Training Engineering Geologists in Developing Countries: South African Perspectives and Challenges

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ABSTRACT: Training of engineering geologists in South Africa started in the early 1960s, although engineering geology was included in civil engineering programmes in the early 1950s. The discovery of diamonds, gold and other strategic minerals in the late 1800s created an environment in which economic and exploration geology was established in an early stage in the development of the academic system in South Africa. The infrastructure development associated with the mining industry and resultant urban development surrounding the inland mining areas, lead to civil engineers and geologists working closely together. Today only two universities present degrees and postgraduate qualifications in engineering geology and supply graduates to the local mining and civil engineering fields as well as to the African continent in general. The appropriate training of engineering geologists for local conditions is a challenging task facing many stumbling blocks such as limited staff numbers and very little financial resources for research.

1 INTRODUCTION

Engineering Geology has a long and illustrious history in South Africa. The civil engineer Andrew Geddes Bain (1797 – 1864), constructed a number of mountain passes that required cuttings into the Cape and Karoo strata. His collection of marine and vertebrate fossils was one of the earliest collections of its kind in South Africa.

A geologist, who was invited to read a paper before the South African Society of Civil Engineers in 1913, Alex L du Toit (1878 – 1948), also had close associations with civil engineering projects in South Africa. The title of the paper was “The geology of underground water supply with special reference to South Africa” (Brink et al. 1997).

The later professor of civil engineering at the University of the Witwatersrand in Johannesburg, Jeremiah Jennings studied under Karl Terzaghi during 1936 at the Massachusetts Institute of Technology. He returned to South Africa with a Master of Science in Engineering and fully convinced of the importance and significance of the belief by Terzaghi that the geologic origin and therefore the geologic history and the constituents of a deposit will determine its physical properties (Brink et al. 1997).

Jennings was appointed as Director of the Building Research Institute at the CSIR and recruited a young geologist to his staff in 1949, Tony Brink. Tony Brink was again recruited by Jennings when he filled the Kanthack Chair of Civil Engineering at the University of the Witwatersrand in 1955. Brink had to teach geology to the civil engineering students.

Initially the Engineering Geologists formed a South African Section of the American based Association of Engineering Geologists (AEG) in 1970. Due to the political situation in South Africa it was felt by some local Engineering Geologists that they will not be welcomed by the European based International Association of Engineering Geology (IAEG). A National Group of the IAEG was eventually formed in 1974 and in 1985 the local South African Institute of Engineering Geologists was formed, driven to a large extent by the poor exchange rate and the resulting high membership fees of overseas professional bodies (SAIEG website).

2 THE DEVELOPMENT OF ENGINEERING GEOLOGY IN SOUTH AFRICA

The economies of the Developing World are generally closely linked, but slightly out of phase with those of the Developed World. The situation in South Africa is somewhat unique in the sense that the so-called mineral revolution and political history were contradictory in some ways. Regionally the post World War II political situation impacted negatively on the country, but the global importance of the large reserves of strategic minerals (e.g. chrome, platinum, gold, diamonds and vanadium) produced locally, supported the economy to such an extent that the political regime could stay in power regardless of its policies and it being a minority government. This anomalous situation in South Africa created an environment in which geologists could operate locally and be part of the development of the deepest gold mines in the World. The availability of research money from government and industry also created an environment in which rock mechanics was established as a strong research field.

Engineering Geology is a relatively young field compared to Geology and was only established as such during the late 1940s through the work of Terzaghi. As was mentioned above one of his students of this time, Jeremiah Jennings, came back to South Africa with a firm impression of Terzaghi's beliefs. He also established engineering geology in South Africa in the academic environment, albeit initially as a supporting subject to the training of civil engineering students (Brink et al 1997; Korf 2006).

A number of important events played a significant role in the development of infrastructure in South Africa of which a few more important ones are listed.

The discovery of alluvial diamonds in 1867 near Kimberley irrevocably changed the agriculture based economy of the time with the advent of the so-called Mineral Revolution. This was followed by the discovery of alluvial gold deposits near Lydenburg in 1873 and later the gold deposits on the Witwatersrand in 1886, which made South Africa at that moment, the largest single gold producer in the World. It was also during this time that the country was colonised by the British government.

The sudden influx of more than 50 000 people to the diamond fields (present day Kimberley) and even larger numbers to Johannesburg on the goldfields as well as the need for railway lines and roads to transport the minerals to the coastal ports resulted in the early interaction between civil engineering and geology.

Transport systems, water supply, sanitation and sources of construction materials were needed in these newly established urban conglomerations, but geology and engineering geology also played a role in the mining operations.

From 1891 Alex du Toit and Harry Frommurze produced foundation reports on dam sites and the Geological Commission of the Cape of Good Hope was involved in water supply schemes (Korf 2006).

The mineral revolution also created a need for formal geologic and mining engineering training and the South African College (later the University of Cape Town), started training in mining during 1890 (Fuller 1997). This School of Mines was moved to Johannesburg in 1902 from which the Universities of the Witwatersrand and Pretoria was formed. The Universities of Cape Town, Witwatersrand and Pretoria all celebrated their centenaries with geology being part of the initial list of subjects presented at these campuses. Where engineering faculties were present it was usual for the teaching staff from the geology departments to lecture applied geology (engineering geology) to the civil engineering and mining engineering students.

The development of infrastructure continued with short interruptions during the First and Second World Wars and the Great Depression (Korf 2006).

The infrastructure development was in the early years focused on the creation of communication and transport lines and a large number of bridges were built as a result. The economic growth after 1933 also saw the improvement of the road network with surfacing being carried out after World War II in large parts of the country.

The Geological Survey of the time played an important role in groundwater surveys to provide water to the South Africa Railway and the Department of Irrigation (Korf 2006).

The strong economic growth between 1949 and 1972 saw the firm establishment of engineering geology in South Africa. The era was brought to an end with the oil crisis in 1973. This was followed by the political upheavals and disinvestment by the USA due to the apartheid government policies. The border wars in Angola and Mozambique, between 1975 and 1988, also drained large sums of money from the economy, although a local arms industry was established.

During the oil crisis OPEC also banned exports to South Africa, although Iran still supplied the country with oil until the Shah's reign was ended in 1979.

The National Party introduced the apartheid policy whereby all the different tribes in South Africa should have their own land and govern themselves. This led to the Homeland policy with a number of economic and infrastructural implications. The acquisition of land for these black homelands drained additional money although infrastructure development took place within these areas in which engineering geology also played a part. The number of people that had to be moved around the country to implement this policy was such that it became clear that the policy doesn't make economic sense.

Probably one of the most significant events that shaped the future of engineering geology in South Africa was the large sinkhole that formed in the Far West Rand gold fields on 12 December 1962. The entire crusher plant at the West Driefontein Mine was engulfed with a loss of 29 lives (Wolmarans 1984). This and many consequent large sinkholes developed due to the dewatering of the karst overlying the gold-bearing rocks with groundwater tables being drawn down hundreds of metres exposing palaeo-cave systems in the dolomite bedrock (Brink 1979).

These events created an opportunity for geophysicists, engineering geologists, mining geologists and engineers as well as geotechnical engineers to work closely together to find ways to determine surface stability in existing residential and planned residential areas in the Far West Rand, but also in all other karst areas of South Africa. This is still today a specialist field in which engineering geologists take the lead regarding research and consultation.

Since 1974 provincial governments promulgated a number of Ordinances, initially to regulate development on dolomite land, but with the establishment of the National Home Builders Registration Council in 1998, all residential development must be investigated geologically prior to township establishment (Brink et al 1997).

The government's drive to eradicate squatter settlements and to provide decent housing to the broad population created a sustained source for housing project site investigations for more than 15 years.

Engineering geologists played an important role during the past 20 years in providing input in the town planning in the homelands, dam site investigations and numerous housing projects as part of the Government of National Unity (post 1994) Reconstruction and Development Programme.

3 HISTORY OF ENGINEERING GEOLOGICAL TRAINING IN SOUTH AFRICA

The South African College (present day University of Cape Town) started to train students in mining in 1890. Geology was taught from 1894 to aid the training of these mining students. During 1902 the School of Mines was moved to Johannesburg and changed its name to the Transvaal University College in 1906. A Campus was opened in Pretoria and later became the University of Pretoria with the Johannesburg campus later changing its name to the University of the Witwatersrand (McCarthy 1997). Geology was taught on both these campuses with geology being introduced on the Pretoria campus in 1908.

From 1937 there was an increase in the interaction between geology and civil engineering with specific courses in geology being presented to the civil and mining engineering students.

The economic growth in South Africa and development of infrastructure to serve the mining and industrial sectors saw a close working relationship between geologists and civil and mining engineers.

Brink was sent to England by Jennings to work in the Road Research Laboratory and when he returned in 1953, he was the first to call himself an engineering geologist (Korf 2006).

In 1952 the geology course taught to civil engineers at the University of the Witwatersrand was adapted to their specific needs. A course called engineering geology was presented at the University of Cape Town in 1958 and since 1947 geology courses were also offered to the civil engineering students at the University of Natal. After the establishment of the engineering faculty at the University of Pretoria in 1950, a geology course was adapted for the civil and mining engineering departments (Snyman 1997).

The University of the Witwatersrand was the first university in South Africa to offer a four year degree in engineering geology, starting in 1962. Postgraduate studies in engineering geology were also encouraged during this time. By 1970 there were 30 Engineering Geologists practicing in South Africa. Some were trained at Wits University and several were trained overseas (Brink et al 1997).

Brink left the Geology Department at University of the Witwatersrand in 1971 when courses in engineering geology also ceased, although it was reactivated during the periods 1982 to 1984 and again 1987 to 1989 when the four year degree course finally ceased (Brink et al. 1997). The main reasons for the discontinuation of this course were staff shortages.

Engineering Geology was also introduced at the University of Natal in Durban, during 1973 by Professor Tavener-Smith, but was discontinued between 1974 and 1980, due to a lack of staff. Since 1980 this four year degree course has been running continuously under the supervision of Colin Jermy.

More than 200 students completed the Honours course with both Masters and PhD degrees also being awarded to more than 50 students (Saggerson et al 1997).

At the University of Pretoria an Honours degree course in engineering geology was introduced by Professor Monte van Schalkwyk in 1979. Isak Venter, who started the course prior to the appointment of Prof van Schalkwyk, obtained his Masters degree in Engineering Geology at Imperial College, London. The initial course content and structure closely resembled the Imperial College degree content.

A total of more than 100 Honours degrees and more than 35 Masters and Doctorates have been awarded in engineering geology at this university.

From 1970 onwards engineering geology was established at South African universities as an autonomous field of study (Korf 2006). Declining student numbers in geology and also engineering geology during the 1980s caused some hardship to the universities and today it is only the Universities of Pretoria and KwaZulu-Natal that still present pre- and postgraduate courses in engineering geology.

Both universities include a fair amount of environmental geology as well as mining related subjects. At the University of Pretoria the option for specialisation in either engineering geology or hydrogeology at fourth year level is possible.

Student numbers at the University of Pretoria varied tremendously over time with lows during 1983, 1988, 1997 and 2005 and the largest classes in 1981, 1990 and 2003. There is a weak correlation with the economic growth cycles and the political sentiment in the country. Relatively sustained high numbers have been recorded

since 1999 in most of the geology departments at South African universities. This may be partly attributed to the sustained post apartheid economic growth, the influx of students from the previously disadvantaged communities and the availability of bursaries to these previously disadvantaged students. All the larger mining and engineering companies in South Africa have to achieve a certain level of black economic empowerment and the numbers of black students have increased exponentially over time.

This increase in student numbers is also reflected in the applied geology fields such as hydrogeology and engineering geology.

There are currently six fourth year engineering geology students at KwaZulu-Natal and eleven at Pretoria of which four are specialising in engineering geology. Third year student numbers at KwaZulu- Natal are 43 compared to the 25 at Pretoria (McCourt pers. com. 2007)

Due to limited staff availability to teach the fourth year, student numbers are usually limited by offering only a set number of places for the honours degree. At both universities there are usually between 10 and 15 places available.

4 CURRICULUM DEVELOPMENT

The initial engineering geological courses presented at South African universities followed closely on the European model with coverage of the following typical topics covered during the fourth year:

- Introduction to engineering geology: rock weathering and clay minerals, rock and soil description, rock mass classification, rock mechanics, residual and transported soils, pedogenic materials, applied structural geology and stratigraphy, geologic hazards, hydrogeology, geomorphology and soil mechanics.
- Construction materials of soil and rock.
- Geological aspects of dams, tunnels, open pits and cuts, fills, harbours, coastal protection and land reclamation.
- Foundation problems and solutions with respect to buildings, bridges, roads and airfields.
- Slope stability and land slides.
- Geological aspects of town and regional planning, environmental science and pollution.
- Site investigation techniques including engineering geophysics, remote sensing, aerial photo interpretation, borehole techniques, mapping and groundwater.
- Reporting and presentation of reports, contractual aspects, specifications.
- Seminar work.
- Project of limited extent.

In some instances certain courses from the civil engineering department were included such as surveying, strength of materials, soil mechanics and where mining engineering departments are present also rock mechanics.

The above outlined course contents obviously required the appointment of a generalist in the field of engineering geology or geotechnical engineering. Faculty positions were generally limited to one or two due to the small number of students in relation to the geology students. In addition to the small student numbers research output and postgraduate students were generally also limited compared to the traditional geology component.

Wide use was therefore made of private consultants and engineering geologists to assist with lecturing and to involve students in projects or site visits.

Pre-graduate training in engineering geology at South African universities usually forms part of the three year geology degree programme, but include additional training in geotechnical engineering or soil and rock mechanics.

The present day four year course composition at the University of Kwazulu-Natal in Durban is summarised in

Table 1 and the course presented at the University of Pretoria is summarized in Table 2 (University of KwaZulu-Natal and Pretoria websites).

Table 1. Summary of the Kwazulu-Natal course

Module	Credits
First year	
Earth and its materials	16
Earth surface processes	16
General principles of chemistry	16
Mathematics and statistics for natural sciences	16
Computing tools for science	8
Electives	56
Second year	
Mineralogy	8
Mineral microscopy	8
Principles of igneous and metamorphic petrology	16
Sedimentary petrology	8
Geostatistics	16
Brittle deformation of rocks	8
Soil resources	8
Water resources	8
Geology field module	16
Electives	32
Third year	
Mining and evaluation	16
Environmental geology	16
Geology and ore deposits	16
Geologic evolution of Southern Africa	8
Rock mechanics	16
Geologic evolution of Southern Africa	8
Soil mechanics	16
Electives	32
Honours degree	
Rock engineering	16
Engineering geology	16
Special topics: no lectures only practicals	16
Mines field class	16
Research project	32
Pollution studies	16
Geotechnical engineering	16

Table 2. Summary of the Pretoria course.

Module	Credits
First year	
Computer literacy	8
Academic literacy	12
General chemistry	32
Calculus	16
Mechanics (Civil engineering)	16
Introduction to geology & physical geology	16
Historical and environmental geology	16
Electives	36
Second year	
Crystal optics and chemistry	12
Mineralogy	12
Igneous, sedimentary and metamorphic petrology	36
Structural geology	12
Introduction to geophysics	12
Groundwater	12
Strength of materials (Civil engineering)	16
Electives	28
Third year	
Ore formation and ore deposits	36
Engineering geology	18
Geostatistics and ore reserve calculation	18
Soil mechanics (Civil engineering)	16
Rock mechanics (Mining engineering)	16
Electives	44
Honours specialisation in engineering geology	
Site investigation projects	16
Engineering geology of Southern Africa	16
Construction materials	16

Rock engineering	16
Engineering applications	16
Mining methods	8
Tectonics of Basin Analysis	8
Business practice and entrepreneurship	16
Electives (48 credits) from:	
Rock and soil improvement	8
Hydrogeological modelling	16
Environmental management	8
Mining project	32
Environmental geochemistry	16
Honours specialisation in hydrogeology	
Site investigation projects	16
Engineering geology of Southern Africa	16
Contaminant transport	16
Environmental geochemistry	16
Mining methods	8
Tectonics of Basin Analysis	8
Business practice and entrepreneurship	16
Electives (64 credits) from:	
Rock and soil improvement	8
Hydrogeological modelling	16
Environmental project	32
Rock engineering	16
Environmental management	8

The four year course consists of a three year B.Sc. degree followed by a fourth year for the Honours degree during which year the specialisation option is selected.

The fourth year Honours degree at the University of Pretoria offers two fields of specialisation, namely engineering geology with the emphasis on rock mechanics and hydrogeology with an emphasis on hydrogeological modelling and contaminant transport.

During the late 1990s and early 2000s environmental geology became the buzz word and courses such as environmental management and groundwater pollution were added to the pre-graduate programmes and environmental studies to the postgraduate programme.

The degrees awarded at both universities are called “Environmental and Engineering Geology” and both have prerequisites for entrance into the Honours (fourth) year. The main limitation is obviously staff capacity, as facilities at all South African universities are under immense pressure due to the increase in student numbers. This increase was aggravated by the amalgamation of a number of tertiary institutions during 2004.

Very small changes were made to the course contents over time with some emphasis on the environmental aspects being included since the middle 1990s and the specialization options at the University of Pretoria that became available in 2003.

There are presently three staff members at the University of Pretoria in the Environmental and engineering geology Division in the Department of Geology. Louis van Rooy has been with the Department since 1985 and was initially appointed to teach to the civil engineering students. He specializes in site investigations for housing, dolomite surface stability assessment and durability of basic igneous rocks in civil engineering works. Most of the rock engineering modules are taught by him.

Kai Witthüsser was appointed in 2003 and received his doctorate from the University of Karlsruhe in Germany. He was specifically appointed to strengthen the hydrogeology component of teaching ands research and is strong in the fields of groundwater geochemistry modelling and contaminant transport. He is teaching the specialisation courses for the hydrogeological option in the fourth year. He is presently instrumental in the establishment of aquifer vulnerability mapping in South Africa.

Matthys Dippenaar was recently appointed and is a product of the postgraduate programme with good all round capabilities in engineering geology and hydrogeology. His present research focuses on the relationship

between borehole yields in fractured Basement aquifers in relation to the structure and stress fields. He is teaching at both pre- and postgraduate level in both engineering and hydrogeology.

The staff component at the University of KwaZulu-Natal consists of four lecturing staff members with Colin Jermy being on the staff since 1980. He is responsible for the rock engineering lectures at postgraduate level. Nick Richards teaches engineering and environmental geology and Molla Demlie specialises in the hydrogeology with pollution studies being taught at honours level.

Karen Taslagyn teaches at pre-graduate level courses in soil mechanics and geology for civil engineers (McCourt pers. com. 2007).

Research output at both universities has been limited due to a number of reasons of which lecturing load, general shortage of postgraduate students at the masters and doctorate level and absence of funding are some of the main reasons.

5 RESEARCH

Fundamental research was typically carried out at governmental institutions such as the Geological Survey and the Building and Road Research Institutes at the CSIR and was also funded by the Water Research Commission, the research arm for the national Department of Water Affairs and Forestry.

The Geological Survey established a separate division for engineering geology in 1950. Their involvement in dam site investigations was strengthened when they became involved with the Orange River Scheme. The influence of geology on dam construction in South Africa was researched over many years at the Geological Survey by Van Schalkwyk and colleagues and culminated in his standard reference work on this topic that was presented as a D.Sc. thesis at the University of Pretoria in 1980 (Van Schalkwyk 1980).

As can be expected the early research topics covered mainly engineering geological properties of the different soils and rocks in South Africa. The more important reference works that come to mind are work on the Dwyka tillite (Paige-Green 1975), durability classification and use of Karoo mudrocks in roads (Olivier, 1976 & Venter 1980), natural road construction materials (Weinert 1980) prediction of heave and foundation solutions (Van der Merwe, 1964), engineering geological aspects of pedocretes, specifically the use of calcrete in road construction (Netterberg 1971 & 1994), properties of granite saprolite (Haskins 2005), use of basalt in engineering structures of the Lesotho Highlands Water Project (Van Rooy 1992) and many more dissertations and theses on different aspects of the varied lithological units occurring in South Africa.

Brink discovered the pebble marker as the horizon separating the transported soils from the underlying residual material. These two horizons have different engineering properties due to the different origins (Brink 1961 & Jennings et.al. 1972). This proposed procedure to describe soil profiles during site investigations are still being followed today with the pebble marker as an important marker horizon to distinguish between soils of different engineering behaviour.

The recording by Brink (1977) of his early knowledge and understanding of the engineering geological properties of the different soils and rocks covering the South African subcontinent culminated in a PhD with the title “On the significance of stratigraphy in the prediction of the engineering behaviour of soils and rocks in Southern Africa”.

Following on this he wrote four volumes on the engineering geology of Southern Africa that was published over a period of six years (Brink 1979, 1981, 1983 & 1985). These books are still today the standard reference works used by practitioners and academics in South Africa (Korf 2006). The compilation of these volumes involved 64 engineering geologists and 58 geotechnical engineers and is an “extraordinary example” of the close interaction between all professionals involved in the geotechnical field in the country.

An early, very important concept to predict the properties and behaviour of especially basic igneous rocks on

the subcontinent was highlighted by Weinert (1974). His climatic subdivision of the subcontinent based on a relationship between the annual precipitation and the evaporation during the hottest month, is still used to predict the behaviour and nature of residual soils on different rock types in the different climatic zones.

Research into mining related as well as natural karst surface instability problems was also carried out at the Geological Survey over many years with major contributions from the related professions, including engineering geology, geophysics, mining engineering and geotechnical engineering. The two contributions that are still used as standard references are the PhD by Wagener (1982) submitted to the University of Natal on construction methods on dolomite and the PhD submitted to Pretoria university by Buttrick (1992) on the scenario supposition method for evaluation of dolomite bedrock areas with a suggested risk classification and proposed development appropriate to the different risk classes.

Other research projects on the stability of slopes in KwaZulu-Natal, engineering geological properties of various rock and soil types, environmental issues related to acid mine drainage, surface and groundwater pollution from mining and long-term stability of open quarries were researched at both KwaZulu-Natal and Pretoria universities.

The Geological Survey also initiated research and developed a method to implement regional engineering geological mapping and a scheme to present and produce these kind of maps (Price 1981, Croukamp 1996, Kleynhans 2002). The final maps are unfortunately limited to growth nodes at the moment and the presentation is so complicated that these maps are only of limited use to engineering geologists.

A number of research projects were also initiated by the research arm of the Chamber of Mines, an organisation that is funded by the large mining houses. Projects on stability in deep mining stopes, surface stability over shallow mined out land, stability of slopes in open cast mines and rehabilitation of old mine dumps and the use of dump material as construction material were some of the issues addressed by engineering geologist practising in the rock mechanics and environmental fields.

Throughout the growth years of the discipline and the local economy, the government created research institutions such as the CSIR in 1945 and the Foundation for Research Development as well as a number of research arms within government departments (Agricultural Research Council, Botanical Research Institute, Department of Transport, etc.). Research at universities were funded through the Department of Education and own funds and money for research projects related to mining and rock mechanics were available in abundance.

A number of practicing engineering geologists and geotechnical engineers also used data collected during large projects, such as the Orange River Project, national road construction programmes, numerous rail, road and water tunnels and large harbours to present postgraduate degrees to the universities.

The decline in economic growth from the oil crises and general World economic slow down on top of the local political problems prior to the first democratic election in 1994, saw a serious slump in infrastructure development with related hardships in the civil engineering and engineering geological professions. The anomalously high student numbers in engineering geology at this time in the Department of Geology at University of Pretoria was a direct result of a number of mining companies awarding bursaries to satisfy their demand for rock mechanics specialists in the surge of new platinum mines opening in the Bushveld Igneous Complex.

Funding opportunities also declined due to the government ridding itself of nonessential expenditure and the traditional governmental institutions such as the Geological Survey became the Council for Geoscience in 2003 and was now partly responsible for a part of its budget, the CSIR was now responsible for 60% of its previous budget received from the government and the same trend became apparent in funding and subsidy strategies at tertiary training institutions (CSIR website). Project

based funding was replaced by a individual based funding system with peer reviews, publication lists and ratings by funding organizations becoming the norm with research relevance being pushed on the background.

In addition to this scenario the democratically elected government of 1994 promised the previously disadvantaged communities housing, water and sanitation, but also instituted a system of black economic empowerment where by all larger employers are required to reach certain targets of staff numbers from the previously disadvantaged population sections. This had serious impacts on management and research capabilities.

Very few large construction projects were launched during the couple of years leading up to the elections and after the elections basic services were delivered rather than large projects. Construction on the Lesotho Highlands Water Project started in 1987 and the first phase was completed during 2003. This project occupied a number of geotechnical and engineering geological professionals (LHWP website).

Present day research opportunities are still limited in the field of engineering geology compared to the available sums of money for research in hydrogeology from the Water Research Commission, the research arm in the Department of Water Affairs and Forestry as well as the recently established platinum mines. Groundwater supply, pollution and mine inflow control are typically issues that need to be researched.

The Gautrain Project, a rapid rail system between Johannesburg, Pretoria and the International airport between these two cities, are presently under construction and a number of research projects into the tunnelling conditions in the bedrock and weathered materials along the route as well as the problems and solutions thereof are registered for postgraduate dissertations.

A number of dams with the De Hoop dam near Steelpoort being the largest project are also being investigated or constructed and this sudden increased spending on infrastructure has rekindled the interest among geology students in the applied fields of both engineering and environmental geology.

It is however clear that traditional research and postgraduate funding sources have declined and changed in the World and especially within the local economic and politic environment and that new ways of acquiring funding will have to be pursued. The country's economic growth of more than 5% over the past couple of years also created a skills shortage never experienced before in the history. The skills shortage is aggravated due to emigration of highly skilled professionals because of unacceptable high crime levels and political policies favouring parts of the population based on skin colour.

The shortage of engineering geologists also has a historic component due to low numbers of student completing the honours course, only 300 students graduated over the past 35 years from the universities of Pretoria and KwaZulu-Natal, and the seriously low numbers of registered engineering geologists practicing in South Africa. There are only 149 registered associate members and members of the South African Institute of Engineering And Environmental Geologists. Graduates are presently in a position to choose between three or more job offers at the end of their honours year.

6 PROFESSIONAL REGISTRATION

The first attempt by government to create a register of natural scientists was the Natural Scientist's Act No. 55 of 1982. This act was replaced in 1993 by The Natural Scientific Professions Act, No. 106 of 1993.

The main aim of these acts was to create a register of natural scientists in South Africa. Prior to 1982 most natural scientists were members of learned societies and were employed mainly in government departments and peripheral institutions including research councils and tertiary institutions. The need for professional registration was never an issue because only a very small percentage of these scientists were practicing in private capacity.

The 1993 act was again repealed in 2003 when the Natural Scientific Professions Act, No. 27 of 2003 was promulgated. The South African Council for Natural Scientific Professions (SACNASP) was established under this act and the main impact on the local natural scientists was the ruling that no natural scientist can any longer practice in a private consulting capacity without being registered under the act (SACNASP website).

The South African Institute of Engineering and Environmental Geologists (SAIEG) came into being in February 1985 and is accepted by SACNASP as a Natural Science Association. It was decided at the time to establish a local body, because it was realised that the membership of local engineering geologists of the international organisations, AEG and IAEG, would not be recognised under the act (Brink et al 1997).

Different avenues were pursued at the time by a steering committee and joining the Geological Society or the Geotechnical Division of the Institution of Civil Engineers was investigated. In the end the local membership opted for an own institute.

At the time the engineering geologists were of the few natural scientific professions where the majority of the members operated as private consultants and the representatives of SAIEG on the SACNASP Council played a major role in the establishment of the registration process and evaluation of the membership applications, as this was part of the engineering geological profession from the early years.

The local situation changed dramatically when it was expected from the traditional research institutions to provide for additional funding by executing contract research and providing consulting services. Natural scientists were now exposed to the consulting environment with the associated professional liability that was not part of the previous researched based dispensation.

Again the engineering geologists took the lead in many discussions on the issue of professional liability, indemnity insurance and ethical and professional conduct in the professional advisory committee for Earth Scientists in the early, formative years of SACNASP.

7 FUTURE OF ENGINEERING GEOLOGICAL TRAINING IN SOUTH AFRICA

The historic perspective on the development and establishment of engineering geology, initially in the isolated First World economy driven by the mineral revolution with associated infrastructure development, and the later role played in the provision of basic services to the Third World component in South Africa, has created enormous challenges to the training of appropriate graduates to serve the present day country's needs.

The unpredictable nature of future economic growth and political uncertainties in South Africa are probably not unique compared to other countries in the developing World. The levels of spending by governments on the provision of basic services such as housing, water and sanitation, transport infrastructure and basic health services and education and social services reach disproportionate levels.

Spending on infrastructure in South Africa increased twofold between the 2003/04 national budget and the 2006/07 budget vote. In the 2006/07 national budget 24% was voted to social development, 5.5% to education, 4% to health, 2.5% to housing, and 1% to public works and science and technology each.

It is clear from the above examples that governments in developing countries are faced with a number of dilemmas. The biggest is probably to balance social development spending with provision of basic education to all and also to advance science and technology.

The one anomaly prevailing in South Africa is the historic and present day important contribution of the strategic minerals industry to the local economy. This situation is extremely beneficial to the geologic and mining engineering professions with money available for research

on mining related problems as well as sustained employment opportunities for engineering geologists in the mining sector.

The list of challenges facing training and research in engineering geology in developing countries is long and some of the more pressing ones are:

- Appropriate training for local conditions without losing the core values of the profession (Knill 2002).
- Implementing relevant research to local problems with local and international funding.
- Identifying disadvantaged individuals for academic and research positions in an environment where remuneration in the consulting environment is more favourable than in the academic environment.
- Convincing students to fill research posts prior to entering the consulting environment.
- Convincing consulting companies to invest in problem solving research issues.
- Obtaining funding to analyse existing project data on rock and soil properties into useful contributions to solve and contribute to future projects.
- Continuing and strengthening the role engineering geology played in the development of infrastructure and mining in South Africa irrespective of the economic and political challenges.
- A major challenge is also to, notwithstanding the local problems, keep the training and research standards at an international level.

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