CHAPTER 5

GEOTECHNICAL CLASSIFICATION SYSTEM DEVELOPED BY ZAWADA (2000) WITH SPECIAL REFERENCE TO THE RIETVLEI DAM 2528CD MAP SHEET

5.1 INTRODUCTION

The Council for Geoscience has embarked on a 1:50 000-scale geotechnical mapping programme aimed at producing engineering geological maps of key development areas delineating the distribution and severity of key geotechnical parameters (Zawada, 2000). The primary objective was to provide a series of geotechnical maps that support a variety of regional planning policy and strategy initiatives.

The findings of an evaluation of the geotechnical aspects of an area south-east of Pretoria, based on the classification system proposed by Zawada (2000) is discussed. The shortcomings of the system is discussed and recommendations are provided to improve the end product (geotechnical map) and the use thereof.

5.2 GEOTECHNICAL CLASSIFICATION SYSTEM (ZAWADA, 2000)

5.2.1 Purpose

Zawada (2000) developed a classification system in which the geotechnical parameters are not generalised into zones for development to ensure that the map could be of value in a variety of land-use and development applications and not only for a specific type of development.

5.2.2 Classification

A total of 13 geotechnical factors were identified and evaluated in terms of their severity (Table 21). Each geotechnical factor was ranked in terms of overall significance to land use issues and the ranked list was then classified into groups having a critical and subcritical status (Table 22) (Zawada, 2000). The ranking of geotechnical factors is not meant to be definitive in the sense that a quantifiable difference exists between an expansive or swelling soil and an area exhibiting slope instability. Its purpose is to enable the identification of the highest ranked factor out of several geotechnical factors present in an area and therefore characterise the area with a dominant geotechnical factor (indicated by a colour type corresponding to the geotechnical factor) and to inform the user that additional critical and subcritical factors may also be present for the same area, which is denoted by a shade of colour corresponding to the dominant geotechnical factor colour (Zawada, 2000).

There are two major factors which are also considered when planning the development of an area, namely: financial cost and/or the environmental implications of the development. The geotechnical factors are therefore classed into these two categories (Table 23) using the following criteria:

Financial costs:

These are geotechnical factors or conditions which require significant financial input to remediate the condition prior to development. For example, an area exhibiting active or swelling soil represents a significant increase in cost for the development of low-cost housing due to the extra cost of specialised foundations to ensure the integrity of the buildings. A cost factor weighting has been assigned to each geotechnical factor. Although the cost weightings are qualitative, they give an indication of the cost factor associated with the geotechnical properties found in designated areas on the map.

Table21: Alphabetical listing of geotechnical factors mapped for the Rietvlei Dam map sheet with definitions, implications for development and classes of severity (after Zawada, 2000).

Active, expansive or swelling soil (Act)	*High cost factor*	*Severity: Act2, Act3, Act4 or Act5*

Explanation - The amount of expansion in millimetres (expressed as total soil heave) that can be expected when the moisture in the soil changes. Moisture changes can be due to seasonal changes in rainfall, or changes in the level of ground water due to abstraction, drainage changes or river modification.

Implications for development - The degree to which a soil expands or contracts is a critical cost factor in the foundation design, especially of single-storey residential buildings. Expansive clays, which can result in significant damage to buildings and pipelines, are probably one of the most widespread problem soils in South Africa.

Severity class -
Act2 Active or expansive soil is present (amount of expected heave is unknown)
Act3 Low expansion (heave is expected to be 0–5 mm)
Act4 Moderate expansion (heave is expected to be 5–30 mm)
Act5 High expansion (heave is expected to be greater than 30 mm).

Acidic soil (Aci)	*Subcritical environmental factor and low cost factor*	*Severity: Aci2*

Explanation - Soils that exhibit pH values of less than 5 (7 being neutral). Acidic soils can occur naturally (estimated to be greater than 14 % of South Africa's land area) or be induced by, for example, acid mine drainage associated with mine rock dumps and slimes dams.

Implications for development - Adverse soil acidity affects metal- and concrete-pipe networks and concrete. It is also a serious yield-limiting factor in agriculture. It is not uncommon to have pH values of 2,5–4 close to slimes dams.This can have negative environmental impacts on the soil and the ground-water quality.

Severity class - **Aci2** Acidic soil is present.

Collapsing or settling of soil (Col)	*Moderate cost factor*	*Severity: Col2, Col3, Col4, Col5 or Col6*

Explanation - The extent to which a soil collapses, settles or decreases in volume (expressed as percentage decrease in soil volume) when a load is applied (such as a single-storey house) and an increase in soil moisture occurs. This problem affects mainly open-textured silty and sandy soils. The amount of settlement depends on the size of load, the amount of moisture in the soil and the structure of the soil.

Implications for development - The degree of soil settlement is a moderate cost factor that must be considered, particularly in the foundation design of single-storey residential buildings.

Severity class -
Col2 Settlement potential is present (amount of decrease in soil volume is unknown)
Col3 Low settling potential (1–5 % expected decrease in soil volume)
Col4 Moderate settling potential (5–10 % expected decrease in soil volume)
Col5 Severe settling potential (10–20 % expected decrease in soil volume)
Col6 Very severe settling potential (greater than 20 % expected decrease in soil volume).

Poorly consolidated soil (Con)	*Moderate cost factor*	*Severity: Con2*

Explanation - Poorly consolidated or highly compressible soils are expected to have low bearing capacities and are therefore liable to differential settlement. Examples of highly compressible materials are areas of fill such as dumping grounds and peat deposits at surface or at depth. The amount of settlement is dependent on the applied load (such as a single-storey house), the moisture content and structure of the soil.

Implications for development - Risk of differential settlement and therefore damage to structures. A moderate to high cost factor requiring compaction techniques to reduce compressibility.

Severity class - **Con2** Area has poorly consolidated soil.

Dispersive soil (Dis)	*Subcritical environmental factor and low cost factor*	*Severity: Dis2, Dis3, Dis4 or Dis5*

Explanation - A dispersive soil is prone to disaggregation or deflocculation in contact with water. The dispersivity of the soil is a measure of its susceptibility to erosion. Soil dispersivity is dependent on the mineralogy and chemistry of the soil and water contained in the soil and the eroding water. A simple laboratory test is done to assess a soil's dispersivity. A dispersive soil is likely to develop erosional features similar to those noted for erodible soil.

Implications for development - High dispersivity values indicate the soil's susceptibility to piping, the formation of erosional gulleys and internal cavities in the soil mass. Dispersivity can lead to stability problems of earth embankments, and increased sediment loads entering river bodies and channels.

Severity class -
Dis2 Soil is dispersive (based on field observation)
Dis3 Slight dispersive reaction (on addition of soil to water)
Dis4 Moderate dispersive reaction (on addition of soil to water)
Dis5 Strong reaction (on addition of soil to water).

Erodible soil (Ero)	*Critical environmental factor and low cost factor*	*Severity: Ero2*

Explanation - The extent to which a soil can be eroded by water flow and wind. The erosional feature may be local, such as erosional channels, dongas, gulleys and piping effects or it may be of a more regional extent.

Implications for development - A critical environmental factor where erosion of soil represents a negative environmental factor. Certain types of development on erosion-prone soil can result in dramatic increases in sediment load entering water bodies and courses. This would have negative impacts on the biotic and abiotic elements of wetland and riverine environments.

Severity class - **Ero2** Erodible soil is present (erosional features were observed).

Excavatibility of ground (Exc)	*High cost factor*	*Severity: Exc2, Exc3, Exc4 or Exc5*

Explanation - The ease with which ground can be dug to a depth of 1,5 m.

Implications for development - A high cost factor in development when installing foundations and underground services such as water pipes and sewers.

Severity class -
Exc2 Excavatibility problems are anticipated (unspecified)
Exc3 Slight excavatibility problems (can be hand dug)
Exc4 Moderate excavatibility problems (backactor is required)
Exc5 Severe excavatibility problems (blasting and/or power tools are required).

Inundation (flooding): (Inu)	*Critical environmental factor*	*Severity: Inu2*

Explanation - Area that experiences flooding by either: (1) flood-water volumes that exceed the channel-carrying capacity of the channel, in which case the flood waters move out and onto the flood plain that is usually present on both sides of the channel, or (2) sheetwash where flooding is unrelated to a channel and occurs as unconfined flow.

Implications for development - Inundation or flooding is primarily a critical environmental factor because floods are natural events that have to be taken into account where development encroaches on or is close to stream channels. Therefore most residential developments, such as houses, cannot be erected in areas below the 1:50-year flood line. Note should be taken, however, that certain developments may have significant effects on the flood behaviour of the river. Factors such as changed hydrology, sediment loads and river diversions can have significant impacts, to the extent that areas with a low risk of flooding before development can become high-risk areas after development. Development planning also needs to be aware of the significant abiotic and biotic effects on sensitive environments such as wetlands, that altered flow and flood patterns of rivers may have.

Severity class - **Inu2** Area at risk from inundation.

Permeability of soil (Per)	*Critical environmental factor*	*Severity: Per2, Per3 or Per4*

Explanation - The permeability of a soil is a measure of how easily fluids (usually water) pass through the soil and is related to the degree to which the pores or spaces of the soil are connected to each other. The permeability of the soil is geologically controlled by factors such as the shape of the mineral grains in the soil, the grain size and the manner in which the grains are held together.

Implications for development - The permeability of a soil is a critical factor that affects the rate at which water and dissolved contaminants can pass through, and into, the ground water. This information is critical to the siting of certain developments such as cemetries and certain types of waste-disposal sites.

Severity class -
Per2 Low permeability ($< 4x10^{-6}$–$9x10^{-10}$ cm/s)
Per3 Medium permeability ($4x10^{-4}$–$4x10^{-6}$ cm/s)
Per4 High permeability ($>4x10^{-4}$ cm/s).

Shallow water table (Sha)	*Critical environmental factor*	*Severity: Sha2*

Explanation - A shallow water table is one where the top of the permanently saturated zone occurs close to the ground surface. This definition also includes a perched water table, where geological conditions result in a local zone of saturation that is far above the regional water table.

Implications for development - A shallow water table is liable to contamination by incorrectly sited developments, such as waste sites, pit latrines and cemeteries. Knowledge of a shallow water table can be critical when planning certain developments.

Severity class - **Sha2** Shallow water table is present.

Sinkhole formation (Sin)	*High cost factor*	*Severity: Sin2*

Explanation - A closed depression of less than 2 m to larger than 10 m in diameter that is formed either by solution of surface carbonate, such as limestone or dolomite, or by the collapse of underground caves. The formation of sinkholes is a natural process. However, the incidence and size of sinkholes are dependent on factors such as the type of carbonate, the presence of underground receptacles, the rate of solution caused by leaking water pipes and the lowering of water levels in underground caves by excessive pumping.

Implications for development - A high cost factor in terms of potential loss of life and structural damage to buildings. Dolomite and sinkhole formations are potentially critical geological constraints that must be incorporated during land-use evaluation and planning.

Severity class - **Sin2** Area is susceptible to sinkhole formation.

Slope instability (Slo)	*High to moderate cost factor*	*Severity: Slo2*

Explanation - Area comprising unstable geological materials that could move either gradually (creep) or suddenly, as a slump or a slide. The risk of movement is determined by factors such as the nature of the slope (solid rock, colluvial material), gradient of slope, role of water, type and nature of vegetation cover, seismicity and impact of human activities, such as undermining of a slope.

Implications for development - Can be a significant cost factor for certain types of development. Detailed slope-stability analysis may be required.

Severity class - **Slo2** Unstable slope.

Subsidence (Sub)	*High cost factor*	*Severity: Sub2*

Explanation - Area is likely to or has experienced collapse or subsidence due to either ongoing or abandoned underground mining activities. Where underground mining is deeper than approximately 250 m, induced subsidence at the surface is not considered to be a problem.

Implications for development - A potentially high cost factor in terms of potential loss of life and infrastructural damage. Could be a highly significant or critical consideration for certain types of development.

Severity class - **Sub2** Induced subsidence problems are anticipated.

Table 22: Ranking of geotechnical factors and classification as critical or subcritical factors, in order of decreasing rank (after Zawada, 2000).

Rank	Mapped Geotechnical Factor	Status
1	Inundation (flooding)	Critical factors
2	Sinkhole formation	
3	Slope instability	
4	Active, expansive or swelling soil	
5	Excavatability of ground	
6	Collapsing or settling of soil	
7	Subsidence	
8	Erodible soil	Subcritical factors
9	Dispersive soil	
10	Acidic soil	
11	Poorly consolidated soil	
12	Shallow water table	
13	Permeability of soil	

Environmental implications:

These are geotechnical factors where development may significantly impact on the environment. For example, development in an area with a shallow water table should take place with care to prevent the infiltration of contaminants into the ground water.

Although the cost weightings are qualitative, they give an indication of the cost factor associated with geotechnical properties found in designated areas on the map. Applying the classification given in Table 23 to each geotechnical factor occuring in designated numbered geotechnical areas on the Geotechnical Map and listed in the accompanying Geotechnical Table enables a qualitative assessment of the area into one of 5 financial-environmental categories (Table 24).

The category into which the area has been grouped gives the reader an immediate indication of the financial cost or environmental implications of development in the area (Figure 9, Table of geotechnical factors and cost and environmental category for each geotechnical area on the map). Although the distinction between the financial and environmental implications of a particular geotechnical factor is partially subjective, it gives planners a broad indication of the cost and/or environmental factors affecting future development in these areas.

Table 23: Classification of geotechnical factors into cost and environmental categories (after Zawada, 2000).

Geotechnical Factor	Financial Cost	Environmental implication
Inundation (flooding)	-	High
Sinkhole formation	High	-
Slope instability	Moderate-high	-
Active, expansive or swelling soil	High	-
Excavatability of ground	High	-
Collapsing or settling of soil	Moderate	-
Subsidence	High	-
Erodible soil	Low	High
Dispersive soil	Low	Low
Acidic soil	Low	High
Poorly consolidated soil	Moderate-high	-
Shallow water table	-	High
Permeability of soil	-	High

Table 24: Financial cost and environmental categories ordered in increasing influence of environmental implications (after Zawada, 2000).

Financial - Environmental category	
1	Financially related geotechnical factors.
2	Mainly financially related geotechnical factors with some environmental factors.
3	Combination of financial and environmental - related geotechnical factors.
4	Mainly environmentally-related geotechnical factors and a small number of factors with a low financial cost.
5	Predominantly environmentally related geotechnical factors.

5.2.3 Presentation

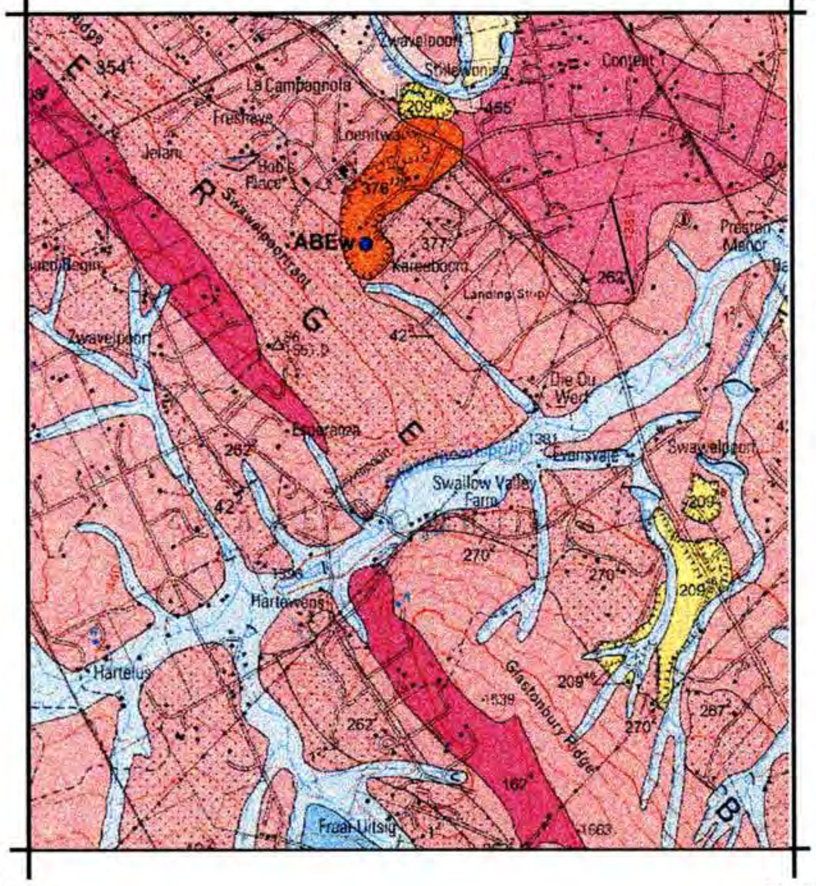
This chapter outlines the findings of an assessment of the geotechnical aspects of an 1:50 000-scale map area south-east of Pretoria, based on the classification system proposed by Zawada (2000), with the 1:50 000-scale geotechnical map presented in Appendix 2. It was decided to use the 2528CD08 1:10 000-scale orthophoto map area once again as a basis to represent this system in order to compare this system with the other engineering geological classification systems previously and currently used in South Africa and which are all presented on the orthophotograph 2528CD08 in Chapter 3.

Each geotechnical unit or area was given an unique geotechnical mapping number that represents a sequence of geotechnical factors and the severity thereof for that specific geotechnical area. The different geotechnical properties and their severity classes are presented in Table 21. Any unique combination of geotechnical factors as given an unique number to be used on all subsequent and adjoining maps.

Each geotechnically distinct area was numbered on the 1:50 000-scale map and listed in the accompanying table, the "Table of geotechnical factors and cost and environmental category for each area on the geotechnical map", from which the reader can identify all the critical and subcritical geotechnical factors identified and mapped in the area, with its financial and/or environmental category (Figure 9).

Realising that an area can exhibit several geotechnical properties, a legend (Figure 9, Table named "Geotechnical Legend") was developed by Zawada (2000) to inform the reader of the dominant geotechnical factors (indicated by a colour type corresponding to the geotechnical factor) and the presence of one or more additional geotechnical factors (denoted by shade of colour corresponding to dominant geotechnical colour) present in any particular area of the map sheet applied. Hatching was used to distinguish between an area with minor differences in geotechnical factors compared to an adjacent area of the same colour (Figure 9, Table of geotechnical factors and cost and environmental category for each numbered area on the geotechnical map).

28° 21' 28° 24'
-25° 48' -25° 48'



-25° 51' -25° 51'
28° 21' 28° 24'

Superscript number refers to the colour of the dominant geotechnical factor shown in the **Geotechnical Legend**

Number of area is used to identify the geotechnical area in the **Table of Geotechnical Factors** from which a listing of the geotechnical factors present in the area can be read.

OPERATIONAL QUARRIES

AGGREGATE QUARRIES		
QUARRY CODE	QUARRY NAME	COMMODITIES
ABEw	Willow Quarries	Aggregate, building sand, river sand and plaster sand

Reference :

- Road
- Track & Hiking Trail
- Power Line
- Buildings
- Excavation
- Original Farms
- Perennial River
- Perennial Water
- Non-perennial River
- Non-perennial Water

Table of geotechnical factors and cost and environmental category for each numbered area on the geotechnical map

Number of geotechnical area	GEOTECHNICAL FACTORS (see 'Geotechnical Factors : Definition, Implications and Severity' for an explanation of abbreviations)						Cost and environmental category				
							1	2	3	4	5
1	Act4	Exc4			Per2		■				
42	Act4	Exc3			Per2		■				
81	Act4	Exc4					■				
155	Act3	Exc3	Col2		Per2		■				
157	Act3	Exc3			Per2		■				
162	Act5				Per3		■				
209	Slo2	Exc2			Sha2				■		
233	Inu2	Act4			Per2				■		
262	Act3	Exc5			Per2		■				
267	Act4	Exc5			Per2		■				
270	Act3	Exc4			Per2		■				
290	Slo2	Act3	Exc4		Per2		■				
302	Act3	Exc3			Per3				■		
308	Act3				Per2		■				
354	Act3	Exc5			Per3				■		
361	Slo2	Act4	Exc3		Per2		■				
365	Act4	Exc3			Per3			■			
376	Col4				Per4				■		
377	Act3	Col4			Per2		■				
392	Inu2	Act4	Exc3		Per2				■		

GEOTECHNICAL LEGEND

Additional Geotechnical Factors				Dominant Geotechnical Factor	
Dominant geotechnical factor plus either no additional factors or one or more subcritical factors	Dominant geotechnical factor plus one critical factor	Dominant geotechnical factor plus one critical and one or more sub-critical factors	Dominant geotechnical factor plus more than one critical factor	Abbreviation	Factor
4	3	2	1	Act	Active, expansive or swelling soil
8	7*	6*	5*	Aci	Acidic soil
12	11*	10*	9*	Col	Collapsing or settling of soil
16	15*	14*	13*	Con	Poorly consolidated soil
20	19*	18*	17*	Dis	Dispersive soil
24	23*	22*	21*	Ero	Erodible soil
28	27	26	25*	Exc	Excavatability of ground
32	31	30	29	Inu	Inundation (flooding)
36*	35*	34*	33*	Per	Permeability of soil
40	39*	38*	37*	Sha	Shallow water table
44	43	42	41	Sin	Sinkhole formation
48	47	46*	45	Slo	Slope instability
52	51*	50*	49*	Sub	Subsidence

Area shows minor differences in geotechnical factors compared to adjacent area of the same colour (see Table of Geotechnical Factors)

5* Combination of dominant geotechnical factor with additional factor(s) is not present in map area

Figure 9 : Geotechnical classification system developed by Zawada (2000) for the Council of Geoscience

Scale : 1 : 50 000

Council for Geoscience

Compiled by : I.Kleinhans
Drawn by : W.L.Buitendag
Date : November 2001

Other information represented on the geotechnical map and the accompanied explanation include the following:

- All operating clay and aggregate quarries were indicated on the map, with information regarding the name and commodities exploited for each quarry. Areas containing potential reserves of construction materials such as brick making clay, building sand and aggregate are identified and discussed in the explanation to ensure that these resources are not sterilized by unplanned development.
- A 1:100 000-scale map of available test-pit and borehole positions to give the user an indication of the information available in the CGS GEODE database.
- The presentation of each geotechnical factor on an A4 size map in the accompanied explanation, depicting the different severity classes for that specific geotechnical factor and the distribution of the severity classes.

5.3 GEOTECHNICAL EXPLANATION OF THE RIETVLEI DAM 2528CD MAP SHEET

5.3.1 Locality

The Rietvlei Dam 2528CD 1:50 000-scale map sheet covers approximately 625 km^2 and is situated south-east of Pretoria, between latitudes 25°45'S and 26°00'S and longitudes 28°15'E and 28°30'E (Fig. 10).

5.3.2 Previous investigations

Apart from site specific geotechnical investigations, two regional geotechnical investigations were conducted within the map sheet area. The first was done by Bester (1981) covering orthophotographs: 2528CD 1 - 10 and the second by Carr (1995) covering orthophotographs: 2528CD 11 - 13, 16 - 18 and 21 - 23. This information was reviewed and incorporated in the compilation of the Rietvlei Dam geotechnical map with explanation booklet.

Existing borehole and test-pit information from several databases of the Council for Geoscience's (CGS) GEODE was consulted and incorporated during the geotechnical mapping process. Information from 1253 test pits and boreholes for the Rietvlei Dam map sheet have been plotted on a 1:100 000-scale base map with the 1:10 000-scale orthophotograph grid (Fig. 11). A summary of the data type, amount and source of information is presented in Table 25.

Table 25: Summary of data in the CGS database (GEODE) for 1253 borehole and test pit positions occurring on the Rietvlei Dam map sheet.

Data type *(DATABASE)*	Number of data points	Data captured
Boreholes:		
Gold exploration *(COREDATA)*	4	Header (longitude, latitude, depth etc), lithologies
Dolomite related *(ENGEODE)*	27	Header, lithologies
Test Pits/Auger/Percussion Data:		
Sampled and tested *(ENGEODE)*	492	Header, moisture, colour, soil type, texture, lithology, origin, water table depth, grading analysis, liquid limit, plasticity index(s) linear shrinkage, total clay, grading modulus, permeability.
Unsampled *(ENGEODE)*	730	Header, moisture, colour, soil type, texture, lithology, origin, water table depth.

5.3.3 Geotechnical method of investigation

The investigation involved a desk study, field work and the compilation of the geotechnical map based on the land facet approach. An integral part of the mapping process was therefore to obtain representative samples on any given geological and landform type. The geotechnical properties were then extrapolated to other areas exhibiting similar geology and land form. A total of 13 geotechnical factors were evaluated in terms of their severity (Table 21).

The first stage of the investigation involved aerial photograph interpretation, using 1:10

000-scale orthophotographs and 1:50 000-scale aerial photographs from which the landforms were identified and compiled on a 1:50 000 scale. A literature study to obtain previously collected geotechnical information from the engineering geological database (ENGEODE) of the Council for Geoscience was done to assess the potential geotechnical problems that occur in the map sheet area and to assist with the siting of trial pits.

The density of test pits during the fieldwork stage depended on the number of land form types, geological variation, access to property and the availability of existing information. An average of eight test pits were excavated for every 1:10 000-scale orthophotograph sheet (approximately 1 test pit per 3 km^2). A total of 103 test pits were excavated using a Case 580K backactor. The soil profiles were described using the MCCSSO (moisture, colour, consistency, structure, soil type and origin) method proposed by Jennings *et al.* (1973). Seventy-five disturbed and three undisturbed soil samples were submitted for geotechnical laboratory testing. Particle size distribution was obtained by sieve analysis and hydrometer tests and the soils were classified according to the Unified Soil Classification system (Howard, 1984). Atterberg limits were determined along with the expected maximum probable heave and expansiveness according to the method of Van der Merwe (1964). Hazen's formula was used to determinate the soil's permeability. Emerson Crumb tests were performed on fifty disturbed samples. This test gives a good indication of the potential erodibility of soils.

The soil profiles, laboratory results, land form analysis and geology were integrated, from which the 1:50 000-scale geotechnical map, covering the Rietvlei Dam map sheet was compiled.

A qualitative assessment has been made of each numbered area on the 1:50 000-scale geotechnical map of the Rietvlei Dam area to classify each area into one of the 5 financial-environmental categories. The category into which the area has been grouped gives the user an immediate indication of the financial cost or environmental implications of development for each particular area (Table 26).

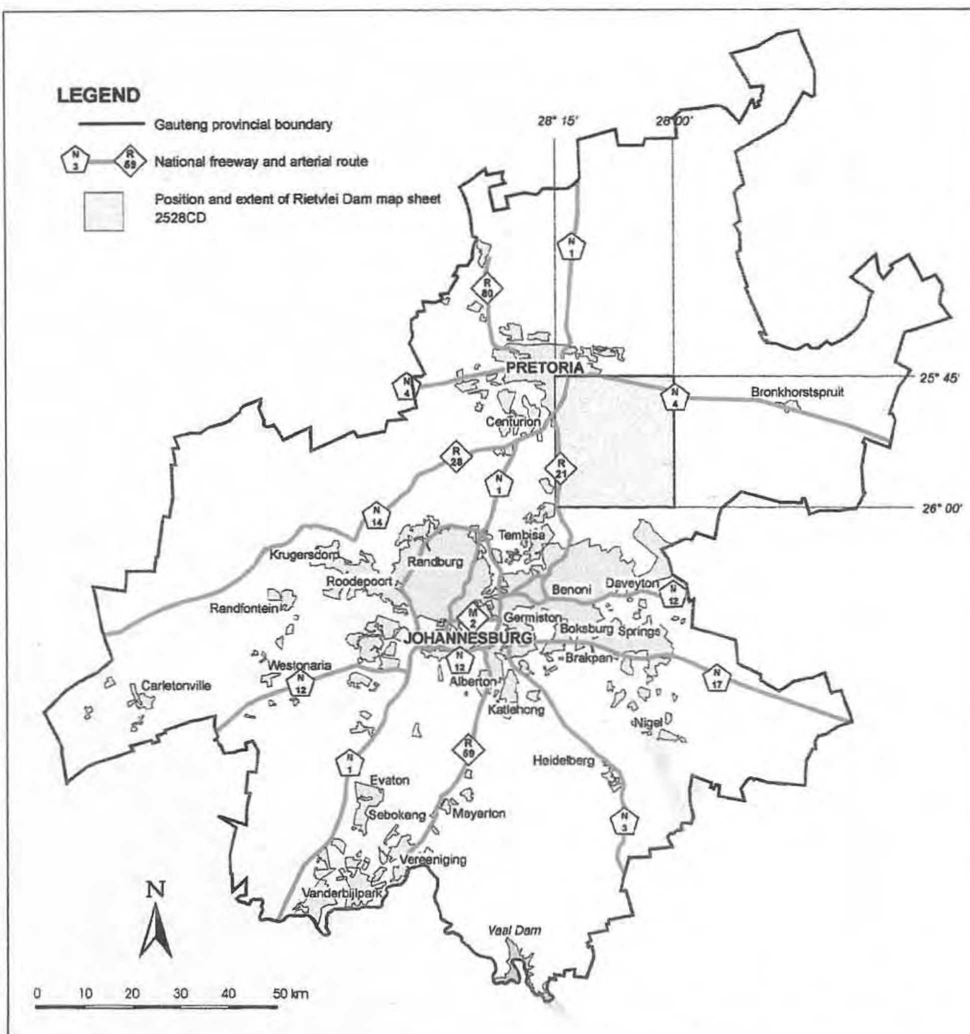


Figure 10: Position and extent of the 1:50 000 scale Rietvlei Dam map sheet 2528 CC.

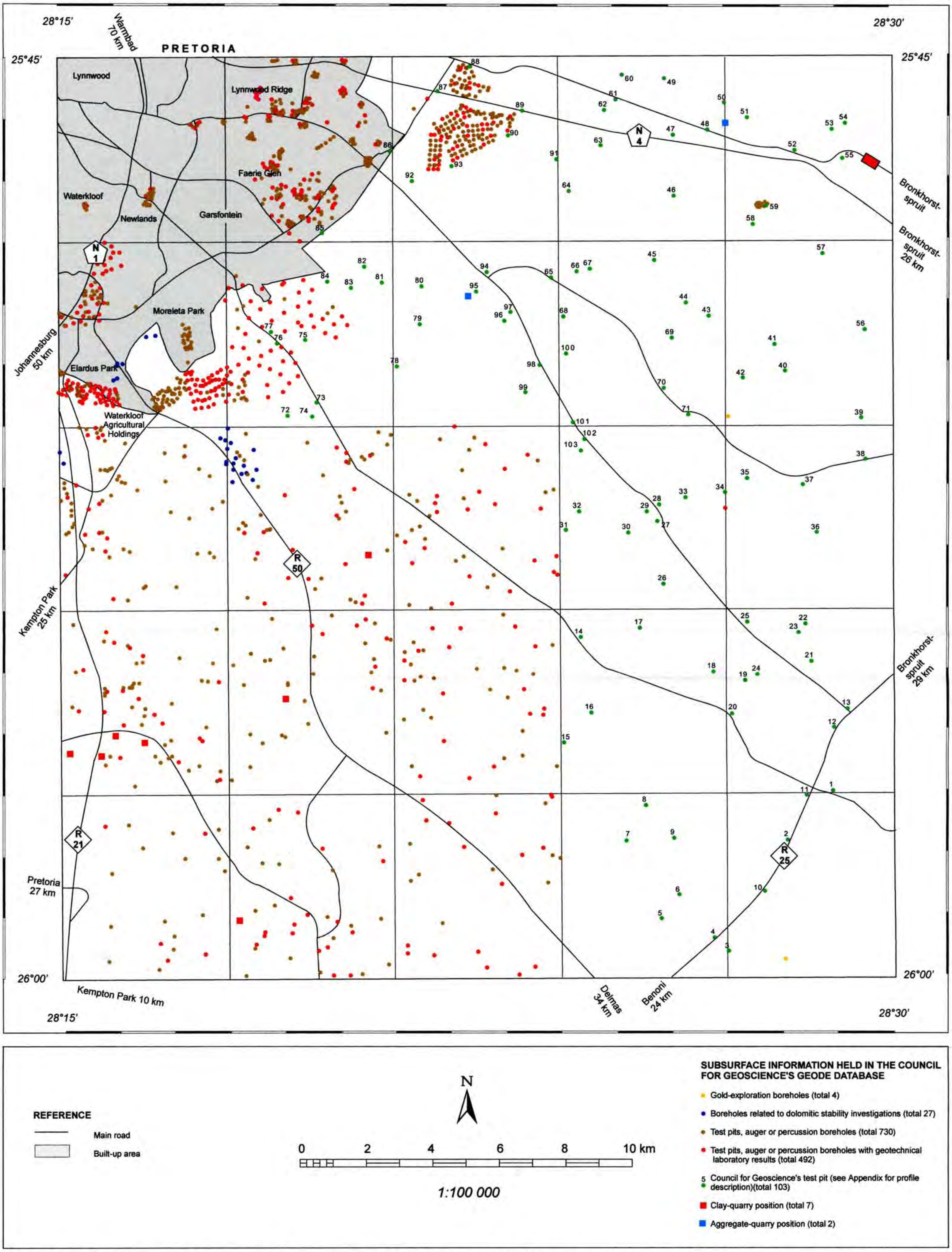


Figure 11: Physoigraphy of the Rietvlei Dam map sheet with an orthophotograph grid showing the positions of boreholes and test pits for wich information is held (Table 25) in the Council for Geoscience's database (GEODE)

Table 26: Listing of geotechnical factors and cost and environmental category for each area numbered shown on the 1:50 000-scale geotechnical map

Number of geotechnical area	GEOTECHNICAL FACTORS (see 'Geotechnical Factors: Definition, Implications and Severity' for an explanation of abbreviations)						Cost and environmental category				
	Critical factors				Subcritical factors		1	2	3	4	5
1	Act4	Exc4			Per2		■				
3	Exc5						■				
8	Col2						■				
9	Exc3	Col2			Per3			■			
17	Act3	Col2			Per2		■				
24	Inu2										■
30	Exc4	Col2			Per3			■			
34	Sin2	Col4			Per3			■			
42	Act4	Exc3			Per2		■				
44	Act4	Exc3					■				
73	Act3	Exc3					■				
74	Sin2	Exc3					■				
76	Sin2	Exc5					■				
81	Act4	Exc4					■				
82	Sin2	Exc4					■				
141	Exc3	Col2			Sha2					■	
146	Sin2	Act4			Con2	Sha2			■		
147	Inu2	Sin2	Act4		Sha2	Per2				■	
148	Sin2	Act3			Per3				■		
149	Inu2	Sin2	Act4		Sha2					■	
153	Sin2	Act2	Exc3				■				
155	Act3	Exc3	Col2		Per2		■				
156	Act5	Col2			Per3			■			
157	Act3	Exc3			Per2		■				
162	Act5				Per3		■				
163	Inu2	Sin2	Act3		Sha2				■		
164	Act2	Exc4	Col2				■				
165	Inu2	Act2			Sha2	Per2					■
167	Slo2	Act2	Exc2	Col2			■				
168	Act2	Exc2	Col2				■				
169	Act2	Col2			Sha2				■		
171	Inu2	Sin2	Act2						■		
180	Act2	Col2			Per2		■				
209	Slo2	Exc2			Sha2				■		
227	Inu2	Sin2	Act5		Per2				■		
233	Inu2	Act4			Per2				■		
241	Act3	Exc4	Col2		Per2		■				
262	Act3	Exc5			Per2		■				
267	Act4	Exc5			Per2		■				
268	Sin2	Act3	Exc4		Per3			■			
270	Act3	Exc4			Per2		■				
271	Act3	Exc5	Col2		Per2		■				
273	Inu2	Act5			Per2					■	
276	Sin2	Act3	Exc4		Per2			■			
278	Slo2	Act3	Exc3		Per2		■				
289	Act3	Exc3			Per4				■		
290	Slo2	Act3	Exc4		Per2		■				
302	Act3	Exc3			Per3				■		
306	Act4				Per2		■				
307	Act3	Exc5			Per4				■		
308	Act3				Per2		■				
321	Act3	Exc5					■				
331	Slo2	Act3	Exc5		Per2		■				
339	Sin2	Act3	Exc5		Per3			■			
340	Sin2	Act3	Exc3		Per3			■			
341	Slo2	Act4	Exc4		Per2		■				
342	Sin2	Act3			Per4				■		
345	Sin2	Act3	Exc3	Col2	Per3			■			
346	Act3	Exc4			Per3			■			
347	Exc5	Col2			Per3			■			
348	Exc5	Col2			Per4			■			
349	Exc4	Col2			Per4			■			
350	Act3	Ero2			Per2			■			
353	Slo2	Act3	Exc3		Per3			■			
354	Act3	Exc5			Per3				■		
356	Act3				Per4				■		
357	Slo2	Act3	Exc5		Per3				■		
358	Act4	Exc4			Per3				■		
359	Act4	Exc5			Per3			■			
360	Act4				Per3			■			
361	Slo2	Act4	Exc3		Per2		■				
362	Act2	Exc4			Per3			■			
363	Slo2	Act4			Per2		■				
364	Act5				Per2		■				
365	Act4	Exc3			Per3			■			
367	Col4				Per2		■				
368	Inu2	Sin2	Act4		Per4				■		
369	Act3	Col4			Per3			■			
370	Act3	Col5					■				
371	Act3	Col2			Per4				■		
372	Act3	Col2	Ero2		Per2				■		
373	Inu2	Sin2	Act4		Per2				■		
374	Inu2	Act3	Exc3		Per2					■	
375	Act3	Col3			Per3				■		
376	Col4				Per4				■		
377	Act3	Col4			Per2		■				
378	Act3	Exc4			Per4				■		
379	Sin2	Act3	Col3		Per3			■			
380	Sin2	Act3	Exc3		Sha2	Per2			■		
381	Inu2	Act3	Exc3		Per3					■	
382	Inu2	Act3			Per3					■	
383	Sin2	Act3	Col4		Per3				■		
384	Inu2	Act3	Exc4		Per3				■		
385	Inu2	Act4	Exc3		Sha2	Per2			■		
386	Inu2	Act3	Exc4		Per2				■		
387	Inu2	Sin2	Act3	Exc3	Per2				■		
388	Inu2	Sin2	Act3		Per4				■		
389	Inu2	Sin2	Act3	Exc4	Sha2	Per2			■		
390	Inu2	Act5	Exc3		Per2						■
391	Inu2	Act2			Per2						■
392	Inu2	Act4	Exc3		Per2				■		
393	Sin2	Act3	Exc5		Per2		■				
394	Sin2	Act3	Sub2		Per3			■			
395	Act4	Exc4	Ero2		Per2			■			
397	Slo2	Act3			Per2		■				
398	Act3	Col2			Per3			■			

Financial-Environmental category

1	Financially related geotechnical factors
2	Mainly financially related geotechnical factors with some environmental factors
3	Combination of financial and environmentally related geotechnical factors
4	Mainly environmentally related geotechnical factors and a small number of factors with a low financial cost
5	Predominantly environmentally related geotechnical factors

5.3.4 Terrain description

5.3.4.1 Physiography

The area covered by the Rietvlei Dam map sheet is relatively flat to gently undulating, with three prominent quartzite and chert ridges striking north-west to south-east across the map area. The first ridge is situated north of the N4 (Magaliesberg), the second (Bronberg Ridge) is situated between the N4 and the R50, with the third situated south of the R50. Slope profiles vary from concave or convex to straight slopes. The majority of slopes exhibit a 1° - 6° gradient, with slope angles greater than 12° in the vicinity of the ridges and some of the hill crests. The highest point in the map sheet area, is situated south of the R25 road at 1668,6 metres above mean sea level (m.a.m.s.l.). The lowest point is situated in the flood plain of the Pienaars River, situated north of the 104 road at 1298 m.a.m.s.l.. Other landforms present in the map sheet area, are plains, drainage channels, river channels, dams, excavations, and marshy areas.

5.3.4.2 Climate

Climatic data was obtained from the Johannesburg International Airport weather station, which is situated approximately 20 km south of the map sheet. The climate of the area is sub-humid, with an average annual rainfall of 760 mm falling predominantly between September and March. Annual temperatures vary from an average summer maximum of 25,8°C to an average winter minimum of 3°C. The prevailing wind direction is north-east and averages 6,5 knots (personal comment Weather Bureau, 1999). Weinert's climatic N-value for this area is N=2.4, which indicates that decomposition is the dominant form of weathering resulting in the formation of thick soils (Weinert, 1980).

5.3.4.3 Drainage

A few perennial rivers (Rietvlei and Pienaars), streams (Sesmylspruit, Moreletaspruit) and several non-perennial streams drain the map area, in a northly direction. Numerous perennial (Rietvlei Dam, Groot Dam, Witfontein Dam, Pan Dam) and non-perennial dams and pans, are scattered throughout the area.

5.3.4.4 Vegetation

Much of the area is occupied by farms and agricultural holdings, with grazing and maize as the predominant crop. Uncultivated areas are described as Moist Cool Highveld Grassland and Rocky Highveld Grassland (Bredenkamp and van Rooyen, 1998). The Moist Cool Highveld Grassland comprises *Cymbopogon-Themeda* Veld (sparse, tufted veld) and *Themeda triandra-Eragrostis curvula* Grassland. The area covered by Rocky Highveld Grassland comprises Giant Speargrass (*Trachypogon spicatus*), Broadleaf Bluestem (*Diheteropogon amplectens*), Red Autumngrass (*Schizachyrium sanguineum*), *Andropogon schirensis*, Loudetia simplex (*Tristachya leucothrix*), *Panicum natalense, Bewsia biflora, Digitaria tricholaenoides, Digitaria monodactyla* and *Sporobolus pectinatus* grassveld types.

5.3.4.5 Geology

The following is an overview of the major rock types that occur in the Rietvlei Dam map area as described by Minnaar and Britz (1997) that accompanies the 1:50 000-scale geological map of the Rietvlei Dam 2528CD map sheet (Council for Geoscience, in prep.) and the geological explanation by Visser *et al.* (1984) for the 1:1 000 000-scale geological map (Table 27).

The map sheet is underlain by three major sequences, namely the Transvaal Supergroup, followed by the Karoo Supergroup, with the youngest geological deposits represented by unconsolidated alluvium and colluvium of Quaternary age. A large number of faults intersects the Pretoria Group rocks, across the map sheet in a general north-east to south-west direction (strike).

Table 27: Summary of the geological units present on the Rietvlei Dam 1: 50 000 map sheet (after Minnaar and Britz, 1997).

GEOLOGICAL ERA	AGE (Ma)		GROUP	SUBGROUP	FORMATION	LITHOLOGY	INTRUSIVE ROCS
Quaternary	0 - 1,6	Surficial Deposit				Alluvium (clays, silts, gravels and conglomerate); colluvium (sands, silts, clays and gravels)	
Permian	250 - 355	Karoo Supergroup	Ecca Group		Vryheid	Sandstone, grit, conglomerate, shale, clay and subordinate coal beds	
Carboniferous			Dwyka Group			Tillite, sandstone and grit	
Mokolian	900 - 2050						Syenite
Vaalian	2050 - 2650	Transvaal Supergroup	Pretoria Group		Rayton	Quartzite	Diabase
					Magaliesberg	Quartzite	
					Silverton	Shale and chert	
					Daspoort	Quartzite	
					Strubenkop	Shale and quartzite	
					Dwaalheuwel	Quartzite and shale	
					Hekpoort	Andesite	
					Boshoek	Quartzite	
					Timeball Hill	Shale and diamictite	
					Klapperkop Member	Quartzite	
					Timeball Hill	Shale and diamictite	
					Rooihoogte	Conglomerate	
			Chuniespoort Group	Malmani Subgroup	Eccles	Chert-rich dolomite and chert breccia	
					Lyttleton	Dark, chert-free dolomite with large, elongated stromatolitic mounds	

Outcrop is good with the resistant lithologies such as quartzite and chert forming hill crests and ridge crests. Alluvium is present in drainage channels, marshy areas and in flood plains, across the map sheet. Much of the area is covered with colluvium, except in areas where alluvium or outcrop occur. Intrusive dykes and sills of diabase (Transvaal related) and syenite (Mokolian age) occur across the map sheet, striking north-west to south-east.

The Transvaal Supergroup consists of clastic and chemical sediments and volcanic rocks, of the Chuniespoort Group and Pretoria Group. The Malmani Subgroup (Chuniespoort Group) comprises alternating bands of chert-bearing and chert-free dolomite, with local occurences of carbonaceous shale and quartz. The Malmani subgroup is subdivided into five formations, of which only the Lyttleton and Eccles Formations occur on the map sheet. The Lyttleton Formation is situated west of the R21 road (on orthophotograph 16) and east of the R50 road (on orthophotograph 17) and the overlying Eccles Formation occurs in the vicinity of the R21 and R50 roads (on orthophotographs 11, 12, 16 - 18 and 21 - 24). The overlying Pretoria Group covers more then 95% of the map sheet area and comprises mainly clastic rocks of quartzite, shale and a prominent volcanic unit with locally occurring carbonates. The Pretoria Group is subdivided into the Rooihoogte, Timeball Hill, Boshoek, Hekpoort, Dwaalheuwel, Strubenkop, Daspoort, Silverton, Magaliesberg and Rayton Formations.

The overlying Karoo Supergroup occurs in the southern portion of the map sheet (on orthophotograph 16 - 18 and 22 - 25) and is subdivided into the Dwyka and Ecca Groups. Remnants of Karoo Supergroup occur as pockets or outliers in dolomite of the Chuniespoort Group. The Dwyka Group is composed mainly of diamictite with subordinate shale and mudstone, containing pebbles, gravel and conglomerate. The overlying Ecca Group is represented by the Vryheid Formation, which comprises sandstone, alternating with beds of soft sandy shale and some coal seams.

5.3.4.6 Hydrogeology

Most of the information in this section was obtained from research done by Kuhn (1989), based on the hydrogeology of the Midrand - Kempton Park dolomite area.

The hydrogeological properties of the dolomite in the Rietvlei Dam map sheet area are controlled by structure, stratigraphy and geomorphology. Water bearing properties of the dolomite stem from preferential development of carbonate dissolution along fault and fracture zones, joints and bedding planes. Chert-rich dolomite formations constitute better aquifers, since the chert layering supports the strata and keeps the leached void system open. The dolomite is traversed by low permeable or impermeable dykes that act as hydrogeological barriers (Kuhn, 1989). The overlying Pretoria Group exhibits very low primary permeabilities and weakly developed secondary permeabilities along faults and fractures (Kuhn, 1989).

Outflow of groundwater from dolomite compartments occurs as discharge into surface drainage systems, underground flow through weathered and fractured dykes or as leakage over impermeable dykes to adjacent compartments. Perched water levels are usually associated with Karoo outliers (Kuhn, 1989).

The positions of Figure 13, 14 and 15 are indicated on Figure 12.

5.3.4.6.1 Water levels

Piezometric water levels in metres above mean sea level (m.a.m.s.l), depth to water level from surface and groundwater contours are shown in Figure 13. The contour map revealed low groundwater gradients (less than 0,006 or 6 m/km) along strike and moderate gradients (up to 0,012 or 12 m/km) normal to strike (Kuhn, 1989). Water levels in the Pretoria Group follow the general topography (Kuhn, 1989).

5.3.4.6.2 Groundwater flow

Groundwater flow in the dolomite rocks occurring in the study area occurs generally from south to north in the highly transmissive Eccles Formation parallel to geological strike, with the Pretoria Group in the east supplying groundwater to the dolomite (Kuhn, 1989).

Piezometric levels in the Sterkfontein compartment (Fig. 14), reveals that the direction of groundwater flow in this compartment is from south-southeast to north-northwest (Fig. 13). Piezometric levels in the Rietvlei compartment (Fig. 14), revealed that the direction of groundwater flow in this compartment is in a south-western direction, whilst the groundwater flow direction in the Witkoppies compartment (Fig. 14) is also from south to north (Fig. 13).

5.3.4.6.3 Hydrogeological Compartments

Dykes can act as linear groundwater barriers, depending on their depth of weathering/fracturing and on the water levels in the adjacent compartments. Dykes which initially do not act as barriers may form groundwater barriers once large scale abstraction results in excessive lowering of watertables. On the other hand, leakage occurring through dykes which form barriers in the present state, might increase due to the increased hydraulic pressure differences caused by abstraction on one side of the dyke (Kuhn, 1989). Figure 12, delineate the different dolomite compartments, created by dykes and other geohydrological barriers, for the south-western portion of the map.

Rietvlei Compartment

This compartment is confined by the Pretoria Group in the north, south and west and the Sterkfontein dyke in the south. Numerous dolerite and syenite intrusions that occur in this area subdivided this compartment into subcompartments (Fig. 15). Dyke A, represents the Sterkfontein dyke that forms the southern boundary of the Rietvlei compartment, with dykes B and C subdividing the compartment into three

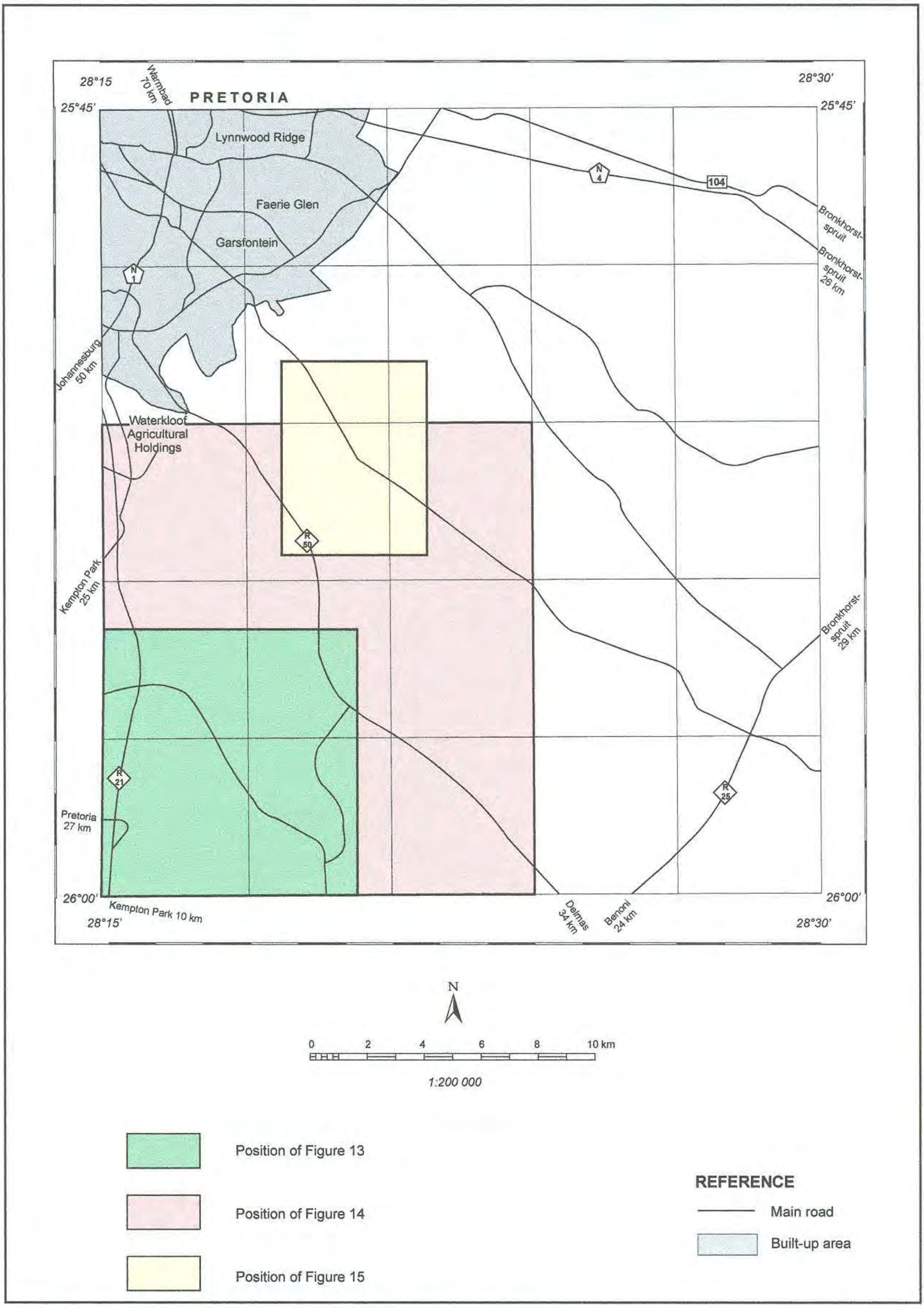


Figure 12: Position of Figures 13, 14 and 15 for the 1:50 000-scale Rietvlei Dam map sheet (after Carr,1995).

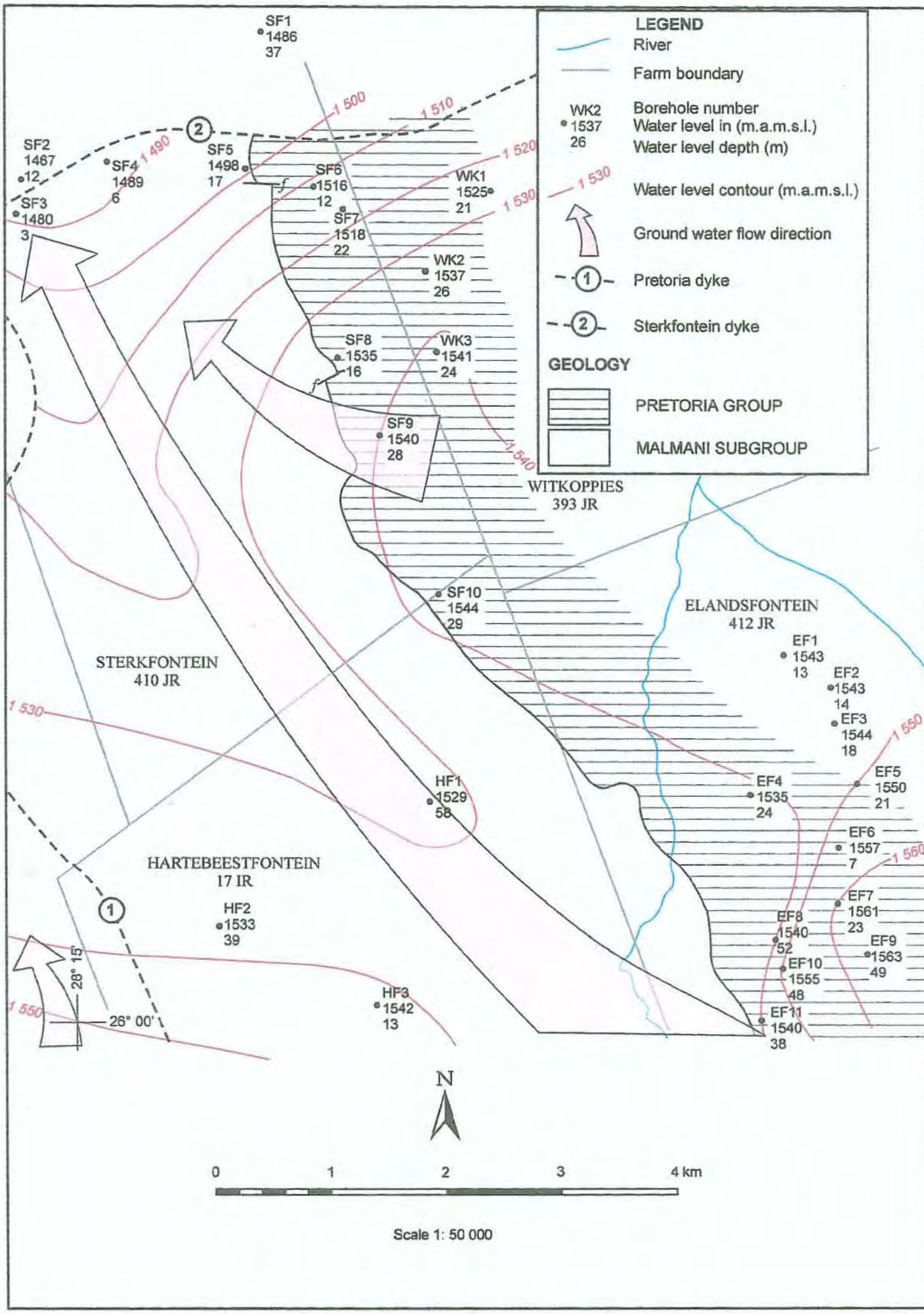


Figure 13: Movements and levels of ground water in the dolomite compartments for the southwestern portion of the Rietvlei Dam map sheet (after Kuhn, 1989).

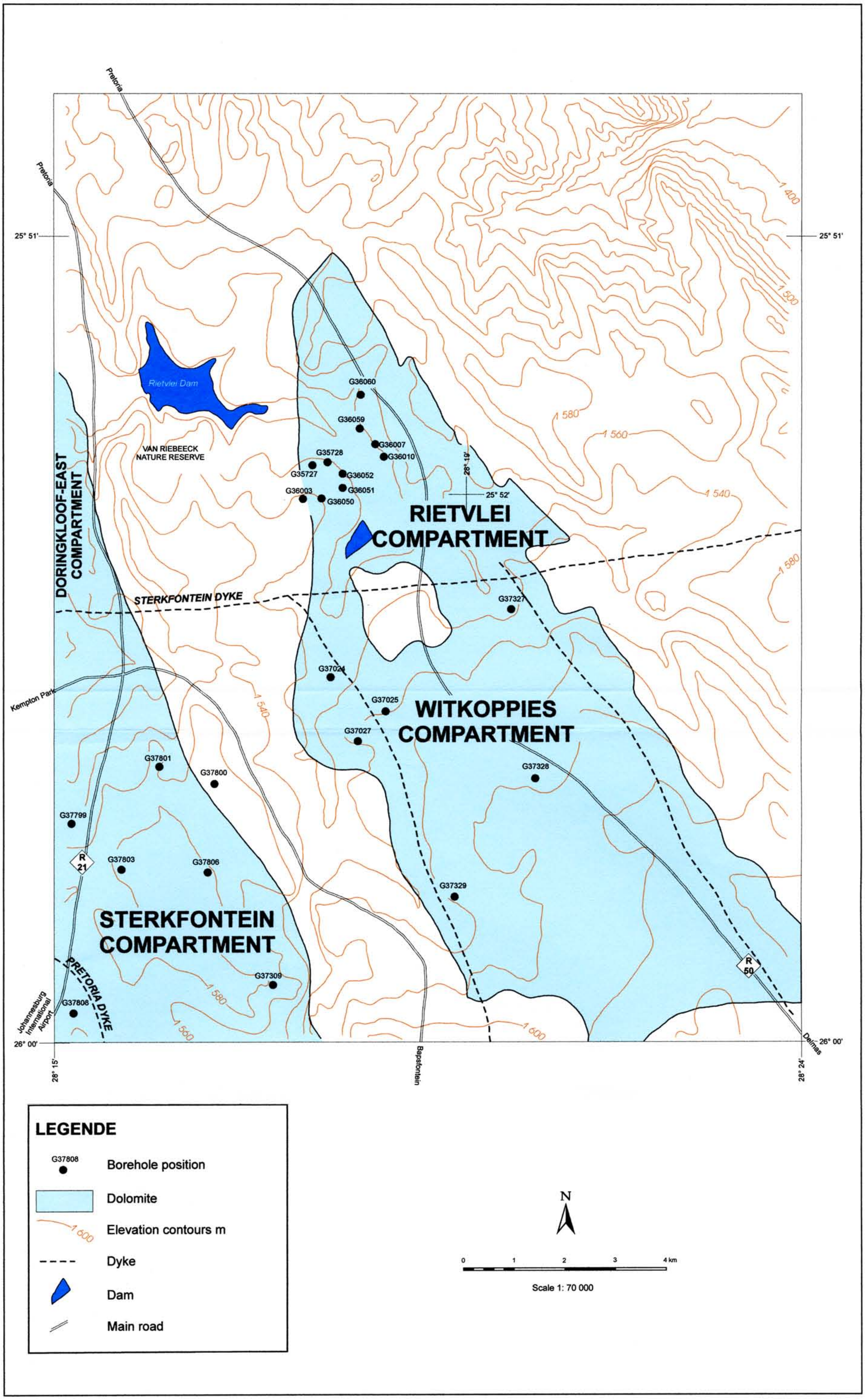


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Figure 14 Dolomite compartments and Department of Water Affairs and Forestry (DWAF) boreholes for the Rietvlei Dam map sheet (after Kuhn, 1989)

subcompartments, X, Y and Z (Kuhn,1989). Loss of groundwater occurs through the discharge of springs and is recharged by rainfall. Compartment X is also recharged by surface inflow from a nearby stream. A purification plant situated at the Rietvlei Dam, purifies effluent discharged from the Kempton Park sewage works that flow into the drainage system of the Rietvlei compartment. Large-scale pumping of groundwater from the compartment has resulted in the lowering of the groundwater table and consequently drying-up of springs. This practice could lead to the formation of sinkholes and dolines in the area (Kuhn, 1989).

Witkoppies Compartment

This compartment is confined by the Pretoria Group in the east and west, the Sterkfontein dyke in the north and the Tweefontein dyke (outside map sheet area) in the south (Fig. 14). An average groundwater depth could not be estimated, due to fluctuating groundwater levels (Kuhn, 1989).

Sterkfontein Compartment

The Sterkfontein compartment is confined by rocks of the Pretoria Group in the east, the Sterkfontein dyke in the north, the Tweefontein dyke (outside map sheet area) in the south and the Pretoria dyke (outside map sheet area) in the west (Fig. 14). The groundwater level for this compartment is less variable than those in the Rietvlei and Witkoppies compartments (Kuhn, 1989). Groundwater is discharged from this compartment mainly for agricultural purposes and municipal water supply (Kuhn, 1989).

Doornkloof-east Compartment

This compartment covers a small area of the map sheet being confined by the Irene dyke (outside map sheet area) in the north, Pretoria Group in the east, Sterkfontein dyke in the south and Pretoria dyke (outside map sheet area) in the west (Fig. 14). No groundwater levels or borehole information is available for this compartment (Kuhn, 1989).

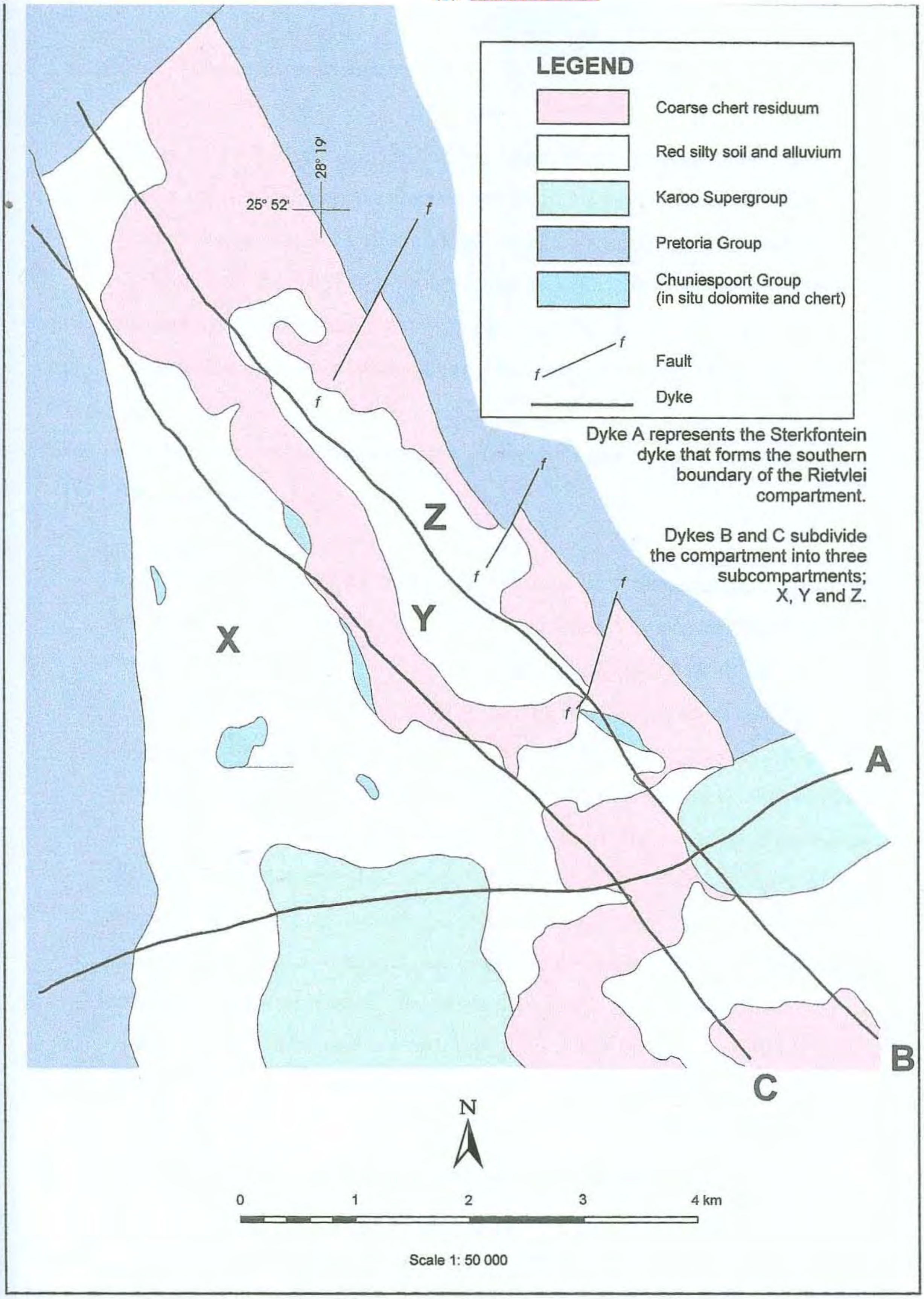

Figure15: Rietvlei dolomite compartment and subcompartments for the Rietvlei Dam map sheet (after Kuhn, 1989).

5.3.4.6.4 Groundwater quality

The groundwater contained within the dolomite and surrounding aquifers is of excellent quality for both human consumption and irrigation purposes, except in the vicinity of the Rietvlei drainage feature, where effluent from the Kempton Park sewage works infiltrates the aquifer (Kuhn, 1989). It was found that groundwater samples obtained from quartzite and shale of the Pretoria Group with pH-values less than 6.5, could be slightly corrosive towards steel structures, although the pH normally changes to 7 on aeration (Kuhn, 1989).

5.3.5 Engineering geological properties of residual and transported soils in the Rietvlei Dam map sheet area

Soil is formed when the parent rock is broken down by chemical and physical weathering processes. Physical weathering (disintegration caused by alternate freezing and thawing) or erosional processes, results in soil particles which retain the same mineralogical composition as that of the parent rock. In contrast, chemical weathering results in changes in the mineral form of the parent rock due to the action of water, oxygen and carbon dioxide and the formation of new minerals (clays and salts). Many of the physical properties of soils are dictated by the size, shape and chemical composition of the individual particles and their origin (parent material). If the products of weathering remain at their original location (in-situ weathering) they constitute a residual soil, but when the products of weathering are transported and deposited in a different location they constitute a transported soil. Below an overview of the general geotechnical properties of soils formed from various rock types that occur on the Rietvlei Dam map sheet is given.

5.3.5.1 Residual soil derived from the Transvaal Supergroup

5.3.5.1.1 Chuniespoort Group (Malmani Subgroup)

The Malmani Subgroup comprises dolomite and chert (Table 27). Ancient carbonate rocks are predominantly composed of the minerals calcite ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) . If a carbonate rock is dominated by calcite (more than 95%) it is called limestone, when it is dominated by dolomite (the mineral) it is called dolomite (the rock) (Warren, 2000). Dolomite, as a rock contains more than 90% dolomite and less than 10% calcite as well as detrital minerals and secondary silica (chert). Very few, if any sedimentary dolomites are realy stoichiometric (($CaMg(CO_3)_2$) and are better represented as: $Ca_{(1+x)}Mg_{(1-x)}(CO_3)_2$, encompassing the spectrum from calcian to magnesian dolomites (Warren, 2000).

Acidic rainwater and groundwater that percolates through the network of joints, fractures and faults in the vadoze and phreatic zones dissolves the dolomite in the form of bicarbonate and giving rise to karst features such as cave systems and voids (Buttrick, 1992). This karst landscape (irregular bedrock of dolomite pinnacles) is buried beneath younger deposits which may collapse or be transported into the voids and cave systems due to the infiltration of surface water, water level draw-down by the lowering of the water table, or ground vibrations, resulting in catastrophic ground movement at the surface, to form sinkholes or where subsidence is gradual to form dolines (Buttrick, 1992).

The occurrence of dolomite floaters that represents former dolomite pinnacles could cause excavatability problems and/or can lead to a misleading interpretation of the bedrock depth and geotechnical conditions (Brink, 1979). Consolidation problems can also be expected where wad (highly compressible manganiferous earth derived from the weathering of dolomite) is present close to the surface (Brink, 1979).

5.3.5.1.2 Pretoria Group

The Pretoria Group comprises mainly quartzite and shale (Table 27). Brink (1979) reported that collapsible sands can be derived from the weathering of quartzite of the Pretoria Group, especially if it has a high feldspathic content. However, foundation problems at shallow depth are usually not encountered on residual shale or quartzite of the Pretoria Group, due to their high bearing capacities (Brink, 1979). The Silverton and Strubenkop shale Formations exhibit smooth and even bedding planes, which can result in sliding of the rockmass along the direction of dip into excavations (Brink, 1979). Differential settlement can occur at the contact between residual soft shale and hard rock quartzite, due to differential weathering (Brink, 1979). Although residual shale of the Pretoria Group exhibits a generally low potential for expansiveness, portions of the Silverton Formation shale contain a high percentage of montmorillonite to give highly expansive residual soils (Brink, 1979). Similarly, residual soil on andesite of the Hekpoort Formation may also be moderately to highly expansive (Brink, 1979). An important feature of the andesite is the extreme variability in depth of weathering and soil profile thickness within several metres of an outcrop (Brink, 1979). This irregular bedrock profile, gives rise to differential settlement problems requiring shallow footings on outcrop and piling in deep residual soils when placing foundations (Brink, 1979). Attention should be given to the occurrence of andesite core-stones and 'floaters', which can lead to a misleading interpretation of the bedrock depth and geotechnical conditions (Brink, 1979).

5.3.5.2 Residual soil derived from the Karoo Supergroup

Tillite, shale and sandstone of the Dwyka Group weathers to form, brown or red brown, clayey to gravelly residual soils that are potentially collapsible and expansive (Brink, 1983). The Vryheid Formation of the Ecca Group, comprises mainly sandstone, shale and coal seams (Table 27). The sandstone weathers to brown or red, medium to fine-grained sand or silt, which may exhibit a collapsible fabric (Brink, 1983). The shale weathers to grey, yellow or black clays, that contain a high percentage of kaolinite and subordinate illite, which implies a low potential for expansiveness. The depth of weathering of the shale varies from 1 m to more than 2 m. According to Brink (1983), dispersive clays are also associated with soils derived from the Dwyka and Ecca Groups.

5.3.5.3 Pebble Marker

The pebble marker is a band of gravel that demarcates the boundary between transported soils and the underlying residual soils or bedrock (Jennings *et al.*, 1973). The pebble marker is not a regular stratigraphic unit but differs in age and mode of origin from place to place. From an engineering geotechnical perspective the pebble marker represents a stratum of free drainage, which must be sealed for certain constructions such as dams. Conversely, where drainage is required it may be retained and be usefully employed to provide free flow of water especially in areas susceptible to inundation (Jennings *et al.*, 1973). The pebble marker may pose excavatability problems where the unit comprise gravel and boulders of fresh quartzite, shale, andesite, chert, dolerite or diabase. Pebble markers were found in more than 40% of the trial pits, at different depths, varying in thickness from 0,1 to 0,4 metres, comprising gravel and boulders of quartzite, chert, shale and andesite, ferricrete concretions and occasionally diabase gravel and boulders.

5.3.5.4 Ferricrete deposits (Pedogenic material)

A colloquial name for ferricrete is 'ouklip'. It forms by the percolation of water through a soil profile in which a fluctuating water table occurs. In areas with a N-value of less than 5, percolating water mobilises soluble, ferrous iron (Fe^{2+}), which is derived predominantly from the partial solution of mafic minerals. This iron is conveyed downward to the base of the perched water table where it is oxidised to less soluble ferric iron (Fe^{3+}) and precipitates to form ferricrete. According to Brink (1985), ferricrete can develop in any soil type where the hydrological conditions are favourable. Geomorphologically, these include gully heads, hillslope-pediment junctions and on pan and vlei side slopes (Partridge, 1975). Ferricrete was encountered in more than 60% of the test pits, at depths of 0,1 to 2,0 metres varying between 0,2 and 1,0 metres thickness. The type of ferricrete varies from concretionary, honeycomb to hardpan ferricrete with the concretionary type being dominant. A ferricrete layer of adequate thickness can also provide stable founding conditions at a shallow depth for structures (Brink, 1985). Severe excavatability problems are also associated with hardpan ferricrete.

5.3.5.5 Colluvium

Colluvium is defined as unconsolidated material on hill or mountain slopes, which has moved downslope principally by the action of gravity and aided by non-channelled running water (Brink, 1985). The engineering characteristics of colluvium are controlled by the nature of the parent rock type and the processes of transportation to which it has been subjected to (Brink, 1985). Colluvial soils vary in exhibiting an intact to open structure with high void ratios and low in-situ densities. The main engineering geological problem associated with these soils is the presence of a collapsible soil fabric. Colluvial material derived from weathered sandstone and quartzite in the map area is potentially collapsible, as was observed in test-pits on Magaliesberg quartzite (on orthophotograph 5). The clays that occur in colluvial soils may also have dispersive properties (Brink, 1985). The good compaction characteristics of these soils render them suitable for use in the lower layers of road pavements.

5.3.5.6 Alluvium

Alluvium includes the most recent deposits and is confined to drainage channels, flood plains and marshy areas. The behaviour of alluvial soils depends largely on the rock type from which it was derived (Haskins, 1994). For example, where quartzite or sandstone is the source, the transported soils will exhibit a collapse potential, whereas transported soils from shale, dolerite or Hekpoort Formation andesite will exhibit a potential for heave (Brink, 1985). The collapsible soils or soft alluvial clays may also exhibit a low shear strength and is therefore highly compressible (Brink, 1985).

5.3.6 Geotechnical laboratory analysis of soils

The 236 disturbed samples obtained during the fieldwork phase and those from an investigation previously conducted by Carr (1995) for the Council for Geoscience, were analysed for key indicator tests and other parameters to determine the geotechnical properties to be expected for unconsolidated materials in the map area.

The following laboratory tests were conducted on disturbed soil samples:

- Particle size distribution
- Atterberg limits
- Emerson crumb test

Particle size distribution was obtained by sieve analysis and hydrometer tests and the soils were classified according to the Unified Soil Classification System (Howard, 1984). Atterberg limits were determined along with the expected maximum probable heave and expansiveness according to the method of Van der Merwe (1964). Hazen's formula was used to determine the soil permeability. Emerson Crumb tests were performed to determine the potential erodibility of the soils.

Nineteen undisturbed samples were submitted for collapse potential tests to determine their potential for collapse and possible problems with settlement.

5.3.7 Geotechnical characteristics of soils in the area and implications for development

A number of geotechnical problems were identified from the fieldwork and laboratory results. An indication of the surface area covered by each of the specific geotechnical entities is given in Table 28. The distribution of severity classes for each geotechnical factor present on the Rietvlei Dam map sheet, are presented in Appendix 1. The more important geotechnical parameters are discussed below.

5.3.7.1 Inundation

Inundation or flooding affects the use of low, flat lying alluvial lands for agricultural, construction and development purposes. Incorrect site development could lead to the loss of life and financial loss through infrastructure damage.

Table 28: Spatial analysis showing the total area (km²) and severity class (Table 21) for each geotechnical factor identified on the Rietvlei Dam map sheet.

Geotechnical Factor	Total area (km²) and % of Map sheet	Area (km²) and % of each Severity Class
Inundation (flooding)	101 (15%)	-
Sinkhole formation	113 (16%)	-
Slope instability	39 (6%)	-
Active, expansive or swelling soil	665 (96%)	Act2: 5 (<1%) Act3: 398 (58%) Act4: 246 (36%) Act5: 16 (2%)
Excavatability of ground	516 (75%)	Exc2: 2 (<1%) Exc3: 324 (47%) Exc4: 123 (18%) Exc5: 67 (10%)
Collapsing or settling of soil	55 (8%)	Col2: 51 (7%) Col3: 0,2 (<1%) Col4: 3 (<1%) Col5: 0,1 (<1%)
Subsidence	0,1 (<1%)	-
Erodible soil	3 (<1%)	-
Poorly consolidated soil	0,2 (<1%)	-
Shallow water table	8 (1%)	-
Permeability of soil	665 (96%)	Per2: 438 (63%) Per3: 215 (31%) Per4: 12 (2%)

Approximately 101 km² (15%) of the map sheet is susceptible to inundation (Table 28, Fig. 16). This includes the areas confined to drainage channels and the flood plains of the Rietvlei River situated west of the R50, the Pienaars River situated east of the R50 road, the Sesmyl Spruit and Moreleta Spruit (Fig. 16). Inundation can also occur at Rietvlei Dam (othophoto 11), Groot Dam (orthophoto 18), Witfontein Dam (orthophoto 13) and Pan Dam (orthophoto 18) (Fig. 16).

5.3.7.2 Sinkhole formation and subsidence

All areas underlain by dolomite exhibit a potential for sinkhole or doline formation. Approximately 113 km² (16%) of the map sheet is susceptible to sinkhole formation (Table 28, Fig. 17). According to Carr (1995), more than 30 sinkholes exist in the area underlain by dolomite, due to abstraction of groundwater for municipal water supply. The sinkholes occurred mainly in the Rietvlei (orthophotograph 12) and Witkoppies (orthophotographs 17, 18, 22, 23 and 24) hydrogeological compartments (Fig. 17). Preferential groundwater movement along faults in the dolomite increases the risk of sinkhole development along these zones.

The regional nature of the geotechnical mapping did not allow the determination of sinkhole formation severity classes for any particular area. Borehole information reveals that the extent of the area underlain by dolomite is much greater than that indicated on the geology map where large areas are shown to be covered by shale and quartzite of the Pretoria Group. Precautionary measures, site specific investigations and specified founding methods should be employed in areas that are underlain by dolomite. According to Buttrick (1992), these may include:

- No accumulation of surface water to be permitted with the entire development being properly drained.
- Conventional foundations (strip or spot footings) for light structures where the risk of settlement is found to be acceptable.
- Split construction where differential settlement is greater than 5 mm.
- Construction of a mattress of improved material below the foundations.
- Inserting reinforcing strips in the underlying mattress.
- Founding on pinnacles.
- Compaction of material overlying dolomite bedrock.
- Grouting of the soil beneath the foundations.

5.3.7.3 Slope instability

Residential development is favoured on slopes with a gradient of less than 12°. The Rietvlei Dam area is relatively flat to undulating with three prominent ridges that trend north-west to south-east across the map sheet and which are capped with resistant quartzite, chert and shale.

Approximately 39 km^2 (6 %) of the Rietvlei Dam map sheet exhibits potential slope instability problems (Table 28, Fig. 18). Natural slope instability (steep slope gradients and the occurrence of faults) comprises ridges and isolated hills, consisting of quartzite, shale or chert breccia of the Transvaal Supergroup (orthophotographs 1, 2, 6, 7, 18 and 19) (Fig. 18). The Pretoria Group rocks of the Transvaal Supergroup dip in a north-easterly direction. The south-western side of hill slopes and ridges may therefore exhibit slope instability in excavations. This was noted in some test-pit profiles, that showed unstable sidewalls in the north-eastern and south-eastern portion of the map sheet, including the farms Zwartkoppies 364 IR, Zwavelpoort 373 JR, Tiegerpoort 371 JR, Mooiplaats 367 JR, Donkerhoek 365 JR, Kleinfontein 368 JR, Klipkoppie 396 JR and Kameel Zynkraal 547 IR. Induced slope instability into excavations can also occur in shale of the Silverton Formation, due to its smooth and even bedding planes along which the rock mass can slide along the direction of dip (Fig. 18).

Existing quarries were classified as exhibiting potentially unstable slopes and occur north of the N4 (orthophotograph 4 and 5), south of the N4 in the northern to central portion of the map sheet, on Zwartkoppies 364 IR, Tweefontein 372 JR, Mooiplaats 367 JR, Tiegerpoort 371 JR and Zwavelpoort 373 JR (orthophotographs 3, 8, 9, 14) and in the south-eastern portion of the map sheet on the farm Onbekend 398 JR (orthophotographs 12, 13, 16, 17, 21 and 22) (Fig. 18).

5.3.7.4 Active, expansive or swelling soils

The method of Van der Merwe (1964) was used to determine the potential heave of soil samples. Although this method is widely used in South Africa, it may under estimate the potential expansiveness. This is ascribed to it's reliance on the plasticity index and clay percentage (fraction of soil passing the 2 micron sieve) of the soil, where the clay fraction could also contain a significant amount of non-swelling minerals such as quartz and calcite. In addition to Van der Merwe's method, the plasticity index and linear shrinkage of soil samples were used to indicate the soils potential expansiveness.

Large areas of the Rietvlei Dam map sheet, approximately 665 km^2 (96%) exhibit swelling or expansive properties ranging from low to high (Table 28, Fig. 19). Areas with high expansive potential are expected to have a heave of greater than 30mm and can be grouped into two geomorphic/geological areas. The first area is confined to parts of the Rietvlei River flood plain situated west of the R50 and the Swawelpoort Spruit flood plain situated east of the R50. The second area is associated with colluvial and residual soils developed on the Hekpoort andesite Formation and the Transvaal Supergroup related diabase situated on the farms Tiegerpoort 371 JR and Zwavelpoort 373 JR (orthophoto 8, 13 and 14). The same applies to the Dwyka Group tillite and shale on the farm Grootfontein 394 JR (orthophoto 18) in the central and south-western portion of the map sheet (Fig. 19). Areas with a medium expansive potential have an expected heave of 5-30mm and are grouped into two north-west to south-east striking geomorphic/geological areas. The first area is associated with colluvial and residual soils developed on the Hekpoort andesite Formation (orthophotos 1, 2, 7, 8, 11, 13, 14, 16, 19, 20, 22 and 25) and Transvaal related diabase (orthophotos 2-5, 8-10, 14, 15 and 20) (Fig. 19). The second area is associated with alluvial soils present in drainage systems, situated on most of the orthophotos except numbers 1, 6, 7, 11-13, 19, 20, 23 and 25 (Fig. 19). Areas with low expansive potential have an expected heave of less than 5mm and are associated with colluvium and residual dolomite, shale and quartzite of the Transvaal Supergroup, that occur across the whole map sheet except in areas of outcrop and some of the drainage features (Fig. 19).

Areas with a potential for expansion but with an unknown severity rating were recognized in profile by the soil colour and structure often being black, dark grey, red or mottled yellow-grey, showing slickensiding or shattering. These areas are associated with pans, flood plains and drainage channels in the southern portion of the map sheet on the farms Elandsfontein 412 JR, Tweefontein 413 JR, Elandsvlei 414 JR and Knoppiesfontein 549 JR (orthophoto 22, 23, 24 and 25) (Fig. 19).

Where development is anticipated in areas with potential expansive soils, one or more of the following modified construction methods proposed by Williams *et al.* (1985), may be employed:

- Pre-wetting of expansive soil horizons.
- Removal of the active layer.
- Construction of moisture barriers and paving around the structures.
- Stiffened raft foundations, sandwich raft foundations (two overlying raft foundations with a mattress of gravel or sand between the rafts) or piled foundations.
- Split construction.

5.3.7.5 Excavatability problems

Excavatability is a high cost factor for development when installing underground services and foundations. Approximately 516 km^2 (75%) of the map sheet exhibits some form of excavatability problem, ranging from slight to severe (Table 28, Fig. 20).

Severe excavatability problems are present over 67 km^2 (10%) of the map sheet (Table 28), where solid rock outcrop or shallow bedrock is present and refusal of the backactor occurred within the first 0,5m from surface. These areas comprise outcrop or sub-outcrop of quartzite, shale, andesite, dolomite, chert and diabase of the Transvaal Supergroup occurring as north-west to south-east striking hill crests and ridge crests and occur in the following areas (Fig. 20): 1) Quartzite of the Magaliesberg Formation in the north-eastern portion of the map sheet (orthophotograph 5); 2) Shale with interbedded chert of the Silverton Formation and diabase dykes, situated between the R104 road and the road south of the N4 highway; 3) Quartzite of the Daspoort Formation situated between the road south of the N4 highway and the road north of the R50; 4) Andesite of the Hekpoort Formation situated in the vicinity of the road north of the R50; 5) Shale and quartzite of the Timeball Hill Formation situated east of the R21 road and in the vicinity of the R50 road; 6) Dolomite and chert situated directly south of the R50 road.

Moderate excavatability problems are present over 123 km^2 (18%) of the map sheet and are associated where ferricrete, shale bedrock, quartzite bedrock, chert bedrock, dolomite bedrock or with andesite boulders occurring at depths of 0,5 - 0,1 m (Table 28, Figure

20). The development of ferricrete is favoured in soils overlying andesite (situated in the vicinity of the road north of the R50 road) and shale of the Pretoria Group (Figure 20). The occurrence and depth of ferricrete development is variable. It is therefore difficult to predict where ferricrete will be encountered in relation to the surface, unless detailed investigations are conducted. Moderate excavatability is anticipated in sub-outcropping shale of the Silverton Formation (between the 104 road and the road south of the N4 highway), shale and quartzite of the Timeball Hill Formation (north of the R50 road and east of the R21 road), quartzite of the Rayton and Magaliesberg Formations situated in the north-eastern portion of the map sheet (orthophotograph 4 and 5) and with quartzite of the Daspoort Formation (in the area between the road south of the N4 highway and the road north of the R50). Moderate excavatability is also expected on chert and dolomite of the Eccles and Lyttelton Formations, situated south of the R50 road (Fig. 20).

Slight excavatability problems are present for 324 km^2 (47%) of the map sheet where refusal of the backactor occurred at a depth of 1,0 - 1,5 m (Table 28, Fig. 20). These are areas associated with ferricrete overlying andesite and shale of the Pretoria Group. Slight excavatability problems are also associated with sub-outcrop quartzite of the Strubenskop Formation in the area between the road south of the N4 highway and the road north of the R50, sub-outcrop of dolomite and chert occurred on the farm Hartebeestfontein 171 IR and Witkoppies 393 JR (orthophoto 17 and 21) and of sandstone and shale of the Vryheid Formation in the southern portion of the map sheet on the farms Sterkfontein 401 JR, Elandsfontein 412 JR, Witkoppies 393 JR and Grootfontein 394 JR (orthophoto 16, 17, 23) (Fig. 20).

Unspecified excavatability problems are present for 2 km^2 (less than 1%) of the map sheet (Table 28, Fig. 20). These are areas where ferricrete concretions, gravels of quartzite, shale and andesite were encountered in the first 1,5 m of the excavation without refusal of the back-actor.

Excavatability associated with chert and dolomite of the Chunniespoort Group is variable due to the highly irregular bedrock topography of the dolomite. Dolomite boulders found in residual soil may also pose an excavatability problem and differential settlements. Soil thicknesses overlying dolomite and dolomite boulders can be between 0 - 100 m (Buttrick, 1992). A detailed investigation is therefore required to determine the severity of these problems in areas underlain by dolomite. Andesite of the Hekpoort Formation weathers irregularly resulting in solid outcrop occurring within metres of a deep soil profile, which also results in variable excavatability conditions.

5.3.7.6 Collapsible soil

Colluvial sediments situated on straight slopes, plains and residual soils on well-drained hill slopes, that were derived from weathered dolomite, sandstone and quartzite of the Transvaal and Karoo Supergroups exhibit a collapsible and open structured fabric. Collapsible soils are dark red, dark red brown, yellow brown or orange brown, loose to very loose in consistency, open structured, silty sands or sands with minor silt.

Approximately 55 km^2 (8%) of the map sheet exhibits soils with a collapse potential ranging from low to severe (Table 28, Fig. 21). Areas with severe collapse have an expected collapse potential of 10% - 20% and are associated with colluvial soil derived from quartzite of the Strubenkop Formation situated in the south-eastern portion of the map sheet on the farm Rietfontein 395 JR (orthophoto 19 and 20) (Fig. 21).

Areas with moderate collapse potential have an expected collapse potential of 5% - 10% and cover 3 km^2 (less than 1%) of the map sheet (Table 28, Fig. 21). They are associated with colluvial soils derived from, quartzite of the Daspoort Formation situated in the northern portion of the map sheet on the farm Zwavelpoort 373 JR (orthophoto 8), dolomite and chert situated directly west of the R50 road (orthophotographs 12 and 17), shale of the Silverton Formation situated on orthophotographs 9 and 14 and with shale of the Timeball Hill Formation situated on orthophotographs 7, 12 and 16 (Fig. 21).

Areas with a low collapse potential have an expected collapse potential of 1% - 5% and are associated with colluvial and residual soils derived from sandstone and shale of the

Vryheid Formation in the south-western portion of the map sheet west of the R21 and with colluvial soils overlying dolomite and chert in the southern portion of the map sheet, east of the R50 road (Fig. 21).

Areas exhibiting a potential for collapse, but where the expected decrease in soil volume is unknown, cover 51 km² (7%) of the map sheet. These areas were classified according to their sandy matrix, open structure and a comparison of disturbed soil samples with Knight (1961) and Errera (1977) grading curves. These soils are associated with: colluvial and residual material derived from quartzite of the Magaliesberg Formation in the north-eastern portion of the map sheet next to the N4 highway, colluvium on orthophotograph 2, 3 and 7, shale of the Silverton Formation on orthophotograph 10, quartzite of the Daspoort Formation on orthophotograph 20, sandstone and shale of the Karoo Supergroup in the southern portion of the map sheet (orthophotograph 22-25), quartzite of the Timeball Hill Formation in the south-western portion of the map sheet (orthophotograph 22), and with dolomite and chert in the southern portion of the map sheet on orthophotograph 23 (Fig. 21).

According to Schwartz (1985), remedial measures to prevent or reduce the impact of collapsible soils include:

- Adequate drainage to prevent the ingress of water into collapsible horizons.
- The use of raft, stiffened raft or pile foundations
- Chemical stabilisation of the soil.
- Densification of the collapse horizons.
- Removal of the collapsible horizons and replacing these with compacted layers (where 0,5 metres is the general depth of excavation for foundations). This is often the most cost effective method, by excavating 1,5 times the width of foundation and recompacted in 150 mm layers at a moisture content of 98% from optimum (Mod. AASHTO) .

A well developed ferricrete layer overlying a collapsible profile will often provide a good founding platform.

5.3.7.7 Erodible soils

The erodibility of soils is a function of the resistance of slope materials to entrainment and transport, and the potential of slope processes that promotes erosion. A multitude of factors influence the erodibility of soils making it difficult to quantify or predict the rate of erosion on a particular slope (Summerfield, 1991). The resistance of the soil to rain splash and slope wash, the slope length and gradient and the proportion of the ground surface that is covered with vegetation are factors affecting erosion and erosion rates. The resistance of soil to erosion is also related to the mechanical strength, cohesion and particle size.

Less than 1% of the map sheet is likely to have erodible soils (Table 28, Fig. 22). Erodible soils can be grouped into two geomorphic areas. The first, is associated with the Pienaars River flood plain situated in the eastern portion of the map sheet on orthophotograph 14. The second, is associated with hillsides comprising quartzite and shale of the Timeball Hill Formation in the southern portion of the map sheet at Bashewa Agricultural holdings (orthophotograph 18, 23 and 24) and in the western portion of the map sheet at Rietfontein Small holdings (orthophotograph 12, Fig. 22).

5.3.7.8 Poorly consolidated soils

Poorly consolidated or compressible soils cause shear strength, compressibility and time related settlement problems. Less than 1% of the map sheet is covered by poorly consolidated soils (Table 28). Poorly consolidated soils occur in flood plain clays, situated in the south-western portion of the map sheet (orthophotograph 21). These soils give rise to settlement problems, unless adequately treated prior to construction.

5.3.7.9 Shallow groundwater

A shallow water table is vulnerable to contamination from incorrectly sited facilities, such as waste sites, ground based sanitation systems and cemeteries. Presence of a shallow water table can be critical when planning certain developments. A shallow groundwater table is expected to occur adjacent to drainage channels, vleis, pans and flood plains, covering approximately 8 km^2 (1%) of the map sheet (Table 28, Figure 23). Groundwater conditions may fluctuate seasonally. The occurrence of ferricrete indicates a present or historic fluctuating groundwater table during which iron is precipitated at the base of the perched groundwater table. Where a soil has a clay matrix, the shrink and swell characteristics will be influenced by a fluctuating watertable.

5.3.7.10 Permeability

Permeability is the ability of the soil to transmit water through voids. The size and inter-connection of the voids, rather than the void ratio, governs the rate of seepage. The size of voids is related to the distribution of particle size, particle shape and soil structure. Where the soil is stratified, permeability is usually higher parallel to the stratification than perpendicular to it. High permeabilities are generally associated with sandy soils and low permeabilities with clayey soils (Brink *et al.*, 1982).

The permeability of soils is an important geotechnical property, depending on the type of development being considered. Permeability controls the rate at which a soil will consolidate under load and is also an important consideration in the treatment of sub-foundation soils in dams and the prevention of seepage into excavations. Low permeability can result in the ponding of water during the rainy season which may be a problem for certain types of develoment and high permeabilities can lead to instant contamination of the groundwater (Brink *et al.*, 1982).

In this study the permeabilities of the soil samples were derived using Hazen's formula, which is more applicable to sandy soils. Other methods to determine the permeability of soil are the constant head permeability test for sandy soils and the falling head permeability test for clay-rich soils (Craig, 1974), neither of which were applied during this investigation. Approximately 12 km^2 (2%) of the map sheet exhibits high permeabilities (Table 28, Fig. 24) and is associated with sandy colluvial and residual soils derived from quartzite of the Magaliesberg Formation on orthophotograph 5; quartzite of the Daspoort Formation on orthophotographs 8 and 20; quartzite and shale of the Timeball Hill Formation on orthophotographs 13, 16 and 18; alluvial soils overlying dolomite in a drainage feature on orthophotograph 12 and colluvium and residual soils overlying dolomite and chert of the Eccles Formation on orthophotographs 18 and 23 (Fig. 24).

Areas with medium permeability covers 215 km^2 (31%) of the map sheet and are associated with colluvial or residual silty sand and sandy silt derived from quartzite of the Magaliesberg Formation on orthophotograph 5; shale of the Silverton Formation and diabase dykes on orthophotographs 4, 5, 9 and 10 and from quartzite of the Daspoort Formation on orthophotographs 1, 2, 8, 13, 14, 19, 20 and 25 (Fig. 24). Residual soils overlying andesite of the Hekpoort Formation (orthophotographs 7 and 12); quartzite or shale of the Timeball Hill Formation (orthophotographs 6, 7, 11-13, 16, 18, 21, 22 and 24), and dolomite or chert of the Eccles formation (orthophotographs 11, 12, 16-18, 21-24), also exhibit medium permeabilities (Fig. 24).

Areas with low permeability cover 438 km^2 (63%) of the map sheet and are associated with silty clay or clayey silt derived from shale of the Silverton Formation and diabase in the north-eastern portion of the map sheet; the Hekpoort Formation andesite in the central portion of the map sheet, and on quartzite or shale of the Timeball Hill Formation in the south-western portion of the map sheet (Table 28, Fig. 24).

5.3.8 Potential construction materials

The rapid growth of South Africa's urban areas and demand for new houses have put immense pressure on existing construction material resources such as brick-making clay, concrete and road aggregate and building sand.

5.3.8.1 Clay

Seven operating clay quarries exist in the Rietvlei Dam map sheet area (Table 29). These clay deposits are confined to the Vryheid Formation of the Karoo Supergroup and the Timeball Hill Formation of the Transvaal Supergroup.

Table 29: Location, type and end use of operating clay quarries for the Rietvlei Dam map sheet.

Quarry Name	Commodity	Host Rock Lithology	Latitude	Longitude	End Uses
Rietvlei Quarry	Brick clay	Vryheid Formation Shale and clay	25° 55' 24"	28° 19' 06"	Face Bricks, Semi-Face Bricks
Victoria Bricks	Brick clay	Timeball Hill Formation Shale / clay	25° 56' 18"	28° 16' 26"	Semi-Face Bricks
Sterkfontein Bricks	Brick clay	Vryheid Formation Shale / clay	25°56' 10"	28° 15' 28"	Face Bricks, Semi-Face Bricks
Olifantsfontein Quarry 1	Brick clay	Timeball Hill Formation Shale / clay	25° 56'03"	28° 16' 09"	Face Bricks, Semi-Face Bricks
Olifantsfontein Quarry 2	Brick clay	Vryheids Formation Shale / clay	25° 56' 12"	28° 15' 45"	Face Bricks, Semi-Face Bricks
Apollo Brick	Brick clay	Timeball Hill Formation Shale / clay	25° 59' 0"	28° 18' 15"	Stock bricks, Semi-Face Bricks
Berko Stock Bricks	Brick clay	Timeball Hill Formation Shale / clay	25° 53' 07"	28° 20' 33"	Stock Bricks

The Vryheid Formation comprises alternating layers of shale, sandstone, coal and conglomerate. The shale weathers to form quartz and kaolinite with impurities of oxides and other clay minerals such as illite and montmorillonite. The clays that are formed varies in colour from pink, cream, grey, brown and black. The Vryheid Formation occurs as patches on the Chuniespoort Group dolomite and chert in the south-eastern portion of the map sheet on the farms Witkoppies 393 JR, Grootfontein 394 JR, Tweefontein 413 JR, Elandsfontein 412 JR, Elandsvlei 414 JR, Sterkfontein 401 JR and Rietfontein 375 JR. The Timeball Hill Formation comprises shale and siltstone at the base, with shale, quartzite and graywacke at the top. In between is a thin layer of quartzite and ferruginous shale. The shale varies from pale-yellow to shades of red. The Timeball Hill Formation occurs in two north-western to south-eastern striking bands. The first band includes portions of the farms Elandsfontein 412 JR and Tweefontein 413 JR in the south and portions of the suburbs Elarduspark and Moreletapark in the north. The second band occurs on the farm Elandsfontein 412 JR in the south and the suburb Elarduspark and Erasmusrand in the north.

Although the Vryheid Formation represents a source of economically viable clay deposits in the map sheet area, its thickness varies, which is an important consideration when identifying future clay quarries.

5.3.8.2 Aggregate

Aggregate is defined as any hard, inert material such as sand, gravel, slag or crushed rock, which constitutes the bulk filler in concrete, mortar, plaster and tarmac, as well as railroad ballast or road metal when used alone. Only two operating aggregate quarries exist on the map sheet area (Table 30).

Table 30: Location, type and end use for operating aggregate quarries on the Rietvlei Dam map sheet.

Quarry Name	Commodity	Host Rock Lithology	Latitude	Longitude	End Uses
Donkerhoek Quarry	Sand, aggregate	Magaliesberg Formation Quartzite	25° 45' 51"	28° 27' 36"	Manufacturing industry
Willow Quarries	Building sand, river sand, plaster sand	Daspoort Formation and Quaternary Deposits Quartzite, aeolian / fluvial sand	25° 48' 54"	28° 22' 21"	Building industry

Quartzite of the Pretoria Group, especially those of the Magaliesberg, Daspoort, Strubenkop and Timeball Hill Formations provides potentially good sources of aggregate that are durable and strong. The Magaliesberg Formation occurs in the north-eastern portion of the map sheet (orthophotograph 5), the Daspoort and Strubenkop Formations in the area between the road south of the N4 and the road north of the R50. The Timeball Hill Formation is situated in the vicinity of the R50 and directly north of it and east of the R21. Other sources of potential aggregate include dolerite, andesite and shale. However, chemical decomposition is the dominant mode of weathering in the area resulting in the formation of secondary clay minerals that may have a deleterious effect on the durability and strength of aggregates obtained from these rocks (Weinert, 1980).

Care should be taken with the use of aggregate manufactured from sandstone of the Vryheid Formation as it has resulted in failure of concrete because of its abnormally high dimensional changes with a change in moisture content (Morrison, 1980). Dolomite is a good source of aggregate, providing that it does not contain more than 15% chert, which is not the case for dolomite of the Eccles Formations (Morrison, 1980).

The potential fine aggregate sources for the Rietvlei Dam map sheet are natural sands or manufactured sands. Natural fine aggregate or building sand is formed by the weathering of rocks and subsequent transport. The sands tend to be well-graded but contain an excessive amount of silt and clay which require the additional expense of washing to make them suitable for use. Areas in the northern portion of the map sheet, are potential sources for fine aggregate, comprising sandy deposits that were formed by weathering of quartzite of the Magaliesberg, Strubenkop and Daspoort Formations and subsequently reworked by wind and water activity. Manufactured or crusher sand is obtained mainly from the crushing of rock material such as quartzite of the Pretoria Group, especially those of the Magaliesberg, Daspoort and Timeball Hill Formations.

5.4 CONCLUSION

The geotechnical classification system proposed by Zawada (2000) for regional geotechnical mapping on a 1:50 000-scale, with the Rietvlei Dam 2528CD map sheet used as an example, was evaluated. The critical evaluation of this system is regarded as useful to guide the Council for Geoscience in the modification and improvement of this system for future implementation.

The following is a summary of the conditions which exist in the Rietvlei Dam 2528CD 1:50 000-scale map sheet area:

- The Rietvlei Dam 2528CD map sheet covers approximately 690 km^2 (25 km × 25 km) and is situated south-east of Pretoria which includes a portion of the Tshwane (Pretoria) municipal area.
- The area is relatively flat to gently undulating, with three prominent ridges striking north-west to south-east across the map sheet area. Other landforms on the map sheet include, hill crests, plains, dams, excavations, marshy areas, drainage and river channels.
- The climate of the area is sub-humid, with an average annual rainfall of 760 mm, an average summer maximum of 25,8°C and an average winter minimum of 3°C. The prevailing wind direction is north-east and averages at 6,5 knots (pers. comm. Weather Bureau, 1999). Weinert's climatic N-value for this area is 2.4, which indicates that decomposition is the dominant form of weathering resulting in the formation of thick soils (Weinert, 1980).
- The area is drained in a northerly direction by the Rietvlei and Pienaars Rivers, the Sesmyl Spruit, Moreleta Spruit and several non-perennial streams.
- Rapid development is taking place in the north-western portion of the map sheet area, whilst much of the remaining area is occupied by farms and agricultural holdings.
- The area is underlain by rock of the Transvaal and Karoo Supergroups, with the surficial deposits consisting of unconsolidated alluvium and colluvium of Quaternary age.
- The dolomite area on the map sheet is subdivided into the Rietvlei, Witkoppies, Sterkfontein and Doornkloof-east hydrogeological compartments. The groundwater within the dolomite area is of excellent quality for human consumption and irrigation purposes, except for the Rietvlei compartment which has been contaminated by effluent from the Kempton Park sewage works.

- Geotechnical factors and their associated severity classes (definitions are given in Table 21) anticipated for the area are represented on the geotechnical map (Appendix 2). These include: Inundation (Inu2), sinkhole formation (Sin2), slope instability (Slo2), swelling or expansive soils (Act2, Act3, Act4, Act5), excavatability problems (Exc2, Exc3, Exc4, Exc5), collapsible soils (Col2, Col3, Col4, Col5), subsidence (Sub2), erodible soils (Ero2), poorly consolidated soils (Con2), shallow water table (Sha2), permeability (Per2, Per3, Per4). Each geotechnical factor is presented on an A4 map, showing the different severity classes for that specific geotechnical factor.
- Existing construction materials extraction or mining include seven operational clay quarries and two aggregate quarries. The clay deposits are confined to shales of the Vryheid Formation of the Karoo Supergroup and the Timeball Hill Formation of the Transvaal Supergroup. The aggregate deposits are confined to quartzite of the Magaliesberg Formation and the Daspoort Formation. Quartzite of the Strubenkop and Timeball Hill Formations also provide potentially good sources of aggregate. The sandy deposits formed by the weathering of quartzite of the Magaliesberg, Strubenkop and Daspoort Formations and reworked by wind and water, provide potential sources of fine aggregate.

The results above show that the classification system proposed by Zawada (2000) can be applied to create a geotechnical map that is of value for a variety of land-uses and development issues. The method seeks to combine computer technology with hard copy map presentations by providing familiar looking printed maps of different geographical areas and yet allows for the generation of maps by computer for specific purposes.

The following shortcomings were identified during the course of this evaluation and should be addressed to improve the end product (geotechnical map).

- Browsing through the accompanying tables in order to understand the meaning of information and/or data presented on the map is too time consuming.
- The ranking of geotechnical factors and the classification of the ranked list into

groups having critical and subcritical status, to enable the identification of the highest ranked geotechnical factor present in an area, could be confusing to the non-geotechnical specialist. This confusion is associated with the fact that the reader may understand that the word 'dominant geotechnical factor' means that this factor will have the largest impact during regional planning and development stages, although it is only classed according to a ranking system developed by Zawada (2000) for general land use purposes, taking into account financial and environmental factors. This problem can be illustrated by looking at the 'number of geotechnical area' on the geotechnical map (Appendix 2), the number 321 represents the geotechnical properties Act3 (low expansiveness) and Exc5 (severe excavatability problems) or by looking at the number 377 which represents the geotechnical properties Act3 (low expansiveness) and Col4 (moderate collapse potential). In both cases the second listed geotechnical factor will pose a much bigger impact on development than the first one, namely Act3 (low expansiveness).

- The dominant geotechnical factor is indicated by a colour type and additional critical and subcritical factors present for the same area are denoted by a shade of colour corresponding to the colour of the dominant geotechnical factor. The consequences of this is that, although other factors listed lower down the ranking list, could impose a much bigger impact, they are not highlighted as the primary geotechnical factor for a specific area on the map, especially in terms of colour distinction. For this reason an important geotechnical factor or factors could be concealed. The example used under the previous point can once again be applied here, for the numbers 321 and 377 the colour codes are shades of red for active clays which is first on the ranking list, although severe excavatability problems represented by the code Exc5 (green is the denoted colour for excavatability) and moderate collapse represented by the code Col4 (peach is the denoted colour for collapse) have respectively higher impacts than low expansiveness (Act3), and for this reason are concealed.
- The above mentioned point not only reduces visibility in terms of contrast, but also could imply that only one or two geotechnical factors are present on the map

sheet. For example, if the domintant geotechnical factor ranked first on the list as developed by Zawada, is active soils, most of the map sheet area will be coloured in shades of red and only after careful scrutiny the user may realise that although the colours of different numbered areas are the same, the geotechnical factors differ.

- The use of only one hatching code to distinguish between adjacent areas of the same colour with minor differences in additional geotechnical factors, could also pose a problem, because the geotechnical factor for which it is applied could be different every time, for example it could be applied where a minor difference exists in excavatability (Exc4 and Exc5) between two adjacent areas, or permeability (Per2 and Per3) or any other geotechnical factor.
- According to Zawada (2000), the purpose of the map was not to generalise the geotechnical parameters into zones for development to ensure that the map would be of value to a variety of land-use and development issues. The outcome of this is a very complex legend which only an engineering geologist with the necessary background would find useful. This map will be of no meaning to the town planner and/or developer and will be regarded as a map full of data that provides no useful information, regarding poor and good areas for potential development (zonation map).