needs to be implemented: It is further recommended that consideration be given to the rezoning of the catchment of the COH WHS to a Special Standard area as far as the requirements for purification of waste water or effluent are concerned (see Government Notice No. 991 of 18 May 1984 as amended by G.N.R.1930 of 31 Aug 1984, G.N.R. 1864 of 15 November 1996). Currently the COH WHS and its catchment fall within the General Effluent Standards zone. Almost all the sewage effluent produced by the two sewage plants discharging water into the COH WHS recharges via streambed loss into the Zwartkrans Compartment of the Cradle while, originally all, and now part of water decanting from the defunct mines enters the groundwater of the COH WHS. This is unsatisfactory and a new set of standards needs to be implemented.

2. Education:

Although a great deal is being done in respect of education in the COH WHS it is considered to be projected to the wrong audiences (mainly tourists and visitors), concentrating mainly on the anthropological history of the COH WHS. Not enough attention is devoted to other aspects of the COH WHS such as geological, botanical and zoological perspectives.

A broader education base is proposed, focusing on the local residents who are operating in, and impacting on the area on a day-to-day basis. Currently many of the residents are uninformed and do not know what the COH WHS stands for. An educated resident population would create a sense of ownership of the area. It is deemed a responsibility of the authorities to inform the residents about the uniqueness of the area and how each and everyone can play a role in protecting the heritage site.

Response:

1. The Sterkfontein Caves and Maropeng are good foci for education but should not only concentrate on the anthropological aspects of the COH WHS. The education programme should be extended to include other aspect of the area as well.
2. A concerted effort must be made on behalf of the authorities to target residents and landowners, and more importantly residents and businesses outside the Cradle but within the catchment, on matters pertaining to the COH WHS and inform them of the threats to its sustainability and integrity. Such an education programme should be ongoing.
3. Education can be undertaken in a number of ways including: a) Pamphlets b) Distribution of information with rates and taxes documentation c) Via security companies operating in the region.
4. A further form of education could be by way of information dissemination at meetings of Residents Associations and Policing Forums. These organisations meet on a regular basis and guest speakers could assist in this regard.
5. The above methods would facilitate dissemination of information to landowners and some residents. Residents and farm workers not owning land can be reached through public meetings and, as indicated in a previous paper, possibly through schools in the area.
6. The issue of lack of roadside information is also raised which requires attention. It is also suggested that the entrances to the COH WHS be demarcated and that traffic be brought to a standstill when entering. It is further recommended that speed control devices be installed within the area.

Once locals become informed and kept up-to-date with current and new matters and legislation, while travellers through the COH WHS are made aware of the existence thereof, prosecution and conviction of transgressors, where these persist, will become easier and most residents would cooperate with the authorities.

3. Monitoring and Research:

As a result of the decanting of mine water of poor quality from the defunct mines, monitoring programmes have been implemented. Unfortunately, much of the work in this connection is being done by different disciplines and in isolation with the resultant duplication of effort. A committee, the “Western Basin Void Technical Group” has been established by DWAF, the aim of which is to coordinate monitoring and to ensure that remedial measures in mitigation of the decanting mine water are implemented. This group is however, only concerned with mine water.

It is considered that there are insufficient monitoring points in the COH WHS for the monitoring of groundwater. The DWAF had some monitoring points drilled in 1986 but these only cover the Tarlton area.

Research is required on a range of subjects to determine how much pressure the COH WHS can withstand before losing its appeal and natural heritage. The general karst environment, the caves and the groundwater are under threat and the problem is exacerbated by the fact that the source of most of the significant impacts is located outside the boundary of the COH WHS, but within its catchment.

Response:

A single body or task team should be established to identify the need for, and to coordinate the water research and water monitoring performed within the COH WHS. The Western Basin Void Technical Group could be expanded to encompass this role or a separate body could be established. One of their functions must be to establish an in-stream water quality objective for streams entering the COH WHS. This would involve establishing monitoring points within the surface streams where chemical and bacteriological quality as well as flow rates of streams are monitored. This would identify polluters and ingress points into the groundwater. A further function of this task team would be to establish a groundwater monitoring programme within the COH WHS. This should include the monitoring of two sets of boreholes for the following purposes: the monitoring of groundwater quality (including regularly pumped holes) and to monitor groundwater levels (which should include holes that are not pumped). Attention will also need to be given to perched water tables where they are encountered.

The database compiled from this monitoring data should be made available to all concerned parties.

Issue Paper 11: The Impacts of Agriculture on the Water Resources and Water-based Ecosystems of the Cradle of Humankind World Heritage Site

J. Groenewald

STRUCTURE AND CONTENTS OF PAPER

The contents of this paper include: Abstract; Introduction; Objective and Scope; Literature Review; Approach; The Soil Environment; Pollutants from Agriculture (Soil and Groundwater Quality - Nitrogen, Phosphorus, Salts, Trace Elements, Organic Chemical (Pesticides), Microbial Contaminants); Groundwater Quantity Problems; Quality Problems due to Agriculture (Animal Husbandry, Application of Fertilisers, Sludge Application on Agricultural Land, Irrigation Practices, Agricultural Use of Pesticides, Conclusions from Case Studies); Agriculture in the COH WHS; Good Farming Practices; Response Required for Sustainability of the Environment (Regulatory, Management, Research Required, Monitoring and Other); References.

FINDINGS OF THE PAPER & RECOMMENDED RESPONSE(S)

The stated purpose of this paper is to broadly explain the technical issues of pollution associated with agricultural activities and the resultant impacts on the immediate and surrounding environment. In this context the environment includes the air, soil, rock surface and groundwater, although emphasis is mainly on the impact on the aqueous environment (hydrology), what steps may be taken to minimise the pollution and what steps and research could be undertaken to better manage the resources in a sustainable manner. The impacts vary from over-saturation of toxic elements in soil, sand and water, salinisation to enteric diseases due to viruses and bacteria.

The paper refers to the following agricultural practices within the COH WHS: dairies, piggeries, feedlots, poultry, game farming, crop farming, horticulture and aquaculture. The contents of the paper are presented in the previous section but within this scope the following are of special relevance to the hydrology: a) The influence of agricultural practices on surface and groundwater (quality and quantity) if overexploited. b) The mechanics and interaction between surface and groundwater, specifically in South Africa and the COH WHS. c) Over-extraction of water for irrigation and the effect of this on fracture systems. d) Application of fertilisers (the excessive use thereof and the accumulation through time) as well as pathogenic influences from livestock, the effect of this on the system and how this is best managed. e) The effects of pesticides together with fertilisers as well as the effect that alteration of the surface area and the banks of streams may have on the underlying dolomitic groundwater aquifers. f) The negative effects of salinisation of soils when water with a high TDS (Total Dissolved Solids) is used for irrigation.

Water science (as other sciences such as geology) can be very technical and appear intimidating to the lay reader. This paper which is one of the longest in this publication is no different and presents in some detail the issues pertaining to the subject. As in the other papers, there is some overlap of content and further details contained in the paper are not discussed in any detail here. Emphasis is placed on the conclusions, responses, monitoring and research required (the reader is referred to the contents of the paper where more detail is required).

CONCLUSIONS

The author presents the following in the main conclusion:

1. It is clear from available data that agricultural activities have contributed substantially to the contamination of surface and groundwater and possibly also of soils in the COH WHS catchment.
2. Proper management to limit agricultural contamination is lacking throughout the area.
3. Except for visible eutrophication in parts of the surface streams, no real environmental changes caused by agricultural activities could be observed.

4. No knowledge of pesticide contamination is currently available.

5. Over-extraction of water over a period of time is evident.

6. Interaction of acidic water with the cave formations and dolomite is not fully understood and documented.

RESPONSES

The author raises the issue of the number of authorities involved in managing different resources within the COH WHS, and stresses the importance of the landowners in the conservation of the area as they, along with industry and the mines, have a most profound impact on the region. The following responses are presented:

1. Regulatory Response:

As indicated previously, there are a number of authorities having jurisdiction in issues pertaining to the environmental well-being of the COH WHS and legislation exists to ensure this. The problem is that the legislation is not being enforced which is largely attributable to a shortage of manpower. It is suggested that education will bring enforcement one step closer to success.

2. Management Response:

The author refers to the matter of the overlapping of environmental protection issues and stresses the importance of cooperation to ensure successful implementation. The following are then listed as overlapping issues: a) Decant of water and AMD from abandoned mines in the catchment possibly ending up and contaminating Cradle resources. b) Negligence or poor agricultural practices followed by piggeries, dairy farms, chicken farms, crop farming and aquaculture within and peripheral to the COH WHS polluting the environment. c) Small industries causing pollution from wash bays, oil spillage, fuel tanks as well as old service stations with leaking fuel tanks. d) Low cost housing with little or no infrastructure creating raw sewage effluent. e) Municipal treatment works function above capacity or not treating effluents to appropriate standards. f) Accidental spillage of transported hazardous substances. g) Dust pollution from tailings dams. h) Construction material derived from mining waste. i) Climate change due to global warming. j) Protection of fauna and flora. k) Natural degradation or weathering of the environment and l) Natural attenuation of rocks and minerals.

It is suggested that the above need to be further researched.

The author also suggests the establishment of a team or working group to address the environmental problems in a more holistic manner and to ensure that action is taken when necessary. Reference is made to the Cradle Working Group (CWG) which has been established under the auspices of the DWAF and currently includes members from DWAF, GDACE, CGS (Council for Geosciences) and the University of Pretoria. The inclusion of other groups and authorities is however suggested.

It is further proposed that GDACE should convene a workshop at the Sterkfontein Caves with the objective of consolidating information on past and current projects together with all available literature to avoid future duplication of effort and to make available all current knowledge in the various disciplines involved in the environmental protection of the COH WHS.

The education of Previously Disadvantaged Individuals and farmers on good practices to prevent contamination of resources is considered important and currently existing information on the matter should be distributed to this end.

RESEARCH REQUIRED

A list of recommended topics for research is proposed on the understanding of the overlapping of such issues as discussed previously. These include the following;

a) Soils studies: these should include those pertaining to the impact on the vadose zone due to rip ploughing, application of fertilisers and pesticides to soils and the depth of occurrence. The level of persistence of nitrogen from this is not well understood, specifically on dolomitic soils.

b) Nitrate is one of the main contaminants concerned and further investigations into the impact of elevated levels of this element on the environment and human health should be undertaken.

c) Further research is also required into methods to determine the rate of bio-available nitrogen release from organic sources such as sludge, different soil types and manures.

d) A synthesis of available information on pesticide contamination needs to be undertaken, especially in the context of the karst system and the COH WHS.

e) Research is required to determine the effects of salinisation on vegetation (natural and cultivated).

f) Further research is indicated into microbial indicators at IAH sites and dairy farms and the effects of the release of harmful bacteria and viruses to the environment and their lifespan.

g) The lowering of pH in water resources due to leachate from stock farming and how this can contribute to “de-dolomitization” requires further research.

h) Investigations are necessary to determine the impact of wastes from local fuel storage sites and workshops (including farm workshops) on surface and groundwater reserves.

i) Data pertaining to phosphate standards for the COH WHS surface streams is necessary to prevent eutrophication.

j) The potential impacts of aquaculture in the COH WHS require investigation.

k) Further investigation is also required in respect of heavy metal contamination in the COH WHS and the associated sources of such metals.

l) Research on aromatic hydrocarbons (specifically DNAPL and LNAPL), their origin and distribution in the COH WHS.

MONITORING REQUIRED

The importance of water monitoring in the context of the karst environment is stated and reference is made to the lack of an effective surface and groundwater monitoring programme in the COH WHS. The current DWAF monitoring programme is deemed insufficient by the author.

A recently revised proposal has been submitted by the CGS to GDACE to initiate an effective monitoring programme. The proposed network to be established will include provision for establishing an understanding of the hydrodynamics of the COH WHS karst and will consider the following (personal communications with the author): a) Hydrocensus of all boreholes, springs and rivers that can be sampled chemically as well as water levels and includes a standard parameter format. b) Surveying of water levels or borehole casing heights to obtain measurable quantities against a specific datum level i.e. sea level. c) Geochemical sampling of all points for major ions, trace elements and microbial indicators. d) Conceptualising the flow with above data and prioritising key areas for monitoring points according to the above findings. e) Establishing a monitoring network and frequency for sampling. f) Rehabilitating extremely polluted areas with identification of I&APs.

From this data set, areas that are currently polluted will be highlighted and base information of non-polluted areas will be established to establish future trends. This will ensure informed decision management by the authorities who will have state of the environment figures available on a continuous basis.

OTHER RESPONSES

The author comments on how South Africa in spite of a good legislative base is lagging behind many countries in respect of multidisciplinary responses to environmental issues and disasters. In terms of the COH WHS this needs to be rectified by the establishment of a multidisciplinary responsive "Task Team" which could act as a precedent in the country.

Issue Paper 12: Legal Aspects of Karst and Cave Use in theCradle of Humankind World Heritage Site

R. Ellis and A. Grove

STRUCTURE AND CONTENTS OF PAPER

The contents of this paper include the following: Abstract; Introduction; Literature Review (Current State of Knowledge – Nationally and Internationally); Problem Statement including:

Negative Impacts and Risks to the Surface of Karst

(Traditional livestock and agricultural farming, Trout Farming, Horse Breeding, Horse Riding Trails, Hiking trails, Coffee Shops, Resorts, Conference Facilities and Restaurants, Informal Settlements, Curio and Adventure Shops, Cafes, Garages and Trading Stores, Nature Reserves, Game Reserves and Conservancy Areas, Improvement of existing public roads and new roads, Making of private gravel roads, Sub-division of land and housing development, Construction of tourist centres and provision of pathways and infrastructure, Harvesting of "Pelindaba Rock", Quarrying and Mining Operations, Industrial Activities, Archaeological activities).

Negative Impacts and Risks to the Subsurface of Karst

(Caves – Commercial show caves, Caving activities in wild caves, Commercial adventure caving, Effects on selected caves caused by human traffic, Effects of archaeological and palaeontological activities on caves, effects of various forms of lighting on the cave environment, Dumping of animal carcases, chemicals and refuse in cave entrances and sinkholes, Filling and closure of cave entrances and sinkholes; Quarrying and Mining Activities; Acid Mine Drainage; Industrial activities; Effects on the water table.

A section on Existing Legislation is then presented followed by a section on Proposals (including: the Current State of the Law (Karst and Caves); Guidelines: Proposals for Protection of the Karst Environment {namely *Protection of the Surface of Karst* – Proposed karst conservation guidelines and legislation; Proposed guidelines and legislation pertaining to quarrying and mining in karst areas; Proposed guidelines and legislation for building on karst areas; and *Protection of the Subsurface of Karst* – Proposed cave conservation guidelines and legislation and proposed guidelines and legislation pertaining to the karst water table.

A section on Further Recommendations follows which includes: Protection of all karst areas in South Africa Caves; Caving Lights; Gating of Caves; Inventory, classification and grading of caves; Access to karst areas and caves; Archaeology and palaeontology; Participative relationships; The existing establishment; Commercial adventure caving; Applying the law. Conclusions, a Bibliography and Appendices (Proposed Cave Conservation Legislation, Karst Management and Cave Conservation Guidelines) follow.

FINDINGS OF THE PAPER AND RECOMMENDED RESPONSE(S)

This paper presents a very comprehensive background in respect of many issues pertaining to karst and caves, the importance and impacts on these and the challenges to the sustainable management of karst environments and karst ecology. The paper in many respects endorses views expressed in the preceding papers but also includes legislative and management perspectives from karst areas outside South Africa.

The contents of the paper (which are not discussed in further detail here) are presented in the previous section to which the reader is referred. As in the previous papers, emphasis is here based on the findings of the paper and recommendations and proposals emanating from it.

PROPOSALS

1. Legal Issues and Guidelines: The authors refer to the non-existence of legislation in South Africa specific to karst, although other legislation does affect karst purely because the subject or area of application happens to be situated on

the karst. The authors are of the opinion that there is probably no need to promulgate new laws specific to the karst environments and refer to the National Environmental Management Act (NEMA) and the NEM: Protected Areas Act and NEM: Biodiversity Act as providing sufficient protection for karst environments. They therefore suggest that all karst be protected by the NEM: Protected Areas Act by the declaration of karst as a "Protected Environment".

2. The authors refer to numerous guidelines in the paper (not discussed in detail here) but of note is that there are no official guidelines written for the protection of caves in South Africa where such guidelines to karst and caves from other countries abound. The only law in South Africa which specifically applies to caves is the Nature Conservation Ordinance of 1983.
3. Guidelines are a necessary prelude to the process of achieving the aim of good environmental practices. There is a need for more practical guidelines specific to karst and caves in order to manage the processes and influences that impact upon them.
4. The paper refers to proposals for the protection of the surface of karsts including those related to: a) Conservation Guidelines. b) Karst Conservation Laws. c) Quarrying and Mining. d) Legislation to Building on Karst Areas. e) COH WHS Cave Conservation Guidelines and f) COH WHS Cave Conservation Legislation.
5. Three comprehensive Appendices are attached pertaining to Karst Conservation Guidelines (Appendix 1), Cave Conservation Guidelines (Appendix 2) and Cave Conservation Legislation – COH WHS (Appendix 3) to which the reader is referred.
6. The COH WHS proposed Cave Conservation Law is a compilation of the best elements from international laws suited to South African conditions.

FURTHER RECOMMENDATIONS

The paper considers further recommendations under the following headings which are not discussed in detail here but to which the reader is referred: a) Protection of Karst Areas in the RSA. b) Permits and Permissions. c) Show Caves. d) Caving Lights. e) Gating of Caves. f) Inventory, Classification and Grading of Caves. g) Access to Karst Areas and Caves. h) Archaeology and Palaeontology. i) Participative Relationships. j) The Existing Establishment. k) Commercial Caves and l) Applying the Law.

Some of the main points arising out of the preceding however include the following:

- There is a need for karst and cave conservation laws and guidelines to be extended to all regions of South Africa. It is recommended that all karst areas across the country be declared "Protected Environments" in terms of the Protected Areas Act, thereby ensuring the preservation of karst and caves for the future.

- It is recommended that authorities and landowners engage the accredited caving clubs in controlling access to caves.
- It is recommended that specific legislation be applied to Show Caves and that owners or operators of these caves be required to become members of an internationally recognised institute and that their activities are monitored on an ongoing basis.
- It is recommended that selective caves within the COH WHS be gated in accordance with international standards (NSS Cave Gating Guide).
- An inventory of known caves in the COH WHS needs to be compiled in which caves are classified according to their geological and ecological sensitivity and graded according to their severity and caving skills required. The methodology should follow accepted international criteria and should be compiled by GDACE in conjunction with scientists, cavers and members of special interest groups.
- The success of the COH WHS will be best served through establishing participative relationships. It is particularly important that GDACE interact closely with landowners and operators within the COH WHS but also that GDACE bring together a core of independent experts and specialists to assist in managing the COH WHS. The authors consider the IUCN-SA KWG to be an appropriate body to fulfil such a function.
- Many activities being undertaken in the COH WHS have been on-going for many years and it is recommended that an audit of all activities be conducted and where necessary, recommendations put forward to improve the situation. A "Management of Change" process to be introduced in the COH WHS is recommended.
- Only less sensitive caves should be used for Commercial Adventure Caving, specific rules and guidelines need to be applied, operators should be permitted and should conform to the legal requirements and all operations should be regularly monitored and audited.
- The lack of capacity in implementation of the law is widely recognised and it is proposed that certain groups and special interest groups be accredited and their members trained and appointed as rangers or wardens to identify and report on illegal activities.

CONCLUSION:

It is quite clear that although the existing laws of the country adequately provide for the majority of issues relating to the COH WHS and its environs, there is a need for specific legislation applicable to the karst in order to bring this unique environment under closer scrutiny and control. This however needs to be done without the law being too prescriptive as the success of the COH WHS ultimately depends on a close working relationship between private landowners and the government. As the Cradle needs to be economically viable it is also essential that legislation makes provision for this fact and does not alienate private landowners or hinder local enterprise and development.

The situation is different however with regard to the caves of the area. The economy of the area is not depending solely on the utilisation of the caves and the number of caves currently developed for tourism is sufficient. Consequently, legislation to protect the caves should now focus more on protecting the geology and ecology of the caves and controlling access and activities inside the caves. To this end it is important that the existing legislation needs to be revised and expanded.

Almost as a prelude to imposing any law it is necessary to educate the people who will be affected directly by such legislation. To this end it is imperative that the local community living within the COH WHS understand what the Cradle is all about and why the laws need to apply. Education is the key and a concerted effort needs to be made by the authorities to enlighten the local residents and to encourage them to take ownership of and develop a sense of pride for the important role that they play in ensuring the success of the Cradle. It is therefore important that people understand the impact that their activities may have on the karst and caves and the reasons why these activities need to be managed. A three-tier educational process needs to be applied. Level one should be directed at people at grass roots level and should primarily explain the reasons behind the establishment of the Cradle and the benefits that the local community can expect. The second level of education should be directed at farmers, landowners, residents and business operators to encourage them to participate and to develop a sense of ownership. At this level it is hoped that a form of community policing could evolve which would be self-propagating. The third level should be directed at the general public who visit the Cradle and at the educational institutions in order to educate future generations.

To assist in this process it is important that karst and cave management guidelines be introduced to give direction to stakeholders and to pre-empt any need to have recourse to the law. The old saying that “Ignorance has no place in the law” certainly applies here and guidelines are a means to educate residents and the general public alike in what to do and how to behave. Many other guidelines for specific activities in the Cradle ranging from farming to candle making need to be drawn up and the authorities are encouraged to develop best operating practices to set the required standards.

THE WAY FORWARD AND THE FUTURE OF THE KARST WORKING GROUP

I.M. Macgregor

The Cradle of Humankind World Heritage Site (COH WHS) with associated hominid and other fossil-bearing deposits represents sites of significant scientific interest and importance, both nationally and internationally. These fossil deposits are however not the only attribute of this site and often overlooked is the fact that the karst system in which the said fossil deposits occur are the oldest extensive shelf carbonates in the world and also contain important Precambrian fossil assemblages (stromatolites and microfossils) which remain largely unresearched.

The commissioning of this publication and the results emanating from it have indicated that much work and research remains to be undertaken in the formulation of an Integrated Environmental Management Plan (IEMP) for the COH WHS karst ecosystem and caves. The current knowledge base is insufficient to this end. The implementation of such an IEMP is deemed essential for the sustainable management and long term integrity of the COH WHS.

The COH WHS is under threat from various sources both from within its boundaries and peripheral to it. These threats include those from mining and industrial operations, urban encroachment, agriculture, tourism and other activities.

The drafting of an appropriate IEMP by necessity will require a comprehensive understanding of the resource base (including biophysical, geological, hydrological elements and other) and the associated potential impacts (many of which have been highlighted in the preceding papers). As a point of departure in the understanding of the resource base it would be appropriate to establish a comprehensive publications database on the COH WHS. This database should include all research and other relevant documentation and contracts undertaken for the management authority pertaining to the COH WHS and other karst environments in southern Africa. The said database together with the findings of this publication would assist in the identification of issues requiring further research. The envisaged IEMP should also include appropriate "Site Specific Management Plans" for the thirteen National Heritage Fossil Sites and caves within the COH WHS (see Macgregor, I.M. 2005 for further recommendations in this regard). Appropriate monitoring and auditing programmes will form an essential element of the IEMP.

It is suggested that the Management Authority in conjunction with the KWG, convene a workshop as soon as possible after the publication of this document, the main objective (apart from others) of which should be to prioritise further research based on the findings of the papers and to identify a strategy to undertake and fund such research.

The Future of the IUCN – SA Karst Working Group:

The background to the IUCN-SA Karst Working Group (KWG) and its formation is briefly discussed in Paper 1 of this publication to which the reader is referred for further details.

Since the formation of the KWG in 2004, Mr Saliem Fakir of the IUCN has acted as "Interim Chairman" of the group. With his resignation in the latter part of 2005 the KWG has been without a chairperson and the administrative and management functions (including issues pertaining to this publication) were taken over by Ms Jenny Tholin of the IUCN with assistance where required from the author.

It was the intention of the author and Ms Tholin to use this publication as a marketing tool to actively explore funding opportunities to facilitate prioritised further research as highlighted in this publication and to raise funds for the future management of the KWG. It has generally been accepted that an appointment of chairperson is overdue and that a champion to steer this group into the future is urgently required. This has become even more urgent as at the time of writing Ms Tholin and the acting head of the IUCN-SA Office had tendered their notice and would be leaving within a month or so. This matter is somewhat disappointing but the KWG has come too far to be allowed to "disintegrate" and it is of the author's (and others') opinion that the future existence of the KWG is paramount to the long term integrity of karst environments in South Africa, be this under the umbrella of the IUCN or other. A future strong liaison with the IUCN International WCPA Working Group on Cave and Karst Protection together with a much closer working relationship with the WCPA Working Group is recommended.

Certain recommendations in respect of the KWG have been cited in several of the preceding papers which are not discussed here. However, the KWG with its diversity of expertise has a major role to play in the future integrity and sustainability of the karst environment in South Africa as indicated above and must become (together with its individual members) more actively involved in issues pertaining to impacts on karst environments. For this reason the future existence of this organisation is essential.

REFERENCES

(Excluding those cited in the individual papers)

BUCHANAN M. and MAGUIRE J. (2002) The Management of Karst Landscapes and Caves. Cradle of Humankind WHS Cultural Heritage Resources Management Project prepared by the Mahube Consortium.

MACGREGOR I.M. (2005) A Short Report on the Site Inspections of Twelve of the National Heritage Fossil Sites within the Cradle of Humankind World Heritage Site by the Management Authority (GDACE) – August 2005. Report compiled on behalf of the IUCN (World Conservation Union).

WATSON J., HAMILTON-SMITH E., GILLIESON D. and KIERNAN K. 1997 Guidelines for Cave and Karst Protection. WCPA Working Group on Cave and Karst Protection, IUCN (World Conservation Union