CHAPTER 3

DEVELOPMENT OF REGIONAL GEOTECHNICAL CLASSIFICATION SYSTEMS IN SOUTH AFRICA

3.1 INTRODUCTION

This chapter will mainly deal with geotechnical maps and associated classification systems developed in South Africa. Each geotechnical classification system will be reviewed considering the purpose, classification and presentation of data. All these classification systems are based on the land system approach, after Brink *et al* (1982). The 1:10 000-scale orthophoto map area 2528CD08, will be used as a base to represent the land system approach that forms an integral part of regional geotechnical mapping. The different geotechnical classification systems, will be compared using the above mentioned area, which will aid in the evaluation of the uses and presentation of each classification.

3.2 LAND SYSTEM APPROACH

A recurrent pattern of genetically linked land facets is known as a land system, thus a land facet represents a sub part of a land system. The principles of modern day terrain evaluation techniques for engineering geological purposes, are based on the Land Facet approach, discussed and advocated by various authors (Price (1981), Brink *et al* (1982), Lawrens *et al* (1993)). This approach serves as a basis for the collection of terrain information, that can be structured, modelled or interpreted in a Geographical Information System (GIS) for land-use planning.

The Land Facet approach to terrain evaluation is a cost-efficient and accurate technique to adopt as it endeavours to consider all the processes and influences on the engineering properties of soil (Stiff, 1994). It allows an area of terrain which has a similar host lithology and has undergone similar soil-forming processes to be compared to analogues in other areas (Stiff, 1994). Sampling points need therefore to be less frequent (limited resources), allowing large tracts of terrain to be mapped in a shorter time span and at much lower costs to identify areas of suitable land for urban development (Stiff, 1994). The major factors which influence the engineering properties of a soil are as follows (Stiff, 1994):

- land form,
- geology (host rock type),
- climatic situation
- geomorphological process (erosional cycle)
- geomorphological province

The basic unit of this classification is the land facet, which is an area of ground with a simple surface form, a specific succession of soil profile horizons (each with reasonably uniform properties, but with varying thickness) and a characteristic groundwater regime (Partridge, 1994). In undisturbed areas the land facet is characterized also by a locally distinctive plant association (Partridge, 1994). A land facet may be delineated on aerial photographs at scales between 1:10 000 and 1:50 000 (scale of regional engineering geological mapping), although in arid areas it may be possible to do so at scales as small as 1:80 000 (Partridge, 1994). Characteristically, land facets are small units and usually correspond to individual physiographic features, such as outcrops and free rock faces, talus slopes, alluvial fans, and alluvial terraces (Partridge, 1994).

Underlying the definition of this unit is the idea of prediction: by knowing and being able to recognize a land facet one may predict, from one occurrence of it to another (Partridge, 1994).

During regional geotechnical mapping (1:10 000 or 1:50 000), because of the scale criteria, many of the facets are too small to form part of the regional map, so that some form of regrouping is required (Price, 1981). This regrouping is known as the facet group analysis (Price, 1981). A facet group may be described as a number of facets grouped together to form one mapping unit, which should be similar in soil profiles, engineering behaviour, regional land form and geology (Price, 1981). These facet groups will consist of areas of outcrop and no outcrop, with the "no outcrop" areas further sub-divided into facet group areas of similar soil profile and engineering parameters (Price, 1981).

Having explained the land facet approach it would be appropriate to give an example to illustrate the construction of such maps. Figure 1 and Figure 2 represent the geology and land form map respectively. These two maps are then combined to produce a land facet map, on which all potential mapping units are delineated (Figure 3). Each land form was coded, based on the codes used by Croukamp (1996) for presentation purposes (Table 1).

Table 1: Classification of landforms based on the codes used by Croukamp (1996).

CODE	LAND FORM	CODE	LAND FORM	CODE	LAND FORM
1	Crest	19	Plains & dunes	37	Bog
2	Mountain crest	20	Plain	38	Delta
3	Hill crest	21	Shifting dunes	39	Sand bank
4	Ridge crest	22	Stabilised dunes	40	River channel
5	Plateau crest	23	Drainage features	41	Drainage channel
6	Mesa ("Tafel koppie")	24	Gully head	42	Dam
7	Tor ("Castle koppie")	25	Gully/donga	43	Spring
8	Bornhardt ("Kaal koppie")	26	Rill erosion	44	Lake
9	Free face/cliff	27	Sheet erosion	45	Solution features
10	Slopes	28	Pan	46	Subsidence area (doline)
11	Talus slope	29	Pan floor	47	Sinkhole
12	Convex slope	30	Pan side	48	Coast
13	Concave slope	31	River terrace	49	Lagoon
14	Straight slope	32	River bank	50	Raised beach
15	Pediment	33	Levee	51	Beach
16	Dissected pediment	34	Flood plain	52	Estuary
17	Land slide	35	Swamp	53	Excavation
18	Fan	36	Vlei/marsh	54	Disturbed land

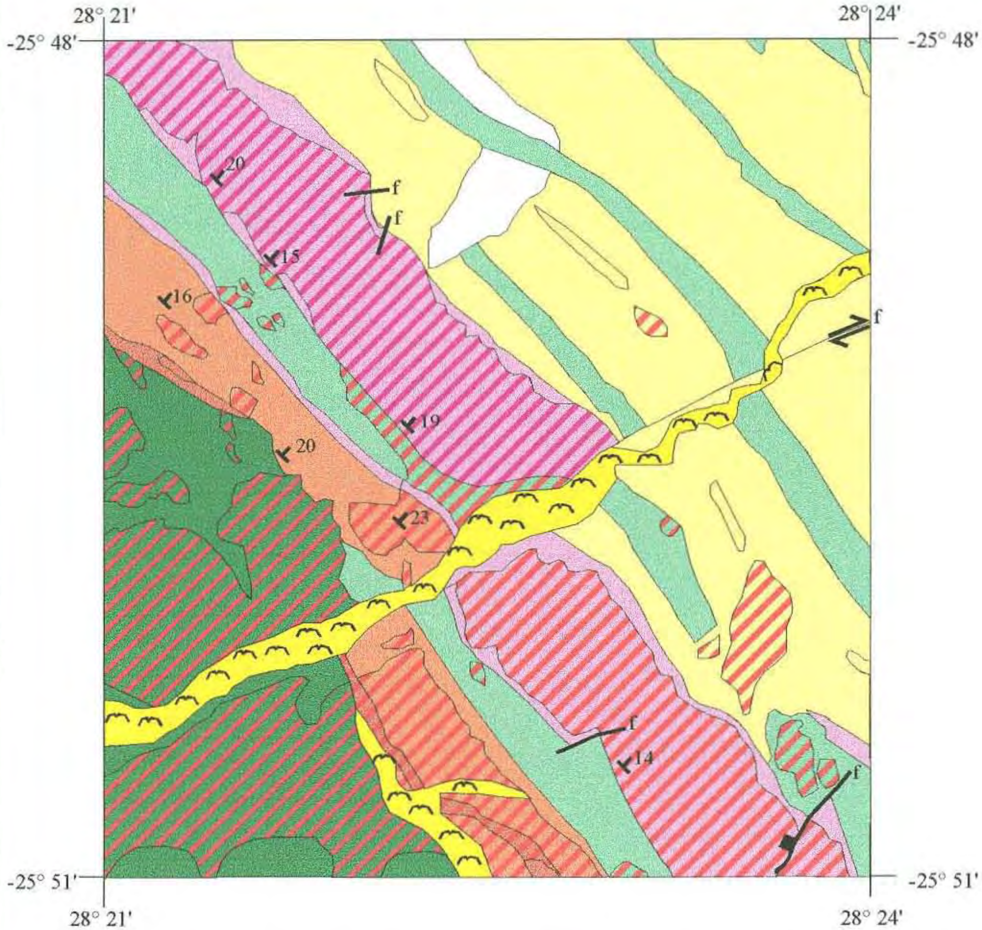

Figure 1 : Geology of Rietvleidam 2528CD08

Scale : 1 : 50 000

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GEOLOGICAL LEGEND

LITHOLOGY	FORMATION	GROUP	SUPERGROUP
Alluvium			
Ground soil, gravel, conglomerate, shale, clay			Surficial deposits
Shale with inter-bedded chert	Silverton		
Quartzite	Daspoort		
Ferruginous shale with basal ferruginous quartzite and conglomerate	Strubenkop	Pretoria	Transvaal
Quartzite and subordinate shale	Dwaalheuwel		
Andesite	Hekpoort		
Diabase dykes and sills			
Syenite dyke			

LEGEND SYMBOLS

- Fault
- Dip & Strike
- Outcrop
- Fault with downthrow side

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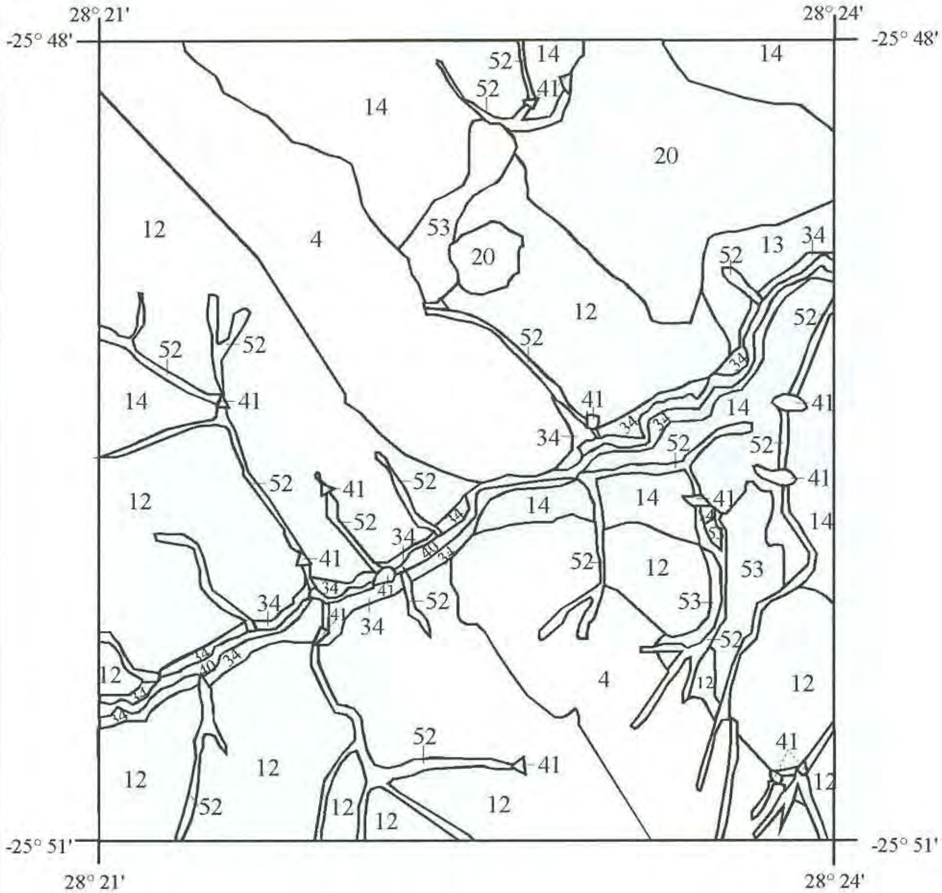

Figure 2 : Land form map of Rietvleidam 2528CD08

Scale : 1 : 50 000

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LAND FORM / LAND FACET LEGEND

CODE	LAND FORM	LAND FORM GROUP	LAND FORM GROUP CODE
4	Ridge crest	Ridge crest	4
12	Convex slope	Convex slope	12
13	Concave slope	Concave slope	13
14	Straight slope	Straight slope	14
20	Plain	Plain	20
34	Flood plain		34
40	River channel	Flood plain	
41	Dam		
52	Drainage channel		
53	Excavation	Excavation	53

Land form codes after Croukamp (1996)

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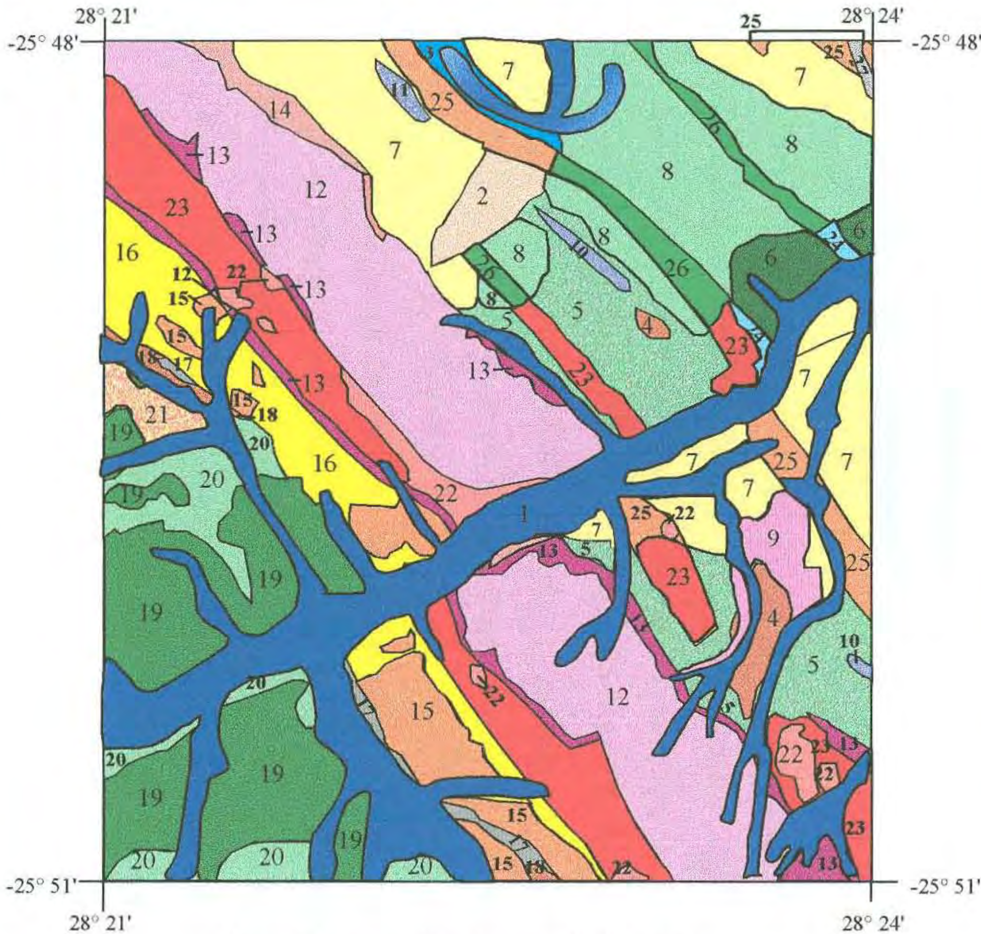

Figure 3 : Mapping Units based on the Land Facet approach for Rietvlei Dam 2528CD08

Scale : 1 : 50 000

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LAND FACET No	GEOLOGY		LAND FORM (CODE)
1			Flood - plain (34)
2	Surficial deposit (ground, soil, gravel, conglomerate, shale, clay)		Excavation (53)
3			Straight slope (14)
4	Silverton shale	Outcrop	
5			Convex slope (12)
6			Concave slope (13)
7			Straight slope (14)
8			Plain (20)
9			Excavation (53)
10	Silverton shale with inter-bedded chert		Convex slope (12)
11			Straight slope (14)
12	Daspoort quartzite	Outcrop	
13			Convex slope (12)
14			Straight slope (14)
15	Strubenkop shale with basal quartzite and conglomerate	Outcrop	
16			Convex slope (12)
17	Dwaalheuwel quartzite and sub-ordinate shale	Outcrop	
18			Convex slope (12)
19	Hekpoort andesite	Outcrop	
20			Convex slope (12)
21			Straight slope (14)
22	Diabase dykes and sills	Outcrop	
23			Convex slope (12)
24			Concave slope (13)
25			Straight slope (14)
26			Plain (20)
27	Syenite dyke		Straight slope (14)

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These codes were derived from the TRH2 (1978) land form classification system, which is generally used in South Africa for the classification of land forms.

3.3 HISTORY OF THE DEVELOPMENT OF REGIONAL GEOTECHNICAL MAPPING IN SOUTH AFRICA

The first real geotechnical map based on the land facet approach was conducted by Brink (1957) for a proposed route between Vryburg and Manchester in the Northwest province (Price, 1981). The then National Institute for Transport and Road Research (NITRR) of the South African Council for Scientific and Industrial Research (CSIR), as well as the University of Oxford-Military Engineering Experimental Establishment (MEXE) Group in Britain began developing a Terrain Evaluation System for road-route planning and military engineering purposes respectively (Stiff, 1994). The NITRR (represented by A.B.A. Brink) and the Oxford-MEXE Group and Australian Group (represented by J.A. Mabbutt) met in 1965 in Oxford and jointly refined the technique, systemised the approach and established the nomenclature for the preparation of soil engineering maps during road construction projects (Stiff, 1994).

The climax of soils engineering mapping for roads in South Africa was reached with the publication of the TRH2 (Technical Recommendation for Highways) draft in 1976 by the CSIR, giving technical recommendations to contributors on the presentation of the maps and data for input into the roads database system. This data store became known as the Roads Data Bank as most of the contributors and users were involved in road construction projects (Stiff, 1994). Unfortunately, the construction of new roads slowed down towards the end of the 1970's and the need for soil engineering maps apparently faded. Because the mapping skills remained available, it became necessary to seek other opportunities for mapping. It was realised that engineering geological mapping on a regional scale could make an effective contribution to the planning of developing areas. A more refined draft of TRH2 was then published in 1978 by the CSIR, introducing a geotechnical map that accompanied the soil engineering map. Support for the Roads Data Bank waned due to technical disputes in the 1970's and lead to its closure in 1980 (Mountain, 1994). The soil engineering map for construction and design, as well as data banking for roads will not be discussed further as it falls outside the scope of this research and attention will only be given to geotechnical mapping for route location (TRH2, 1978).

In the early 1980's the Council for Geoscience recognized the great need for regional engineering geological maps to facilitate urban expansion. This has led to the mapping of areas around some of the larger cities by workers like Bester (1981), Price (1981) and Mountain(1994).

Van Schalkwyk and Price (1990) did some further research on the regional geotechnical mapping method proposed by Price (1981). This included a site classification system to distinguish between good, fair and poor site class areas for residential development. Partridge, Wood and Brink (1993) introduced a geotechnical classification system for township development, to be used during urban planning in the PWV (Pretoria, Witwatersrand & Vereeniging) Metropolitan Region, currently known as the Gauteng Province of South Africa. This classification system was endorsed by the South African Institute for Engineering Geologists (SAIEG) in association with the South African Institution of Civil Engineers (SAICE). It is also supplemented by the *Standards and Guidelines* of the National Home Builders Registration Council (NHBRC, 1995) for Urban Planning, which are aimed at facilitating the production of housing units in accordance with the Reconstruction and Development Programme of the African National Congress (ANC, 1996).

In 1996 the Division of Building Technology of the CSIR in partnership with a consulting firm Partridge, Maud and Associates published a series of 1:50 000-scale maps considering the geotechnical suitability of vacant land in the central Gauteng Province. The descriptors of relevant constraints and the severity thereof, was based on the classification system of Partridge *et. al.* (1993), with minimal modification.

Croukamp (1996) designed an engineering geological geographical information system

(EGGIS) model and classification criteria for a development potential map for urban development. This was based on the integration of a number of data sources intended to be used for land-use planning by town planners and / or developers.

In 2000, the Council for Geoscience (CGS) embarked on a regional geotechnical mapping programme, with the aim to provide geotechnical maps on a 1:50 000 scale of areas, which are important for future development.

Geotechnical mapping specifically for dolomite land-use was developed in the CGS by Buttrick (1992) and falls outside the scope of this project and will not be discussed further.

Evaluation of classification systems used for regional geotechnical mapping from the 1970's to date, revealed that most of these systems are based on work previously done in the field of engineering geological mapping, with little or no modification. There was a decrease in interest in the development of/or research in geotechnical classification mapping systems, from 1981 to 1993. No standardised geotechnical classification system existed and the TRH2 system, although not designed for this purpose, was used for urban development planning. Partridge, Wood and Brink (1993) developed a standardised method to conduct urban engineering geological investigations, which is still regarded by the engineering geological fraternity as the accepted standard of practice in South Africa. This method is also endorsed by SAICE, SAIEG and the NHBRC

3.4 CLASSIFICATION SYSTEMS

The various mapping systems mentioned above, with the exception of the system developed by Zawada (2000), are described in detail below in chronological order, with an example of each end-product applied to the same area. The system developed by Zawada will be explained, evaluated and is presented in Chapter 5.

3.4.1 TRH 2 (Technical Recommendations for Highways, 1978) - Geotechnical mapping for route location

3.4.1.1 Purpose

The objective was to provide the necessary information to define the best possible location for a route of a planned road. The engineering geological map covers a large area including areas of future urban development. The information gathered should enable the planner to take cognizance of potential geotechnical properties in addition to the following criteria, when selecting possible routes:

- Existing land-use
- Population densities.
- Archaeological and historical sites.
- Land values and parcel size (areas held by private land).
- Potential land-use (development or agricultural).
- Environmental considerations (wildlife, vegetation, endangered species, areas of recognized scenic beauty).

The geotechnical map and report are used only to assess geotechnical aspects. These in conjunction with other criteria, such as land-use are studied, to determine a final road corridor. Soil profiling or testing is not required for route location mapping.

3.4.1.2 Classification

No classification criteria was applied to these maps and geotechnical properties were based on the land facet system (Brink *et al.*, 1982).

3.4.1.3 Map presentation

The geotechnical map (Figure 4) was done on a 1:50 000-scale, using the topographical sheet as base map to allow for easy orientation. The following were also indicated on the geotechnical map (Figure 4):

- Geological contacts, faults, joints, brecciated zones, strike and dip, all transferred from the published geological maps.
- Only those mapping units (lithostratigraphic units) which are of direct significance to route location.
- The drainage system, transferred from the 1:50 000 tophographical sheet, including rivers, lakes, pans, flood plains, marshy areas, areas with a shallow water table and dams.
- Any anticipated problem areas, such as sinkholes, expansive clays, or collapsible soils, delineated by map symbols for "Problem areas" which are of significance to route location.
- Potential sources of construction materials, are delineated by map symbols for "Materials".
- All major existing quarries and borrow pits which contain material of proven quality.

3.4.2 Engineering geological land-use classification system developed by Price & Bester (Geological Survey, 1981)

3.4.2.1 Objective

The objective of the mapping was to develop techniques to produce geotechnical maps on a regional scale, and to apply them in practice.

3.4.2.2 Land-use Classification

The classification consists of a matrix with two rows for development categories and six columns for influencing factors, presented in Table 2A (after Price, 1981) and Table 2B (after Bester, 1981). After completion of a mapping project, each facet group is classified

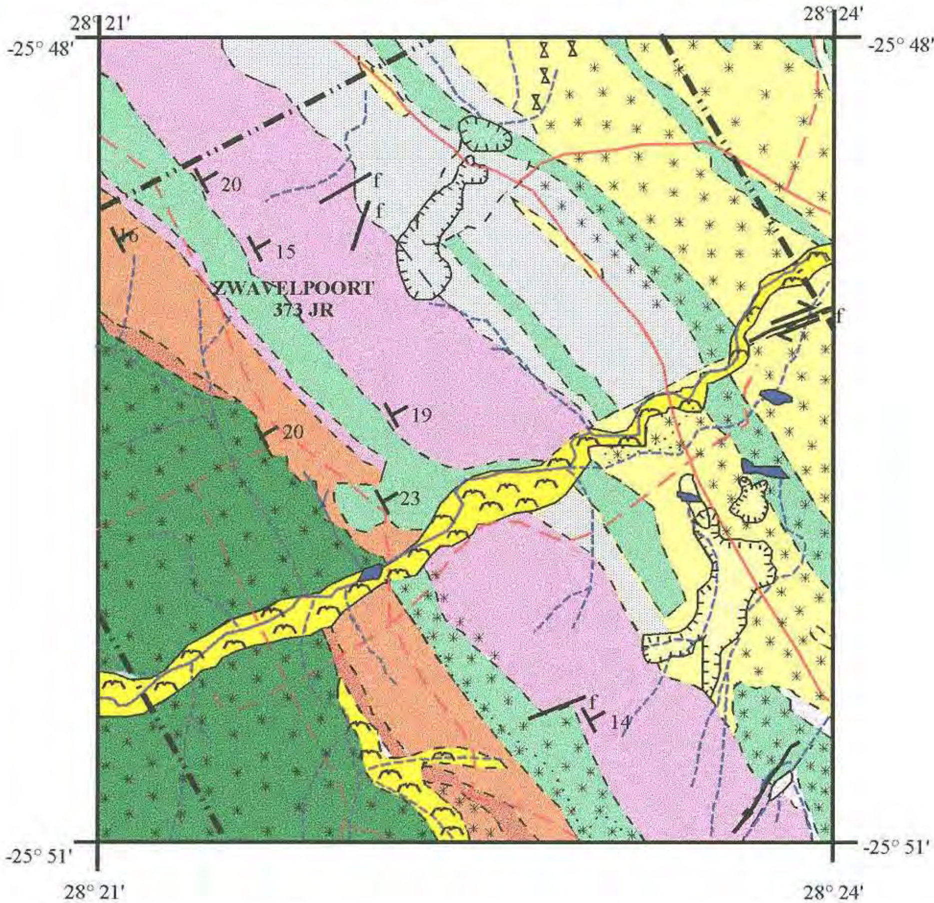

Figure 4 : Geotechnical map constructed using the TRH2 (1978) method

1 : 50 000

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GEOLOGICAL LEGEND

LITHOLOGY	FORMATION	GROUP	SUPERGROUP
Alluvium			
Ground soil, gravel, conglomerate, shale, clay			Surficial deposits
Shale with inter-bedded chert	Silverton		
Quartzite	Daspoort		
Ferruginous shale with basal ferruginous quartzite and conglomerate	Strubenkop	Pretoria	Transvaal
Quartzite and subordinate shale	Dwaalheuwel		
Andesite	Hekpoort		
Diabase dykes and sills			
Syenite dyke			

LEGEND SYMBOLS

- Fault
- Dip & Strike
- Outcrop
- Fault with downthrow side
- Farm boundaries and farm names
- Main roads
- Secondary roads
- Geological boundaries
- Drainage Features (Non-perennial)
- Drainage Features (Perennial)
- Quarry

Map Symbols for Problem Areas

- Expansive materials
- Collapsing sand

Map Symbols for Materials

- Sand
- Gravels
- Boulders

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individually. Table 2A (Price, 1981) and Table 2B (Bester, 1981) are the controlling matrix tables with the maximum rating (MR) indicated and a space provided for the rating as assessed by the user. The assessed rating is obtained from Table 3, where each influencing factor is sub-divided into five classes of decreasing merit from one to five, each with its own rating.

The influencing factor "Potential Natural Resources" (Table 3) were further divided into the different types of construction materials (Table 4a-c). These construction materials, defined by type and quality are each divided into five sub-classes. The sub-class from which a mapping unit is recognised as a potential natural resource or not, is then transferred to the corresponding class of the influencing factor in Table 3.

The column "Overriding positive or negative aspects" (Table 2A) or "Critical influencing factors" (Table 2B) was introduced to remedy a situation where one factor overrules all the others, in spite of a high total rating value. For example, an area may be geologically sound but situated in a flood plain. In this way a rating for an area situated in a flood plain, or on dolomitic karst with known subsidence potential, would be drastically reduced to account for the negative overruling factor.

The accumulated rating out of a maximum of 100 is then compared, for each development category, as to its land-use potential in Table 5 and some idea is formed as to the engineering geological condition of an area. The benefit of the classification is that the general suitability of an area for development is immediately indicated and also whether an area is suited to both, only one, or none of the development categories.

During the implementation of the classification system certain problems and shortcomings were identified by Bester which needed to be revised, including:

- The classification of a mapping unit's excavatibility potential will depend on the type of development that will take place. Distinction should be made between light structures (excavatability < 1,0m), services and deep excavations (> 1,0m),

Table 2A: Control table: Rating allocated to influencing factors with regard to development categories (after Price, 1981).

INFLUENCING FACTORS	1	2	3	4	5	6	OVERRIDING POSITIVE OR NEGATIVE ASPECTS	TOTAL RATING	CONSTRUCTION MATERIAL DESCRIPTION
	DRAINAGE CONDITION	SUITABILITY OF FOUNDATIONS	EASE OF EXCAVATION	SLOPE STABILITY CONDITIONS	LAND FORM AND ACCESSIBILITY	POTENTIAL NATURAL RESOURCES			
DEVELOPMENT CATEGORY	MR* 15	25	22	20	12	6		100	
TOWNSHIP DEVELOPMENT FOR LIGHT STRUCTURES									
	MR* 15	10	10	20	30	15		100	
SURFACE TRANSIT SYSTEMS									

MR* **Maximum Rating**

Table 2B: Control table: Rating allocated to influencing factors with regard to development categories (after Bester, 1981).

INFLUENCING FACTORS	1	2	3	4	5	6	AWARDED VALUE	7	8
	DRAINAGE CONDITION	SUITABILITY OF FOUNDATIONS	EASE OF EXCAVATION	SLOPE STABILITY CONDITIONS	LAND FORM AND ACCESSIBILITY	CONSTRUCTION MATERIAL		EXISTING DEVELOPMENT	CRITICAL INFLUENCING FACTORS
DEVELOPMENT CATEGORY	MR* 15	25	22	20	12	6	100		
TOWNSHIP DEVELOPMENT									
	MR* 15	10	10	20	30	15	100		
TRANSPORT SYSTEMS									

MR* **Maximum Rating**

Table 3: Rating of each influencing factor, sub-divided into five classes of decreasing merit from one to five (Price & Bester, 1981).

Influencing factor	Class	Description	Rating			
			Township development for light structures		Surface Transit Systems	
			P	B	P	B
Drainage conditions	I	Almost continuously dry land or land with excellent drainage conditions (high permeability, granular soil). Soils: GW, GP, GM, SW.	15	15	15	10
	II	Well-drained ground even under an extremely high precipitation rate. Soils: SP, SM.	12	12	12	8
	III	Ground with good run-off but with a deficiency in deep drainage (only drains under less than moderate rainfall). Soils: GC, SC.	8	8	8	6
	IV	Poor drainage in depth and at surface. High water table. Soils: ML, CL, OL.	3	3	3	2
	V	Extremely poor drainage. Very high water table. Marsh areas, bogs and continual ponding even under minor precipitation. Soils: MH, CH, OH, Pt.	1	1	1	1
Suitability of foundations	I	Compact, well-graded mixes of granular and cohesive soils in zones of soil profile >2,0m. Continuous rock at depth below surface in excess of 2,0m. Rock sound, hard, massive with high to very high strength. Slake durability 95-100%, Plasticity Index<6, Grading Modulus>2, Linear Shrinkage<6%. Low water table. Soils: GW, GM, SW, SM.	25	35	10	10
	II	Poorly graded but dense granular/cohesive soils. Continuous or scattered rock of a minimum depth below surface of 2,0m. Rock fractured and slightly to moderately weathered. Closely spaced joints; tight. Rock of medium to high strength. Slake durability 80-95%, PI: 6-12, GM: 1.75-2.0, LS: 6-8%. Low water table. Soils: SP, GP, GC, SC.	20	30	8	8
	III	Some scattered outcrop. Rock highly to very highly weathered and of moderate strength, at surface. Slake durability 50-80%. Rock quality increases with depth. Joints close, gouge filled. Poorly graded soil of medium density. Consistency stiff to very stiff. PI: 12-18, GM: 1.4-1.75, LS: 8-10. Water table <3m. Soils: CL, ML, OL.	13	20	5	5
	IV	Loose transition soils, plastic clays and silts. Localised areas of collapsing, dispersive or expansive soils. PI: 18-24, GM: 1-1.4, LS: 10-15. High water table. Soils: MH, CH.	6	10	3	3
	V	Turf, highly compressible and expansive clays. Refuse, landfill, dispersive soils, collapsible sands. PI: >24, GM: <1, LS: 15%. Highly fluctuating water table. Soils: CH, OH, Pt.	3	5	1	1
Ease of excavation	I	Very loose - moderately dens granular and very soft - firm cohesive soil of at least 2.0m depth with <10% boulders. Low water table and no outcrop.	22	12	10	15
	II	Dense - very dense granular and stiff - very stiff cohesive soil of at least 1.0m and with 10-30% boulders or core stones.	18	10	8	12
	III	Bedded or foliated moderately to highly weathered, highly fractured soft rock with soil profile as above, but with >30% boulders or core stones. High % of clay with a high moisture content.	11	6	5	8
	IV	Continuous outcrop of moderately weathered, fractured, soft to hard rock or scattered outcrop of slightly - unweathered rock with soil as in II & III. Extremely clayey material with a high moisture content.	7	4	4	6
	V	Massive, hard, slightly - unweathered rock, mostly outcrop or covered by a thin layer (0.5m) of soil, description as in I & II; deep soil loose - moderately dense with water table very close to surface. Saturated clays.	3	2	2	3

P - Price B - Bester

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Table 3 (cont.): Rating of each influencing factor, sub-divided into five classes of decreasing merit from one to five (after Price & Bester, 1981).

Influencing factor	Class	Description	Rating: Township development for light structures P	Rating: Township development for light structures B	Rating: Surface Transit Systems P	Rating: Surface Transit Systems B
Slope stability conditions	I	Soil profile with competent and stable ground even in high slopes. Rock massive or horizontally bedded and of high strength. Stable soil conditions. Strata dips steeply into the natural slope (no wedge failure). Soils: GW, GM, SW, SM.	20	20	20	20
	II	Minor stability problems (debris on slope base) but with little effect on development. Rock massive but at times slightly weathered with moderately spaced joints. Stable soil. Strata dipping mostly into slope (no wedge failure). Soils: SP, GC, GP, SC.	15	15	15	15
	III	Areas of moderate slope erosion, localized swelling, collapsing or dispersive soils (minor). Fluctuating water table. Rock highly weathered in places, joints open or clay-filled; some slaking. Strata dipping partially out of slope. Soils: ML, CL, OL.	10	10	10	10
	IV	Ground susceptible to changes in moisture content. Some risk of sliding and mass movement. High water table. Rock weathered, close and very closely-spaced joints, gouge-filled, steep dip slope. Soils as in III not uncommon. Strata dipping out of slope. Soils: OL, MH.	3	3	3	3
	V	Slopes highly susceptible to slides and flows. High and fluctuating water table; large deposits of talus; known landslide area. Rock highly fractured, weathered and disintegrates easily when exposed. Very steep dip slope. Subsidence or collapsing ground, dispersive soil or soft organic or expansive soils. Strata with high dip out of slope. Soils: CH, OH, Pt.	1	1	1	1
Land forms & accessibility	I	Few rivers and streams with road bridges. National and provincial tarred road provide access. Gravel roads and farm tracks common. Land forms: Constant slope, pediment, plain.	12	12	30	25
	II	No steep slopes. Mainly gravel and farm roads, some provincial roads. Land forms: Plateau crest, bump, fan, dry pan floor.	10	10	24	20
	III	Some ravine and gully development. Few gravel roads, mainly farm tracks. Land forms: Hill crest, ridge crest, talus slope, dune street, gully, river terrace, raised beach.	8	8	18	15
	IV	Prominent gully development. Very few gravel roads or farm tracks. No national or provincial roads. Land forms: Mountain crest, stabilized dunes, gully, water-filled pan floor.	4	4	10	8
	V	Low to high mountains and escarpments - high to very high relief (>300m). Deeply incised rivers or gorges with no existing roads only a few tracks or paths. Land forms: Cliff, free face, ledge, landslide, shifting dunes, flood plain, swamp, delta, river channel, doline, sinkhole, beach.	2	2	4	3
Potential natural resources	I	At least one natural resource for at least on of the three criteria being evaluated, and if it conforms to the sub-class 1 of the natural resources.	6	6	15	20
	II	Resource available. Conforms to sub-class 2.	5	5	12	16
	III	Resource available. Conforms to sub-class 3.	2	2	5	6
	IV	Resource available. Conforms to sub-class 4.	1	1	1	2
	V	No natural resources.	0	0	0	0

Table 4a-4c: Natural Resources

Table 4a: Classification of road material.

SUB CLASS	LAYER	LIQUID LIMIT (%)	PLASTICITY INDEX	GRADING MODULES	CBR	DENSITY (%)
1	Unstabilised base	≥ 30	≥ 6	≤ 2	≤ 80	≤ 98% mod.
2	Unstabilised sub-base	-	≥ 10	≤ 1,5	≤ 45	≤ 97% mod.
3	Unstabilised selected sub-grade	-	≥ 3 G.M. + 10	≤ 0,5	≤ 10	≤ 93% mod.
4	Unstabilised fill	-	≥ 35	≤ 0,5	≤ 3	≤ 90% mod.

Table 4b: Classification of coarse aggregate.

SUB CLAS S	STRENGTH	UCS (MPa)	RQD %	DURABILITY %	P.L.S.I. (MPa)
1	Very high strength	> 200	90 - 100	95 - 100	> 8
2	High strength	100 - 200	75 - 90	80 - 95	4 - 8
3	Medium strength	50 - 100	50 - 75	50 - 80	2 - 4
4	Low strength	< 50	< 50	<50	< 2

Table 4c: Classification of fine aggregate, mining potential & building stone and brick-making materials.

SUB CLASS	FINE AGGREGATE (SUB-CLASS DESCRIPTION)	MINING POTENTIAL AND BUILDING STONE (SUB-CLASS DESCRIPTION)	BRICK-MAKING MATERIALS (SUB-CLASS DESCRIPTION)
1	Clean, well-graded quartzite sand.	Area being mined: proven resources of building stone and minerals.	Clays composed of mixtures and clay minerals with 25-50% unsorted fine grained non clay minerals. Quartz ± 40%, Illite and Sericite 25%, Kaolinite 12%, Chlorite 4%, Montmorillonite 2%, Feldspar 10%.
2	Fairly clean, some silt, well-graded sand.	Area zoned for possible mining potential. Good quality building stone available.	Large percent quartz with minor or lesser amounts of clay. Low plasticity.
3	Moderately clean, fair % of fines, poorly graded.	Old diggings, mines, disused building stone quarries.	Sufficient amounts of non-clay minerals and clays but very high alkaline, iron and alkaline earth elements (reduce virtrification range temperature) and >2% montmorillonite.
4	Dirty, large % fines, requires washing, poorly graded.	Some minor amounts, but of poor quality, building stone (e.g. weathered slate).	Good clay/non clay matrix but very high proportion consists of montmorillonite.

Table 5: Engineering geological land-use classification (after Price & Bester, 1981).

TOTAL RATING	LAND-USE POTENTIAL	ENGINEERING GEOLOGICAL QUALIFICATION
91 - 100	VERY GOOD	GENERALLY ACCEPTABLE FOR DEVELOPMENT
71 - 90	GOOD	ACCEPTABLE WITH SOME MINOR INVESTIGATION OF CERTAIN INFLUENCE FACTORS.
41 - 70	FAIR	TERRAIN ECONOMICALLY VIABLE WITH FURTHER INVESTIGATION.
21 - 40	POOR	DEVELOPMENT UNECONOMICALLY VIABLE. ANALYSIS OF THE ECONOMIC IMPLICATIONS REQUIRED BEFORE ANY FURTHER INVESTIGATION.
< 21	VERY POOR	TOTALY UNACCEPTABLE FOR DEVELOPMENT. IF DEVELOPED THEN AT EXTREMELY HIGH COST.

and those for roads.

- Distinction should be made between the suitability of foundations for light structures and roads, due to different financial implications.
- The Primary category "Roads" should be sub-divided into different road types. A difference in unit costs could cause that certain influencing factors plays a major role in one type of road during construction, whilst for another it will be of minor concern. Tables 4a-c represents the five types of construction materials, each sub-divided into four classes of quality according to certain minimum standard requirements. If these requirements aren't fulfilled, it can not be classed as a specific type of construction material. For this reason it was decided that the classification was not applicable and that a mapping unit can only be identified for one or the other source of construction material, with no sub-divided classes describing the quality of the construction material.

3.4.2.3 Presentation

The engineering geological maps produced by Price (Figure 5) and Bester (Figure 6) were compiled on a 1:50 000-scale, using the topographical sheet as base map to allow easy orientation. The geotechnical maps produced by Price and Bester consist of the following:

- Geological lithology, contacts, faults, joints, brecciated zones, strike and dip.
- Delineation of existing and potential construction material resources.
- Delineation of each facet group or mapping unit.
- Price gives a description of each facet group (mapping unit) with a map symbol allocated in Figure 5 in terms of: 1) Soil description & Unified classification, 2) Engineering geological land-use rating for township development and roads & railway, 3) Potential geotechnical problems, 4) Construction materials, 5) Engineering geological land-use potential, according to the rates in Table 5.
- Bester gives a description of each mapping unit with a map symbol allocated in Figure 6 in terms of: 1) Typical soil profile description, 2) typical land form, 3)

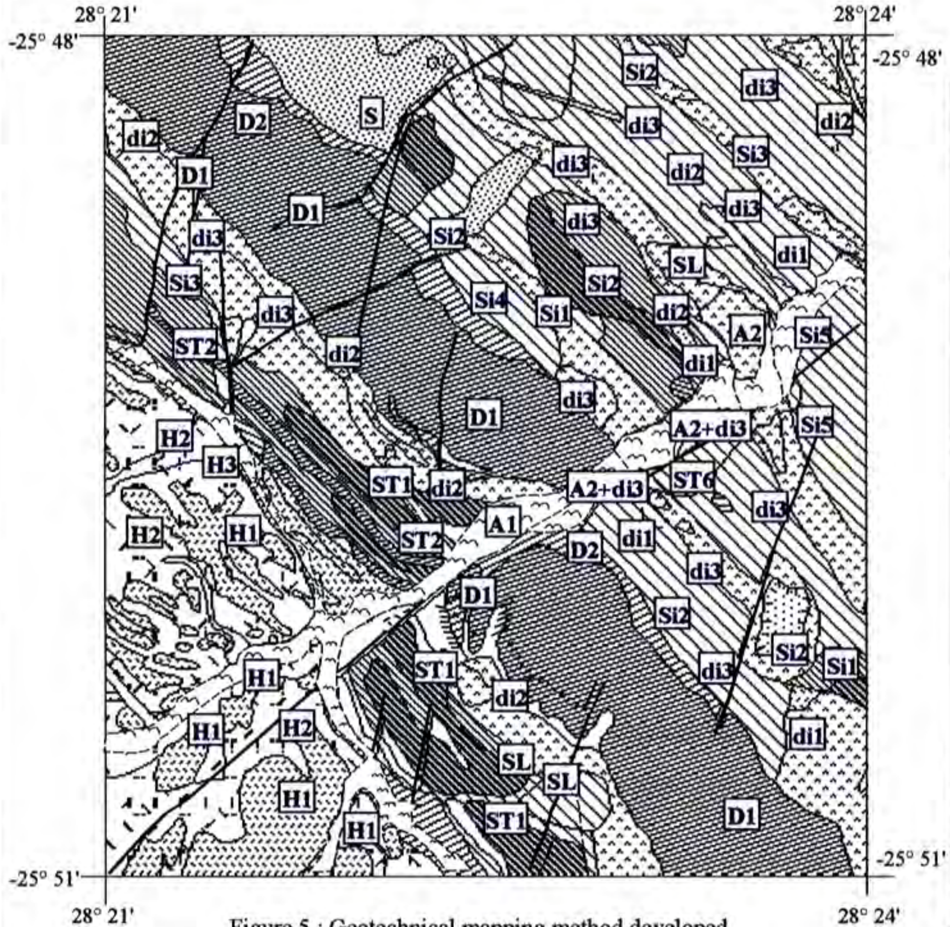

Figure 5 : Geotechnical mapping method developed by Price (1981) with an overlay of the different site classes

1 : 50 000

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GROUP / SUBGROUP	FORMATION	FACET GROUP	MAP CODE	FACET GROUP DESCRIPTION & UNIFIED CLASSIFICATION	ENG. GEOL. LAND-USE RATING		POTENTIAL PROBLEMS	CONSTRUCTION MATERIALS	ENG. GEOL LAND-USE POTENT
RECENT DEPOSITS					TOWNSHIP	ROAD & R'WAY			
RECENT UNCONSOLIDATED DEPOSITS		A1		SILTY SAND, SANDY CLAY, SILT, GRAVEL, CLAY - VARIABLE	0	0	FLOODING		V POOR
		A2		ALLUVIAL CLAY (CH)	0	0	FLOODING EXPANSIVE		V POOR
		S1		COLLUVIAL SILTY SAND (SM) / VARIETY OF ROCK TYPES	75	74	COLLAPSIBLE GRAIN STRUCTURE	FINE AGGREGATE SUBGRADE	GOOD
TRANSVAAL SUPERGROUP									
PRETORIA GROUP	SILVERTON SHALE	Si1		CONTINUOUS OUTCROP OF FINE GRAINED SILTY & GRAPHIC SHALE	64	67	SLOPE UNSTABLE IN DEEP EXCAVATIONS	SUBBASE, S SUBGRADE	FAIR
		Si2		SCATTERED OUTCROP WITH INTERSTITIAL SILTY GRAVEL (GM)	66	71		SUBBASE, S SUBGRADE	FAIR - GOOD
		Si3		KHAKI COLLUVIAL SILTY GRAVELLY SAND (SM,SP) / SHALE	88	87		BRICKS, S SUBBASE	GOOD
		Si4		YELLOW / BROWN COLL. - CLAYEY & SILTY GRAVEL (GC) / SHALE	75	73		BRICKS, FILL	GOOD
		Si5		RED / BROWN COLL. - SANDY CLAY WITH FERRICRETE (CL) / RES. SILTY GRAVEL (GM) / SHALE	54	50	ACTIVE CLAY		FAIR
		Si6		BLACK COLLUVIAL CLAY (MINOR CALCRETE) (CH) / RES SILTY GRAVEL (GM) / SHALE	16	17	EXPANSIVE		V POOR
	DASPOORT	D1		CONTINUOUS OUTCROP OF MEDIUM GRAINED ORTHO-QUARTZITE	30	40	EXCAVATION	FINE & COARSE AGGREGATE, BASE	FAIR
		D2		SCATTERED OUTCROP WITH INTERSTITIAL SILTY SAND (SM) & QUARTZITE BOULDERS / QUARTZITE	85	90			GOOD
	STRUBENKOP	ST1		CONTINUOUS OUTCROP OF FINE GRAINED HIGHLY JOINTED SHALE	64	67	SLIDING IN DEEP EXCAVATIONS		FAIR
		ST2		SCATTERED OUTCROP OF BROWN FERRUGINOUS SHALE INTERS. SILTY GRAVEL	63	67			FAIR
		ST3		RED / YELLOW COLL. SILTY GRAVEL (GM) / SHALE	73	73			GOOD
		ST1		CONTINUOUS OUTCROP OF FINE GRAINED IRON-RICH INTENSELY JOINTED QUARTZITE	75	70	EXCAVATION		GOOD
		ST2		SCATTERED OUTCROP OF QUARTZITE / INTERSTITIAL GRAVELLY SILTY SAND (SM) / QUARTZITE	83	80			GOOD
	HEKPOORT	H1		CONTINUOUS OUTCROP OF VERY HARD ANDESITE	71	63	EXCAVATION		FAIR - GOOD
		H2		SCATTERED OUTCROP OF AMYGDALOIDAL ANDESITE / INTERSTITIAL SANDY CLAY	51	36	EXCAVATION		FAIR
		H3		RESIDUAL RED SILTY CLAY (CH) / RED / OLIVE RES. SILTY CLAY (CL) / ANDESITE	35	44	EXPANSIVE		POOR - FAIR
IGNEOUS INTRUSIVE									
SYENITE DYKES		e1		SYENITE ROCK (DYKES) WITH OR WITHOUT SILTY SANDY SOIL	31	32			FAIR
DIABASE DYKES & SILLS		d1		CONTINUOUS OUTCROP OF MEDIUM GRAINED, VERY HARD DIABASE	61	64	EXCAVATION		FAIR
		d2		SCATTERED OUTCROP WITH INTERSTITIAL RED SANDY CLAY	61	64	EXPANSIVE		FAIR
		d3		RED RESIDUAL SANDY CLAY (CL) / GREEN-GREY RES DIABASE (CL) / DIABASE	31	32	EXPANSIVE		POOR

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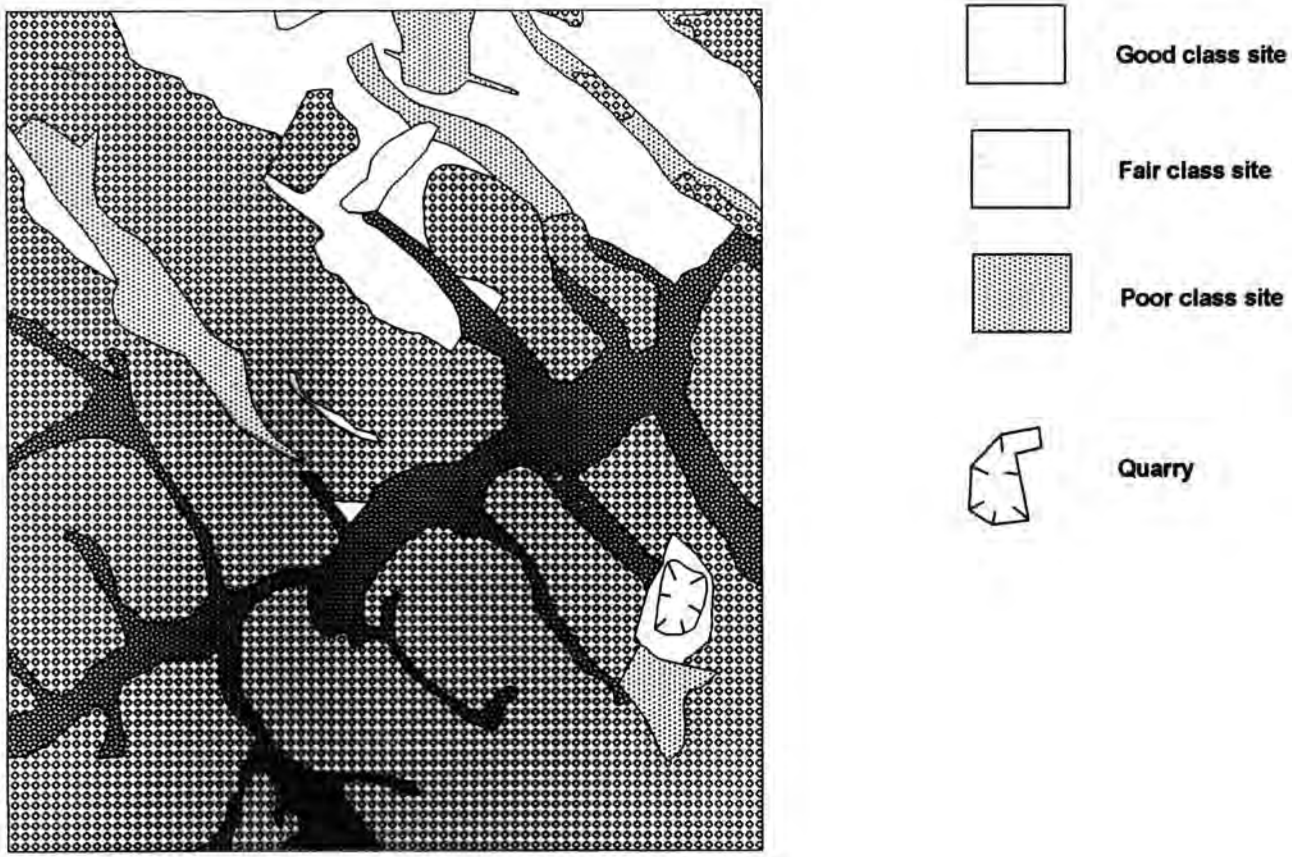

Figure 5 Overlay
1:50 000

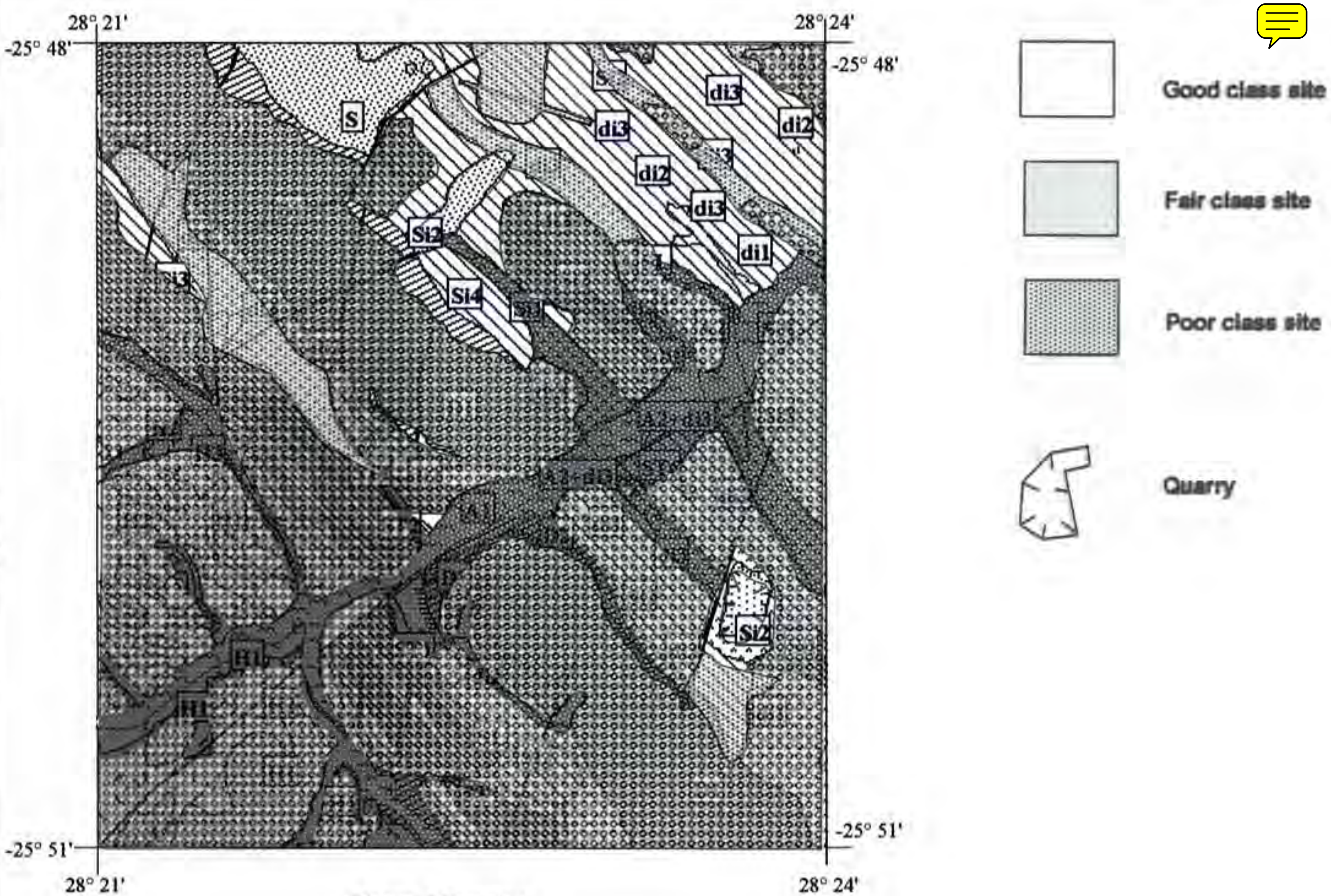

Figure 5 Overlay
1:50 000

1 : 50 000

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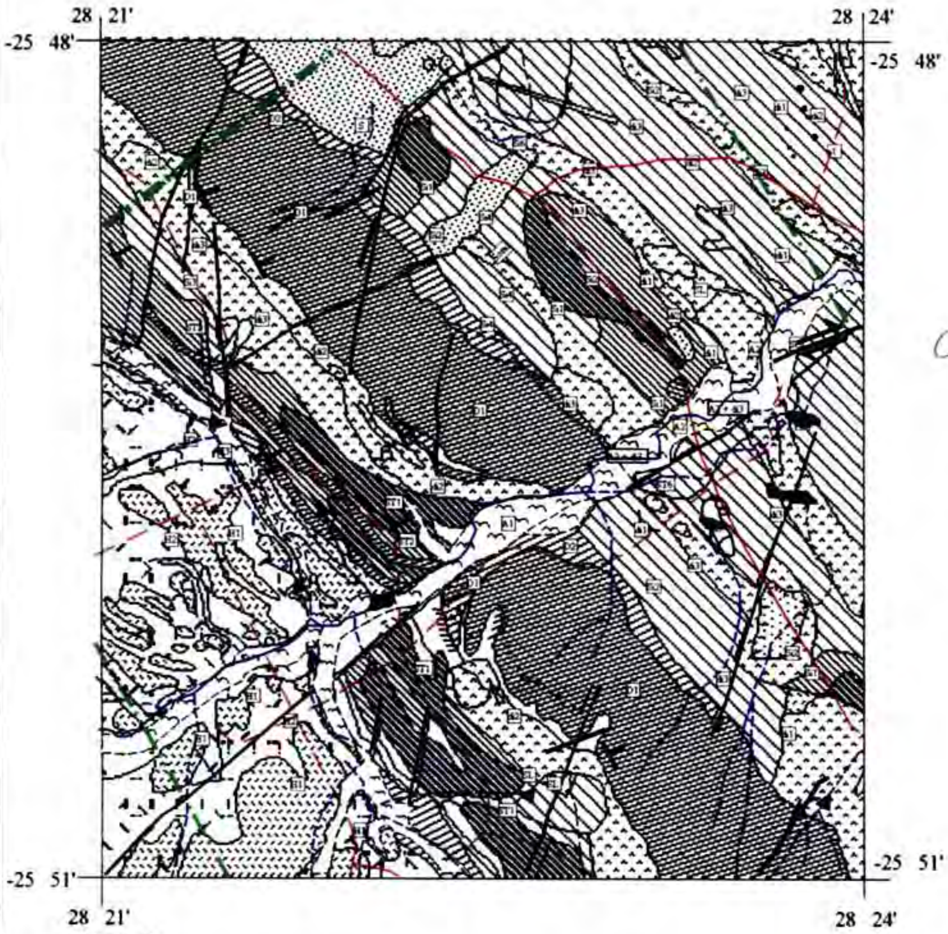

LEGEND:

LEGEND SYMBOLS

- Fault
- Main joint orientation
- Dip & Strike
- Geological Contact
- Borders between mapping units
- Farm boundaries and farm names
- Main roads
- Secondary roads
- Geological boundaries
- Drainage Features (Non-perennial)
- Drainage Features (Perennial)
- Quarry
- Mapping unit / Geological formation

UNCONSOLIDATED MATERIAL

ALLUVIUM	
SAND	(S)

CONSTRUCTION MATERIAL QUARRIES

- Sand
- Clay

SYMBOL: OUTCROP	SYMBOL: SCATTERED OUTCROP	SYMBOL: NO OUTCROP	ROCK TYPE	FORMATION	GROUP	SUPER GROUP
			Shale	SILVERTON (Si)	PRETORIA	TRANSVAAL
			Quartzite	DASPOORT (D)		
			Shale	STRUBENKOP (ST)		
			Quartzite			
			Andesite	HEKPOORT (H)		
			Diabase (dyke and/or sill)			
			Syenite (dyke)			

DEVELOPMENT CATEGORY: PRIMARY	DEVELOPMENT CATEGORY: SECONDARY		DEVELOPMENT POTENTIAL: FAVOURABLE	UNFAVOURABLE	UNCERTAIN	MINING POTENTIAL
TOWNSHIP DEVELOPMENT	Light structures (foundation excavatability <1,0m).		Si2, Si3, Si4, D2, H2, H3, ST1, ST2, ST3 (shale), ST2 (quartzite).	D1, Si6, H1, ST1 (quartzite), di1, A1, A2.	Si1, Si5, di2, di3, S.	
	Deep excavations (>1,0m).		Si3, Si4, H2, H3, di3, S.	D1, H1, ST1 (quartzite), di1.	Si2, D2, ST1, ST2, ST3 (shale), ST2 (quartzite), di2, A1, A2.	
	Roads (except bridges)		Same as for light structures, as well as Si5, di2, di3, S.	Same as for light structures.	Si1	
ROADS (except bridges)	National roads (highways)		All other.	D1, H1, ST1 (quartzite).	Si6, A1, A2.	
	Provincial roads (tar)		All other.	Same as for national roads, as well as A1, A2.	Si6, di3.	
	Other (gravel)		All other.	D1, H1, di1.	-	
CONSTRUCTION MATERIAL	Coarse aggregate.		D1.	All other.	di1	
	Fine aggregate.		D1.	All other.	-	
	ROADS	Base.	D1.	All other.	di1	
		Sub-base.	Ferricrete over andesite.	All other.	Si2, Si3, ST2, ST3 (shale).	
		Selected Sub-grade.	-	All other.	Si4, S.	
		Fill.	-	All other.	Si4, Si5, S, di2, H3	
	Building sand.		-	All other.	s.	
	Brick clay.		-	All other.	-	

General interpretation of the development potential for each development category

MAPPING UNIT: SYMBOL	TYPICAL PROFILE DESCRIPTION	GENERAL ENGINEERING GEOLOGICAL CHARACTERISTICS: TYPICAL LANDFORM	DRAINAGE (surface)	EXCAVATABILITY (after Weaver, 1975)	GENERAL FOUNDATION	GENERAL STABILITY	
Si 1	Continuous outcrop. Soft to hard rock, olive grey to yellowish brown, well layered, intensively jointed SHALE.	Hill crest	Good	Difficult rippability, although blasting may be required for deep excavations.	0 - 0,2m	Stable as foundation material and the side walls of deep excavations.	Continuous outcrop, not good for light structures.
Si 2	Scattered outcrop with a profile in between of loose to compact slightly moist, silty GRAVEL (GP) of 0,2m thickness, over soft shattered, highly to totally weathered SHALE, with a decrease in weathering with depth.	Straight slope	Good	Mainly difficult rippability, blasting required for excavations deeper than 1,0m.	0 - 0,2m	do	None
Si 3	No outcrop. Colluvial sandy, silty GRAVEL (GP) of 0,4m thickness, over soft intensively jointed highly to totally weathered SHALE, with a decrease in weathering with depth.	Straight to concave slope	Good	Difficult rippability with slight blasting in deep excavasions.	0,2 - 0,5m	Stable as foundation material and in deep excavations.	None
Si 4	No outcrop. Stiff, moist, dark brown, colluvium silty SAND (SM) to sandy CLAY (SC) of 0,4m thickness, over a 0,3m thick ferricrete concretion pebble marker, over stiff to very stiff, moist, residual, sandy CLAY (SC), over SHALE.	Flat straight slope	Poor (ground water level between 5m-10m).	Easy to difficult rippability. With no blasting required for excavations to a depth of 3,0m.	0,2 - 0,5m (due to ferricrete layer).	Ferricrete stable as foundation material, whilst the side walls of excavations may be unstable under the ground water level.	None
Si 5	No outcrop. Soft to stiff, moist, colluvium, sandy CLAY (CH) with gravel (shale fragments) to a depth of 1,0m over a 0,5m thick horizon of stiff, moist, residual silty CLAY (CL), over loose to medium dense residual clayey SAND (SC) with gravel over SHALE.	do	Poor	Easy rippability	>0,5m	Sandy CLAY with medium to high expansiveness, with 27% montmorillonite.	Medium to highly expansive clays, precaution should be taken against differential movement.
Si 6	No outcrop. Stiff to very stiff, highly plasticity CLAY (CH) of 0,3m thickness over stiff to very stiff, black, highly plasticity clay (CH).	Flood plain	Poor (marshy areas develope during rainy seasons).	Easy rippability, but elevated ground water levels could pose a problem.	>0,5m	Highly unstable due to expansive clays. Side walls of excavations unstable due to shallow ground water levels and pressure.	Clay highly expansive with a rise in the ground water table.
D 1	Continuous outcrop. Hard to very hard greyish white to light brown, medium grained, jointed to solid quartzite.	Hill crest	Good to the north east.	Extremely difficult rippability blasting required.	0-0,2m	Stable as foundation material and as side walls in deep excavations.	Continuous outcrop, not good for the development of light structure.
D 2	Scattered quartzite outcrop with a in between profile of dry, loose, colluvium silty SAND (SM) with weathered quartzite boulders to a depth of 0,35m over hard to very hard, mediumgrainedquartzite(slope40 N).	Straight slope	Good	Blasting required for excavation in rock & easy rippability in sand.	0-0,2m	Stable as foundation material and as side walls in deep excavations.	None
ST 1	Continuous outcrop. Soft to very hard, brown to purple, highly jointed, weathered to unweathered SHALE.	Concave slope	do	Blasting required for excavation in rock & easy rippability in sand.	0-0,2m	Stable as foundation material and as side walls in deep excavations.	None
ST 2	Scattered shale outcrop with a profile in between of loose to medium dense, colluvium gravely (shale fragments) SILT (GM) with a thickness of 0,5m over soft shattered highly weathered, weathering decreases with increase in depth.	do	do	Easy rippability for shallow excavations, but difficult for deep excavations.	0,2-0,5m	do	None
ST 3	No outcrop, dry, loose to dense, colluvium silty GRAVEL (GP) with a thickness of between 0,2m to 0,5m over weathered to unweathered SHALE.	do	do	Easy rippability	do	do	None
ST 1	Continuous outcrop. Hard, red brown, fine grained iron-rich, intensely jointed QUARTZITE.	Hill crest	Good	Extensively difficult rippability, blasting required.	0-0,2m	No stability problems anticipated.	Continuous outcrop, not good for the development of light structures.
ST 2	Scattered quartzite outcrop with a profile in between of slightly moist, loose to dense, gravely, silty SAND (SM) to a depth of 0,3m over soft (harder with depth), stratified and shattered weathered to unweathered QUARTZITE.	Straight slope	Good	Extensively difficult rippability, blasting required.	0,2-0,5m	No stability problems anticipated.	None.
H 1	Continuous outcrop. Very hard, dark greyish green, massive ANDESITE.	Hill crest	do	Difficult to extensively difficult rippability, blasting required.	0,2-0,5m	Stable as foundation material & stable side walls of deep excavations.	Spherical weathering under outcrop could be misleading, not good for the development of light structures.
H 2	Scattered andesite outcrop with a profile in between of dry, medium dense, colluvium sandy GRAVEL as the matrix with semi-rounded boulders of andesite to a depth of 0,35m over a PEBBLE MARKER, over slightly moist, stiff, residual silty CLAY (CL) to a depth of 2,0m.	Straight slope	do	Difficult rippability for excavation in between outcrop, with blasting required in rock.	0,2-0,5m (spherical weathering).	Differential movement may occur due to a big change in moisture condition of silty CLAY.	Silty CLAY (Residual andesite), with medium expansiveness & a free swell potential of 15-13mm.
H 3	No outcrop. Slightly moist, firm, colluvium silty CLAY (CL)) to a depth of 0,4m over a PEBBLE MARKER over slightly moist to moist, firm, residual silty CLAY (CL) to a depth of 2,0m.	Flat straight slope	Moderate to poor	Difficult to extensively rippability blasting required for deep excavation.	0,2-0,5m (reinforced foundation or split construction required)	Different movement may occur due to a big change in moisture condition of silty CLAY.	Colluvium CLAY & residual CLAY, with medium expansiveness & a free swell potential of 15-30mm.
s	Slightly moist, loose to dense, reddish brown to yellowish white, colluvium silty SAND (SM) with a thickness between 1,0 to 4,0m.	Straight slope	Poor (deep ground water level)	Easy rippability	0,2-0,5m (depended on the density of SAND).	In general stable. Side walls of deep excavations fairly stable due to free drainage.	SAND with a collapse potential may occur at the foot of the Magaliesberg and the Daspoort Ridge.
di 1	Continuous outcrop of hard, greyish green, DIABASE (stained joints).	Hill crest	Good	Mainly blasting with extensive difficult rippability where spheric weathering occurs under outcrop.	0-0,2m	No stability problems anticipated.	Continuous outcrop, good for the development of light structures.
di 2	Scattered outcrop with a profile in between of dry, stiff, microshattered, colluvium sandy CLAY (CL-CH) of 0,35m over slightly moist, microshattered, residual sandy CLAY (CH) to a depth of 1,0m over DIABASE.	Straight slope	do	Difficult to very difficult rippability, moderate blasting required.	0,2-0,5m (reinforced foundations or provision should be made for differential settlement	Differential movement could be anticipated if founded on rock & soil.	Medium to highly expansive CLAY, with a free swell potentail of >10mm.
di 3	No outcrop. Dry to slightly moist, firm, colluvium, silty CLAY (CL-CH) to a depth of 0,45m over a PEBBLE marker over dry to slightly moist, residual silty CLAY (CL-CH) to a depth of 1,0m over soft, sandy CLAY (highly weathered diabase).	Flat straight slope	Poor	Difficult to very difficult rippability,with slight blasting required for deep excavations.	do	Differential settlement could be anticipated, due to expansive CLAYS.	do
sl	Continuous outcrop, very hard, yellowish brown SYENITE.	Hill crest	Good	Extensively difficult rippability, blasting required	0-0,2m	No stability problems anticipated	Continuous outcrop, good for the development ofl ight structures
A 1	Alluvium deposits of sandy CLAY with lenses of Alluvium gravel.	River channel & terrace	Poor (fluctuating ground water level.	Easy rippability, but problems with ground water could be anticipated.	Unknown	Stability problems anticipated, due to fluctuating ground water table.	Development and stability could be influenced by floods.
A 2	Alluvium CLAY (poorly drained areas).	Flood plain	Very poor	Easy rippability, but problems can be anticipated with difficult workability & poor drainage.	Mostly >0,5m and provision should be made for differential movement	Unstable foundation conditions. Side walls of excavations unstable due to shallow ground water levels & pressure.	Flood plain, extremely poor drainage conditions & highly expansive CLAYS.
SL	Gully development where a thin colluvium soil layer consisting of material transported from the immediate environment.	Gully	Generally good	Not applicable	Not applicable	Not applicable	None

Description of the general engineering geological characteristics for each mapping unit

Figure 6 : Geotechnical mapping method developed by Bester (1981)

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Drawn by : W.L.Buitendag
Date : October 2001

General description of engineering geological characteristics (e.g. drainage, excavatability, general foundation depth and general stability), 4) Critical influencing factors.

- After revision of the classification system, Bester divided the "Development category" into three Primary categories, namely "Township development, Transport systems and Construction material". Each Primary category were sub-divided in Secondary categories and each was then described in terms of it's Development Potential (favourable, unfavourable or uncertain). A separate column was also added to describe the mining potential of units (Figure 6).

3.4.3 Engineering Geological Mapping for Urban Planning in Developing Countries by Van Schalkwyk and Price (1990)

3.4.3.1 Purpose

The purpose was to develop a site classification system to distinguish between good, fair and poor site class areas for residential development. Such a sub-division, provided as an overlay to the engineering geological map, can readily be understood and used by planners.

3.4.3.2 Classification

For housing development, the most important geological influencing factors to take into account are the: 1) foundation, 2) slope stability and 3) drainage conditions. Each of these factors is classified in terms of their severity into three sub-classes and allocated a rating point. The three sub-classes are namely, favourable (rating point of 1), slightly unfavourable (rating point of 2) and unfavourable (rating point of 5).

Guidelines to identify the different conditions for each of the geological influencing factors, are represented in Tables 6 - 8. In order to classify foundation conditions, the term volumetric stability was used to describe the behaviour of swelling or shrinking clays, collapsible and compressible soils. The various terms are defined in Table 9.

Table 6: Guidelines for the identification of different foundation conditions (after Van Schalkwyk & Price, 1990).

CONDITION	RATING	DESCRIPTION
Favourable	1	1) No risk for sinkhole or doline formation, 2) > 500 mm of volumetric stable topsoil
Slightly unfavourable	2	1) Low risk for sinkhole or doline formation, 2) < 1 500 mm unfavourable layer of volumetrically very unstable topsoil, 3) > 1 500 mm layer of volumetrically moderately unstable topsoil, 4) Scattered or continuous rock outcrop
Unfavourable	5	1) Medium to high risk for sinkhole or doline formation, 2) > 1 500 mm layer of volumetrically very unstable topsoil

Table 7: Guidelines for the identification of different drainage conditions (after Van Schalkwyk & Price, 1990).

CONDITION	RATING	DESCRIPTION
Favourable	1	1) Good surface drainage - no ponding, 2) Deep groundwater table, 2) Highly to moderately permeable topsoil and bedrock
Slightly unfavourable	2	1) Satisfactory surface drainage - occasional surface ponding, 2) Seasinal groundwater level fluctuations, 3) Poor draining topsoil on permeable bedrock
Unfavourable	5	1) Poor surface drainage - standing water, 2) Permanent shallow groundwater table - marshy areas, 3) Located in valley, below 1: 50 year flood line, 4) Poor draining topsoil on impermeable bedrock

Table 8: Guidelines for the identification of slope stability conditions (after Van Schalkwyk & Price, 1990).

CONDITION	RATING	DESCRIPTION
Favourable	1	1) Low surface gradient (<10°), 2) Deep groundwater level, 3) Good sub-surface drainage, 4) Dense granular topsoil, 5) Sound bedrock with favourable bedding dip
Slightly unfavourable	2	1) Moderate surface gradient (10 - 20°), 2) Fluctuating groundwater level, 3) Reasonably good subsurface drainage, 4) Unstable topsoil < 500 mm thick, 5) Evidence of soil creep, 6) Sound bedrock with favourable dip
Unfavourable	5	1) Steep surface gradient (>20°), 2) Shallow groundwater table, 3) Poor sub-surface drainage, 4) Unstable topsoil > 500 mm thick, 5) Evidence of hummocky ground or slip scars, 5) Discontinuous bedrock with unfavourable dip

Table 9: Definition of volumetrically unstable soils (after Van Schalkwyk & Price, 1990).

VOLUMETRIC STABILITY	SHEAR STRENGTH (Cu: kPa)	TOTAL MOVEMENT (mm)
Stable	> 200	< 6
Moderately unstable	50 -200	6 - 50
Very unstable	< 50	> 50

Table 10: Site classification in terms of total rating (after Van Schalkwyk & Price, 1990).

SITE CLASS	TOTAL RATING
Good	3
Fair	4 - 6
Poor	7 - 15

The three influencing factors are individually rated for each mapping unit and the total rating for each unit is obtained by adding the points for each factor. The site is then classified as Good, Fair or Poor according to Table 10. This classification implies that for a site to be good, all three geological factors must be favourable. One or more slightly unfavourable conditions place the site in the fair class, while one or more unfavourable conditions classify the site as poor.

3.4.3.3 Presentation

The site classification map developed by van Schalkwyk and Price (1990) is represented as an overlay for the regional engineering geological map (Figure 5). On this map, distinction is made between good site class areas (blank), fair site class areas (open dotted) and poor site class areas (dotted).

3.4.4 Geotechnical classification system for township development by Partridge, Wood & Brink (1993) and modified by the CSIR (1996)

3.4.4.1 Purpose

The classification system developed by Partridge *et. al.* (1993) was specifically for township development and use during urban planning. This classification system was approved by the South African Institute for Engineering Geologists (SAIEG) as the nomenclature for Regional Engineering Geological Mapping (SAIEG, 1997) and is also supported by the National Home Builders Registration Council (NHBRC, 1995) *Standards and Guidelines* for Urban Planning.

The Division of Building Technology of the CSIR in partnership with the consultants Partridge, Maud and Associates published a series of 1:50 000 scale maps in the year 1996, with the objective to rate the geotechnical suitability for housing development of vacant land in the greater Johannesburg, Gauteng province. The descriptors of relevant constraints and the severity thereof, was based on the classification system of Partridge *et. al.* (1993), with minimal modification by the CSIR, as indicated in the table "Geotechnical classification for urban development" shown in Figure 7.

3.4.4.2 Geotechnical Classification System for Urban Development

Land facets are classified into categories of constraints. The constraints that will have an influence on development can be grouped into three main categories; firstly, geological (dolomitic areas) and mining hazards, secondly physical and thirdly, geotechnical constraints and are described briefly in Table 11. Terrain types can be identified by allocating an alphanumeric code for each constraint present in the mapped unit. The categories of development suitability (most suitable/favourable, intermediate and least suitable/unfavourable) with respect to geotechnical constraints A to L are listed in the table "Geotechnical classification for urban development" presented in Figure 7.

The information and development suitability of map sheets produced by the CSIR, has been derived from the generalisation of data contained in a Geotechnical Information System (GeoIS) housed at the Division of Building Technology at the CSIR (Murphy and Stiff, 1994) as well as the assessment of geotechnical constraints within each terrain mapping unit. These maps therefore represents a generalisation of the occurrence and expected severity of a particular constraint within an area and are only to be used as a guide for the planning of housing projects.

3.4.4.3 Presentation

The terrain mapping units indicated on the maps have been coloured green, yellow and red, providing 'stop - go' colours with respect to the suitability for housing development.

Table 11: Geotechnical constraints for Urban Development (after CSIR, 1996).

CONSTRAINT	ASSOCIATED PROBLEMS
GEOLOGICAL & MINING HAZARDS	**Dolomitic areas:** Formation of sinkholes or dolines, which is a high cost factor in terms of potential loss of life and structural damage to buildings. Should be investigated on a site specific level according to the evaluation proposed by Buttrick and van Schalkwyk (1995). Dolomitic areas are denoted as 3H on the map.
	Undermined ground: Potential collapse of stopes in shallow undermined areas, which is a high cost factor in terms of potential loss of life and structural damage to buildings. Information on the location of mining activities should be obtained from the relevant local authority, before planning developments in areas of undermined land . Denoted as G on the map)
	Slimes dams and mine tailings: Footprints (reclaimed slimes dams) cannot be considered ideal for housing development, due to potentially high radon levels from decaying radioactive elements present in the soil and remnant materials. Denoted as 3S on the map.
	Seismicity: Natural seismic events, would occur in a very unstable geological environment (e.g. active fault zones). Induced seismicity could be caused by activities such as mining and is fairly common in the Central and far West Rand where deep level mining has taken place. SABS 0160-1989 provides design guidelines for the building design of structures in such areas. Denoted as K on the map.
PHYSICAL CONSTRAINTS	**Topographic features:** Areas that show a resilience to weathering and forms prominent physical features (e.g. ridges and hill crests), with poor soil development and high excavation costs to establish infrastructure. These areas are often also associated with excessively steep slopes. Denoted as I on the maps.
	Drainage features: Areas of river systems or seasonal drainage channels that are prone to flooding after heavy rainfalls, should not be developed, due to the potential loss of live and structural damage. It is therefore important that development adhere to the proclaimed 1:50 year flood line. Areas where a risk of inundation by flood waters exist are denoted L on the maps.
	Wetlands: Significant ecologically sensitive wetland systems, also denoted as L on the maps.
GEOTECHNICAL CONSTRAINTS	**Heaving clay:** The amount of expansion in millimetres (expressed as total soil heave) that can be expected when the moisture in the soil changes, causing vertical heave and differential movement that leads to structural damage. These areas are denoted as C on the maps.
	Collapsible soils: Associated with open structure soils, mainly silty and sandy soils. An increase in the moisture content of these soils under sufficient external load (such as a single-storey house) results in the collapse of their structure, expressed as % decrease in soil volume. Differential settlement occurs causing structural damage. Denoted as A on the maps.
	Compressible soils: Associated with thick, transported soils on side slopes adjacent to escarpments, or saturated soils with a low bearing capacity, causing differential settlement. Denoted as D on the maps.
	Poor excavation: The ease with which ground can be dug to a depth of 1,5 m. This is a high cost factor when installing foundations and underground services. Problematic areas are associated with prominent relief, shallow bedrock or the presence of pedocretes. Denoted as F on the maps.
	Slope instability: Natural slope instability, associated with areas comprising unstable geological materials that could move. The risk of movement is determined by the nature of the slope, slope gradient, role of water, vegetation cover, seismicity and impact of human activities such as undermining and excavations. Denoted J on the maps.
	Erodible soils: The extent to which a soil can be eroded by the action of water or wind. Erodibility needs otherwise only to be considered as a local occurrence, such as erosional channels, dongas or gulleys. Denoted as E on the maps.

Green represents areas that are most favourable for development (Class 1) and red represents areas least favourable for development (Class 3). Inside each coloured area is an alphanumeric code, which is a descriptor of the geotechnical constraint relevant to that particular area. The descriptors to relevant constraints and the severity thereof are given in the table "Geotechnical classification for urban development" represented in Figure 7. For example a code 2AB describes an area of intermediate suitability for housing development (coloured yellow on the maps) due to a potential for collapse (denoted A) and seepage condition (denoted B) in Class 2 for both of these constraints.

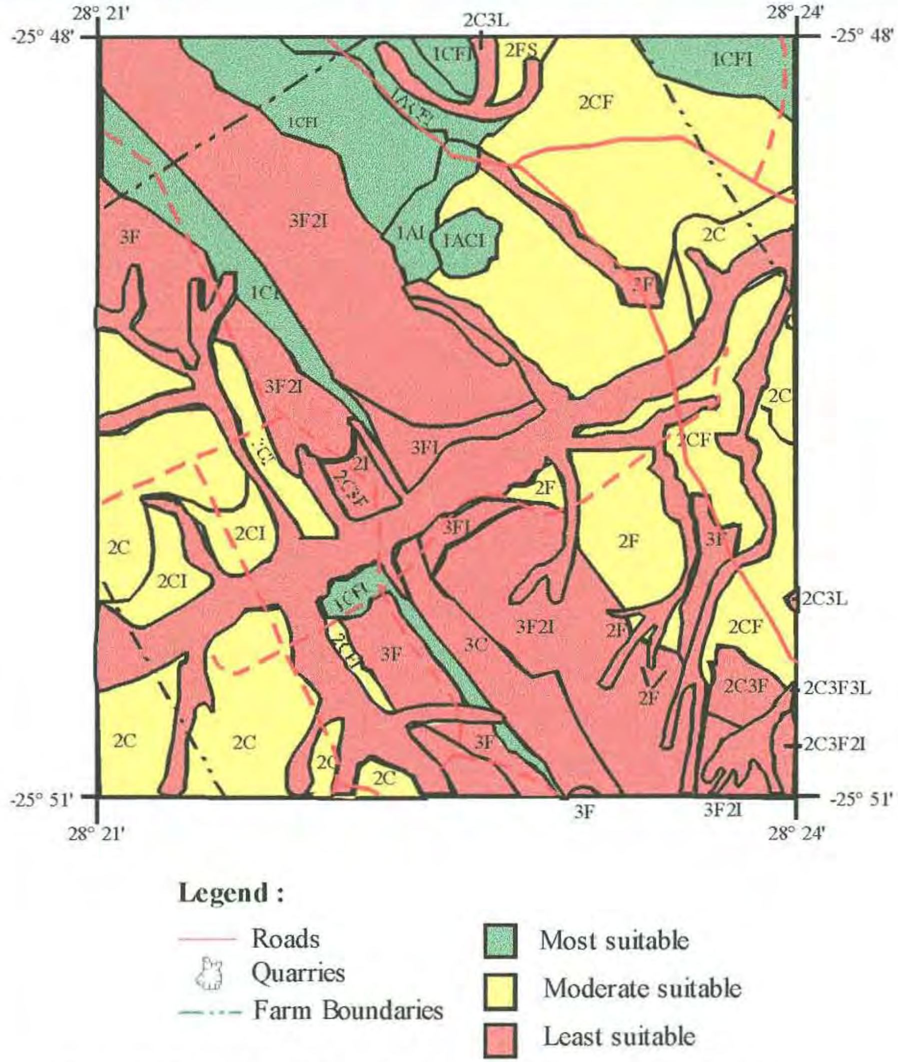

Figure 7 : Geotechnical classification method developed by Partridge, Wood & Brink (1993) and used by the Council for Scientific and Industrial Research (1996)

Scale : 1 : 50 000

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GEOTECHNICAL CLASSIFICATION FOR URBAN DEVELOPMENT (Partridge *et.al.*, 1993)

PARAMETER		Class 1 (Most Favourable)	Class 2 (Intermediate)	Class 3 (Least Favourable)
A	Collapsible soil	Any collapsible horizon or consecutive horizons totalling a depth of less than 750mm thickness.	Any collapsible horizon or consecutive horizons with a depth of more than 750mm in thickness.	A least favourable situation for this constraint does not occur.
B	Seepage	Permanent or perched water table more than 1,5m below ground surface.	Permanent or perched water table less than 1,5m below ground surface.	Swamps and marshes
C	Active soil	Low soil-heave potential predicted*.	Moderate soil heave potential predicted.	High soil-heave potential predicted.
D	High compressible soil	Low soil compressibility expected.*	Moderate soil compressibility expected.	High soil compressibility expected.
E	Erodability of soil	Low	Intermediate	High
F	Difficulty of excavation to 1,5m depth.	Scattered or occasional boulders less than 10% of the total volume.*	Rock or hardpan pedocretes between 10 & 40% of the total volume.	Rock or hardpan pedocretes more than 40% ofthe total volume.
G#	Undermined ground	Undermining at a depth >100m below surface (except where total extraction mining has not occurred).	Old undermined areas to a depth of 100m below surface where stope closure has ceased.	Mining within less than 100m of surface or where total extraction mining has taken place.
H	Instability in areas of soluble rock.	Possibly unstable	Probably unstable	Known sinkholes and dolines
I	Steep slopes	Between 2 and 6° (all regions).	Slopes between 6 & 18° and less than 2° (Natal and Western Cape). Slopes between 6-12° and less than 2° (all other regions).	More than 18° (Natal and Western Cape). More than 12° (all other regions).
J	Areas of unstable natural slopes.	Low risk	Intermediate risk.	High risk (especially in areas subject to seismic activity).
K#	Areas subject to seismic activity	10% probability of an event less than 100 cm/s² within 50 years.	Mining-induced seismic activity more than 100 cm/s²	Natural seismic activity more than 100 cm/s²
L	Areas subject to flooding	A "most favourable" situation for this constraint does not occur.	Areas adjacent to a known drainage channel or flood plain with slope less than 1%	Areas within a known drainage channel or flood plain.

* These parameters are not considered by the CSIR geotechnical classification system.

\# These areas are designated as 1A, 1C, 1D or 1F where localised occurences of the constaint may arise

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Date : November 2001

Potential resources of construction materials, sites most suitable for cemeteries and waste-disposal can also be indicated on the map.

3.4.5 An Engineering Geological Geographic Information System (GIS) Model for Land-use Planning by Croukamp (Council for Geoscience, 1996)

3.4.5.1 Purpose

The purpose was to design a geographic information system with the primary objective to create an engineering geological development potential map. The map with classification criteria, will assist the engineering geologist in the determination of the development suitability of an area and the information provided is in a ready to use digital format.

3.4.5.2 GIS model & classisification criteria for a development potential map

A GIS can be regarded as a computer based system storing different spatial data sets (layers) or attribute data relevant to a certain locality for later retrieval and/or manipulation (Croukamp, 1996). It may be used for instance, to create a geotechnical or development potential map. Table 12 represents the different data layers with a brief description of each layer, that could be used for an engineering geological data model, as identified by Croukamp (1996). Each layer was assigned codes for ease of use during mapping and the codes are represented in Tables 13-19.

Other coverages (data sets) that could also be stored in the database include soil maps from the Institute of Soil, Climate & Water (ISCW), Weinert's climatic N-value map (1980), satellite imagery and hydrogeology.

The geotechnical map (Figure 8) was compiled by combining the coverages geology, land form and geotechnical properties. Each land facet was given an unique mapping number that represents the geotechnical properties and the severity thereof for that specific land facet. The codes of the different geotechnical properties were derived from Table 15.

The final product was a development potential map (overlay to Figure 8) based on the integration of a number of data sources (geology, land form, slopes, dolomite risk assessment, agricultural potential, construction material sources and geotechnical properties) intended to be used for land-use planning by town planners and / or developers. The classification criteria which were applied are presented in Table 20.

Table 12: Data layers and the type of data captured in each coverage for an engineering geological model (after Croukamp, 1996).

Data layer	Type of data
Geology (Lithology)	Lithological, stratigraphical and chrono-stratigraphical information of bedrock geology, including recent deposits (soil cover /regolith).
Structural Geology	Faults, shear zones and other linear features.
Landforms	Geomorphological features (e.g. river channels, fans, hillcrests) mapped from aerial photographic interpretation and coded as defined in TRH2 (1978) with some adaptions as shown in Table 1.
Slope grade	Height information is obtained either from digitizing the contours (1:10 000-scale) or from the Surveyor General's office and then changing the information into a gridded point data layer. These points are then stored in pre-defined slope classes (Table 13).
Instability features	Sinkholes, landslides and undermined areas.
Outcrop nature (Soil depth and rocky outcrop)	The occurrence and lateral extent of rock outcrops mapped from aerial photographic interpretation, subdivided into nine classes, as shown in Table 15.
Geotechnical properties	All geotechnical data, such as the presence of active clays, collapsing sands, erodibility, excavatibility, etc., for a given area. Where possible, an indication of the severity is also given. The information in this layer must be verified by laboratory testing (Table16).
Land-use	Existing land-use (e.g. farm, residential, informal or game reserve).
Construction materials	Information on road building material. The major classes defined are coarse aggregate (roads & concrete), fine aggregate, brick-making materials and dimension stone. Present or future utilization, as a material source, is also stored (Table17).
Soils	The soil depth, classified into four different classes, for use in determining the suitability of an area for the establishment of a cemetery site and/or the difficulty of surface excavations during the placement of services.
Cadastral data	Farm boundaries, names & ownership.
Infrastructure	Roads, railways and power lines.

Table 13: Codes used for the different slope grades (after Croukamp, 1996).

CODE	GRADE	GRADE DESCRIPTION	CODE	GRADE	GRADE DESCRIPTION
1	0° - 6°	Flat to gentle slopes	3	12° - 18°	Steep slopes
2	6° - 12°	Moderate slopes	4	> 18°	Very steep slopes

3.4.5.3 Presentation

The geotechnical properties (Table 15) which are represented by each geotechnical mapping number **with a distinctive colour** (Figure 8), are based on a coding system with an alphabetical part denoting the geotechnical property and a numerical part indicating the severity or magnitude of the property, for instance if the code is A3, A indicates the presence of swelling clay in a specific mapping unit and 3 indicates a moderate/medium activity (Croukamp, 1996).

Table 14: Codes used for instability features (after Croukamp, 1996).

CODE	FEATURE	CODE	FEATURE
1	None	18	Sinkhole -Tunneling -Recent
2	Piping	19	-Paleo
3	Slope instability	20	-Backfilled
4	Landslide	21	-Reactivated
5	Paleo	22	-Mining -Recent
6	Modern	23	-Paleo
7	Undercut slope	24	-Backfilled
8	Toppling failure	25	-Reactivated
9	Wedge failure	26	-Dewatering -Recent
10	Circular slip	27	-Paleo
11	Rockslides	28	-Backfilled
12	Mudflow	29	-Reactivated
13	Subsidence	30	Undermined area
14	Tunneling	31	- < 92m
15	Mining	32	- 92 - 244m
16	Dewatering -Dolines	33	- > 244m
17	-Surface cracks		

The development potential map is presented as an overlay to the geotechnical map (Figure 8). The development potential map depicting three classes of land, namely Category 1-land, showing High Development Potential, Category 2-land, being of

Moderate Development Potential and Category 3-land, depicting Low Development Potential (Croukamp, 1996). Category 1 could be considered as those areas most favourable for development and Category 3 as least favourable for development. This system relies on computer technology to produce maps fulfilling a certain set of criteria and each map produced will differ depending on the proposed land-use (Croukamp, 1996). It relies greatly on "produce and demand" rather than presenting a standard series of maps (Croukamp, 1996).

Table 15: Codes used for geotechnical properties (after Croukamp, 1996).

CODE	GEOTECHNICAL DEVELOPMENT CONSTRAINTS	CODE	GEOTECHNICAL DEVELOPMENT CONSTRAINTS
A/1	Active clay -No	H/1	Shallow water table -No
2	-Yes	2	-Yes
3	-High expansion (> 30 mm)	I/1	Permeability -Not tested
4	-Medium expansion (5 - 30mm)	2	-Low ($\leq 4 \times 10^{-6}$ - 9×10^{-10}cm/s)
5	-Low expansion (< 5mm)	3	-Medium ($\leq 4 \times 10^{-4}$ - 4×10^{-6} cm/s)
B/1	Collapse potential -No	4	-High ($\geq 1 \times 10^{-1}$ - 4×10^{-4} cm/s)
2	-Yes	J/1	Inundation -No
3	Slight trouble (1 - 5%)	2	-Yes
4	Moderate (5 - 10%)	K/1	Slope instability -No
5	Severe (10 - 20%)	2	-Yes
6	Very severe (> 20%)	L/1	Shifting sands -No
C/1	Erodible soil -Not tested	2	-Yes
2	-No	M/1	Sinkholes -No
3	-Yes	2	-Yes
D/1	Corrosive soil -Not tested	3	-Low risk
2	-No	4	-Medium risk
3	-Yes	5	-High risk
E/1	Dispersive soil -Not tested	N/1	Pseudokarst -No
2	-No	2	-Yes
3	-Yes	O/1	Excavatability problems -No
4	-Slight reaction	2	-Yes (> 1,5m)
5	-Moderate reaction	3	-Slight (1 - 1,5m)
6	-Strong reaction	4	-Moderate (< 1,0m)
F/1	Poorly consolidated soil -No	5	-Severe (< 0,5m)
2	-Yes	P/1	Slaking -Not tested
G/1	Induced subsidence -No	2	-No
2	-Yes	3	-Yes

Table 16: Codes used for outcrop/soil depth (after Croukamp, 1996).

CODE	OUTCROP	CODE	OUTCROP
d1	Solid rock outcrop (≥ 80% of area covered)	d3	No outcrop
d2	Scattered rock outcrop (> 0% & < 80% of area covered)	d3a	Sub-outcrop/thin soil cover (0m < soil cover ≤ 1m)
d2a	Sub-outcrp / thin soil cover (0m < soil cover ≤ 1m)	d3b	Medium soil cover (1m < soil cover ≤ 3m)
d2b	Medium soil cover (1m < soil cover ≤ 3m)	d3c	Deep soil cover (soil cover > 3m)
d2c	Deep soil cover (soil cover > 3m)		

Table 17: Codes used for construction materials (after Croukamp, 1996).

CODE	POTENTIAL CONSTRUCTION MATERIALS [included samples (yes/no), tests (yes/no), number of borholes or test pits]
1	Construction materials
2	-Clay
3	-Sand
4	-Stone (Dimension stone)
5	-Fill material (Landfill use)
6	-Aggregate
7	-Aggregate (concrete)
8	-Aggregate (road building)

Table 18: Codes used for the type of mining activity (after Croukamp, 1996).

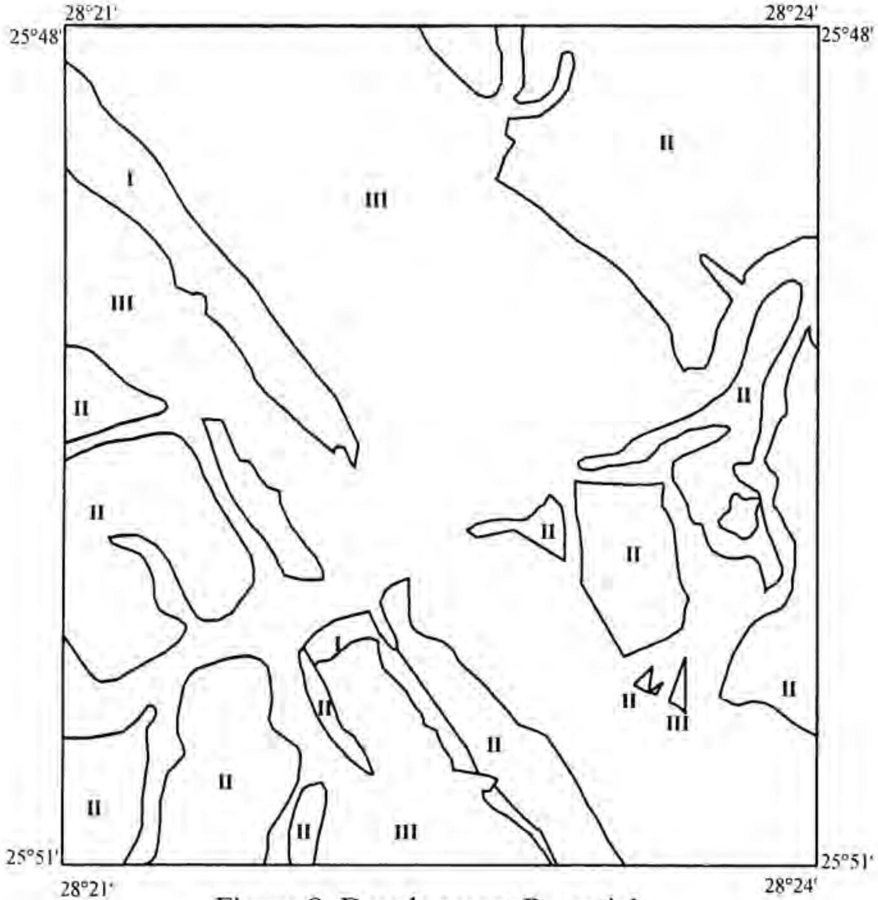
CODE	TYPE OF MINING ACTIVITY
1	Mine
2	Opencast
3	Quarry
4	Sub-surface

Table 19: Codes used to define the sinkhole class (after Croukamp, 1996).

CODE	SINKHOLE (included event date, length, width, depth, shape)
1	Class I (0 - 5 m diameter)
2	Class II (5 - 10 m diameter)
3	Class III (10 - 20 m diameter)
4	Class IV (> 20 m diameter)

Table 20: Classification criteria applied for development potential map (after Croukamp, 1996).

CRITERION	CATEGORY 1 LAND	CATEGORY 2 LAND	CATEGORY 3 LAND
AGRICULTURAL POTENTIAL	Low potential	Medium potential	High potential
LANDFORMS	Convex slope, concave slope, plain.	Talus slope, pediment & dissected pediment, fan, rill erosion.	Crest (Hill, < ridge & mesa), sand bank, drainage features, excavation/mine dumps/landfills.
SLOPE CATEGORIES	< 6°	6° - 15°	> 15°
DOLOMITE RISK CHARACTERISATION		Risk classes I to IV	Risk classes V to VII
GEOTECHNICAL PROPERTIES	Collapsible soils, compressible soils.	Medium excavatability (1m < rock depth > 3m), heaving/active clays, shallow ground water level, poorly drained areas.	Shallow excavatability (outcrop/rock depth < 1m), steep/unstable slopes (>15° or highly erodible), drainage channels.
CONSTRUCTION MATERIALS			Identified potential resource areas.



Development Potential Legend

I	Category 1: High development potential
II	Category 2: Moderate development potential
III	Category 3: Low development potential

Figure 8: Development Potential

1:50 000

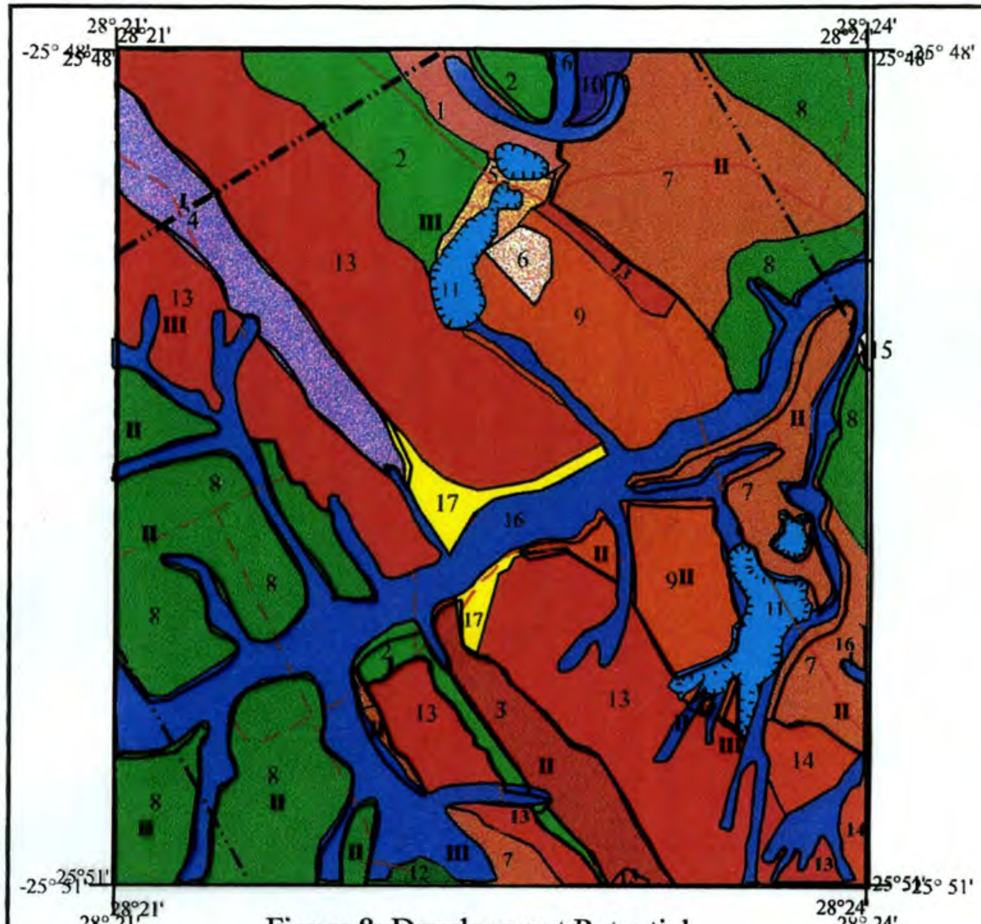


Figure 8: Development Potential

1:50 000

Figure 8 : Classification system developed by Croukamp (1996) to determine the Development Potential of an area (geotechnical map with an overlay of the different development potential classes)

1 : 50 000

Council for Geoscience

Development Potential Legend

- I — Category 1: High development potential
- II — Category 2: Moderate development potential
- III — Category 3: Low development potential

GEOTECHNICAL MAPPING NUMBER	GEOTECHNICAL PROPERTIES	DESCRIPTION
1	A5, B2, O3	Low activity clays, collapsible soils, slight excavatability problems
2	A5, O3	Low activity clays, slight excavatability problems
3	A3	Highly active clays
4	A5	Low activity clays
5	B4	Moderate collapsible soils
6	A5, B4	Low activity clays, moderate collapsible soils
7	A4, O4	Medium active clays, moderate excavatability problems
8	A4, O3	Medium active clays, slight excavatability problems
9	A5, O4	Low active clays, moderate excavatability problems
10	[illegible]	Low active clays, slope instability, moderate excavatability problems
11	H2, K2, O2	Shallow water table, slope instability, excavatability problems
12	A4, J2	Medium active clays, inundation
13	A5, O5	Low active clays, severe excavatability problems
14	A4, O5	Medium active clays, severe excavatability problems
15	A4, K2, O3	Medium active clays, slope instability, slight excavatability problems
16	A4, J2, O3	Medium active clays, inundation, slight excavatability problems
17	A4, K2	Medium active clays, slope instability

Legend :

- Farm boundaries
- Roads
- Quarries

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Date : October 2001

3.5 CONCLUSION

Methods to present regional engineering geological information and/or data in South Africa, based on the land facet approach, started as early as the 1950's. The main objective was then to define the best location for a route of a planned road, with no or little consideration towards land-use planning.

The scope of regional engineering geological mapping changed after the need for road construction slowed down at the end of the 1970's and it was realised that engineering geological mapping could make an effective contribution to the planning of developing areas, such as urban expansion.

Evaluation of classification systems used for regional engineering geological mapping since the 1970's, revealed that most of these systems are based on work previously done in the field of engineering geological mapping, with little or no modification. There was a decrease in interest in the development of/or research in engineering geological classification mapping systems, from 1981 to 1993. Up until 1993, no standardised engineering geological classification system existed and the TRH2 system, although not designed for this purpose, was the standard nomenclature used for urban development planning. Partridge, Wood and Brink (1993) developed a standardised method to conduct urban engineering geological investigations, which is still regarded as the accepted standard of practice by the engineering geological fraternity used in south Africa, including SAICE, SAIEG and the NHBRC.

Each classification system was evaluated in terms of, the objective, method of classification and map presentation. The following conclusions could be made for each system:

- The TRH2 system is a very simplified method and the map is easy to compile. The map presents, geology, structural geology, topography, physiography, potential soil problem areas and potential construction materials, with the geology used as the base map. The shortcomings of the system is that, although it could be used for regional land-use planning purposes it does not give any indication of the severity of potential problem areas and the potential for land-use of these areas.

- The method proposed by Price (1981) and Bester (1981) are both very complex systems. During the compilation of these maps, difficulty was experienced with the application of the proposed engineering geological land-use ratings for each influencing factor of each mapping unit. All the information is displayed as an overlay on the published 1:50 000 topographical map. Each mapping unit on the map, was indicated by a symbol and hatching code. Both these maps are very difficult to read, due to the format and amount of information displayed.

The associated table for the map developed by Price, gives a description of each facet group in terms of the Unified Soil Classification, engineering geological land-use rating for township and road & railways, potential geotechnical problems, construction materials and their engineering geological land-use potential. Van Schalkwyk and Price (1990) refined the method proposed by Price and developed a site classification system to distinguish between good, fair and poor site class areas for residential development, based on the rating of the following geological influencing factors: 1) foundation, 2) slope stability and 3) drainage conditions. This was provided as an overlay to the geotechnical map of Price (1981) that could easily be understood and used by planners.

The associated explanation table for the map developed by Bester, gives a description of each mapping unit in terms of, the typical soil profile description, land form, engineering geological characteristics (drainage, excavatability, foundation conditions and stability) and critical influencing factors. Furthermore, Bester developed a general interpretation for each development category, which he divided into Primary categories (township development, transport systems and construction materials), each Primary category was sub-divided into Secondary categories and each was then described in terms of its development potential (favourable, unfavourable or uncertain).

Although both systems provide a significant amount of information, the presentation of all this information on a 1:50 000-scale map is complex. The readability of and distinction between mapping units/facet groups are reduced by the use of only one colour (black) for the drawing of lines, hatching of mapping units/facet groups and text. Information is displayed as an overlay to the topographic map, making it very difficult to pinpoint a specific area and the associated geotechnical factors for that area.

The advantage of displaying so much information on one map, is that it is useable by the engineer and/or engineering geologist to recognise potential geotechnical factors and their associated problems, as well for the town planner and/or developer to recognise potential poor or good areas for development purposes, from the accompanied tables. The disadvantage is that a magnifying-glass is necessary to read the text on the map and in the accompanied tables, which makes the information and map unpractical. If the information was displayed on a map scale of 1:10 000, it would have been very clear and more useful.

- Based on all available information and the comparison of the different geotechnical classification methods proposed in this chapter, it seems that the system developed by Partridge et. al. (1993) and modified by the CSIR (1996), can be regarded as one of the best and most practical systems in use to classify terrain for planning and development purposes. The system developed by Partridge et. al. (1993) is presently still regarded as the accepted standard of practice in South Africa, by the engineering geological fraternity, including the SAICE, SAIEG and NHBRC.

Geotechnical constraints that are taken into account during the evaluation of a terrain for development purposes include collapsible soils, seepage, active soils, compressible soils, erodibility of soil, difficulty of excavation, undermining, instability associated with soluable rock, steep slopes, areas of unstable natural slopes, areas subjected to seismic activities and areas subjected to flooding. The parameters undermined ground and areas subjected to seismic activity are not considered by the CSIR geotechnical classification system.

The simplicity of the map and the information displayed is such that it could be utilised by engineers/engineering geologists and town planners/developers. The category of development suitability (most, moderate, least) for each terrain mapping unit has been coloured green, yellow and red, respectively, with an alphanumeric code, which gives a description of the relevant geotechnical constraints and the severity thereof. The use of three basic colours makes it possible for the developer/town planner to easily distinguish between the different categories of development suitability (most, moderate, least) and to select the area with the least geotechnical constrains to avoid high financial costs. The alphanumeric code and the indication of the severity of each constraint in each terrain mapping unit, makes it possible for the engineer/engineering geologist to interpret the different geotechnical constraints present in each mapping unit in order to determine the potential foundation requirements and design necessary for that specific area.

- The engineering geological geographical information system (GIS) model for land-use planning developed by Croukamp (Council for Geoscience,1996) includes different data layers, that could be stored, retrieved or manipulated to create different types of thematic maps (e.g. geotechnical or development potential). Advanced computer technology will steer future mapping technology for efficient land-use planning, towards the electronic environment.

The geotechnical map was compiled with ease. Each land facet was given an unique mapping number with a destinctive colour that represents the geotechnical properties and the severity thereof for that specific land facet. The geotechnical properties are presented in a coding system with an alphabetical part denoting the geotechnical property and a numerical part indicating the severity or significance of the property.

Problems that did occur during the compilation of the geotechnical map, was the confusion of the severity classes for the geotechnical factor active clays, because they are not ordered from low to high as the rest of the geotechnical factors with severity class sub-divisions. The use of different colours for different land facets makes it possible to easily distinguish between them on the map and increase the readability.

The development potential map, presented as an overlay and based on the integration of the data layers, geology, land form, slopes, dolomite risk assessment, agricultural potential, construction materials and geotechnical properties, provides a good overall land-use potential, taking into account financial and environmental implications. Each of the layers was assigned codes for ease of use during mapping and was sub-divided into three classes of land, namely Category 1-land (High Development Potential), Category 2-land (Moderate Development Potential) and Category 3-land (Low Development Potential) (Croukamp, 1996), which makes it possible to distinguish between areas that are safe for development purposes and environmental friendly versus those that are not. Category 1 could be considered as those areas most favourable for development and Category 3 as least favourable for development.

The advantages of a system like this is that different data layers could be incorporated, stored in a digital format and manipulated to produce different thematic geotechnical maps, based on the requirements of the client. The advantage of data stored in a digital format, is that information is immediately available and accessible, without any time constraints. The disadvantages of a system like this is the time and cost involved to develop a database that are user friendly where information could be stored, retrieved and manipulated. Other obstacles according to Croukamp (1996) is the lack of skilled personnel, inappropriate and ineffective hardware and/or software and inaccurate or insufficient original data.