CHAPTER 4

REGIONAL GEOTECHNICAL MAPPING PROCEDURES PROPOSED BY THE COUNCIL FOR GEOSCIENCE

4.1 INTRODUCTION

Regional geotechnical mapping is based on the land facet approach. A land facet can be classified as an area of ground with a simple surface form, a specific succession of soil profile horizons (each with reasonably uniform properties, but can vary in thickness) and a characteristic groundwater regime (Stiff, 1994). The assumption is made that an area of terrain with the same host lithology and land form will provide similar soil profiles and therefore similar geotechnical properties.

A systematic approach is proposed and the process can be divided into six phases (Swanepoel, 2001), namely: 1) Data gathering or desk study, 2) reconnaissance survey, 3) field mapping, 4) laboratory analysis, 5) compilation of the geotechnical map and 6) report writing. The different stages are discussed in detail in the following paragraphs.

4.2 DATA GATHERING OR DESK STUDY

This phase involves the accumulation and interpretation of existing data.

4.2.1. Data accumulation

Data from the following sources could be useful and should be accumulated if available:

- Maps: Topographic, geology, orthophotographs, geophysical, agricultural, soil, etc.

- Aerial photographs and satellite imagery: Most recent and older sets, in order to delineate landforms that have become obscured by new development and to observe temporal changes such as donga formation and new infrastructure.
- Reports: Geological, site specific geotechnical, hydrogeological and geophysical.
- Existing databases: Council for Geoscience, CSIR, etc.
- Other information: Economic geology (minerals and mining), climatic data (Weinert's climatic N-value, temperature, rainfall & wind direction), etc.
- Published relevant literature: Engineering Geology of South Africa (Brink, 1979 - 1985), etc.

4.2.2 Data processing

The preliminary interpretation of existing data is now possible in order to assist planning of the fieldwork phase. This will include:

- Compilation of a landform map from aerial photographs and orthophoto interpretation, where the boundaries of the different landforms are identified and delineated on a transparent aerial photo overlay. These overlays are captured digitally and GIS software is used to compile a landform map on a 1:50 000 scale or the boundaries can be transferred manually onto a transparent overlay using the 1:50 000 topographical map as a base.
- Adding all the other available information to the base map (1:10 000 or 50 000).
- The four volumes by Brink (1979 - 1985) on the engineering geology of South Africa, gives a broad overview of conditions to be expect on different rock types in South Africa and should be consulted prior to any regional geotechnical mapping project, carried out in South Africa.

4.3 RECONNAISSANCE SURVEY

During this stage the accuracy of the information gathered and interpolated during the desk study is checked by a walk-over site survey. Test pit positions are provisionally identified by overlaying the landform and geology maps to ensure that all mapping units delineated from the land facets will be profiled during the fieldwork stage. Information regarding possible undermining, occurrence of construction materials, current land-use and accessibility are evaluated. Fieldwork can now be planned in a more effective way.

4.4 FIELD MAPPING

The field mapping can be subdivided into geological and geotechnical mapping.

4.4.1 Geological mapping

Geological mapping is only necessary if no regional geological map on a scale of 1:50 000 (sometimes available on a 1:10 000 scale, with outcrop information) exists for the area. Geotechnical mapping can only commence after the geological map is compiled by a geologist, due to the fact that the geotechnical properties are derived directly from the underlying bedrock geology and land form. The published geology map should be checked during the geotechnical mapping phase.

4.4.2 Geotechnical mapping

Geotechnical mapping comprises the excavation of and description of soil profiles in test pits or soil profile description of exposed road cuttings and quarries, in order to determine the succession of soil layers present in a specific land facet. This information can then be extrapolated to other similar land facet types. A minimum number of three test pits per land facet type for regional geotechnical mapping is suggested by SAIEG (1997) for correlation purposes.

Representative soil samples (disturbed and undisturbed) are collected from the possible problem soil horizons for laboratory analysis.

The individual soil layers in each profile are described according to the MCCSSO method (Jennings *et al*, 1973). This method allows for the systematic description of surficial soil horizons in terms of moisture condition, colour, consistency, structure, soil type and origin. Soil profiling provides the basis for the first assessment of the engineering properties of the soil. The bedrock, if present in profile, is described in terms of colour, the degree of weathering, fabric & discontinuity spacing, rock hardness, rock type and a description of the discontinuity surface (SAIEG, 1996).

In addition, each soil profile should include notes on the position of the test pit, method of excavation, if the water table has been encountered or not, a description of the type of water table (perched or permanent) if encountered, at what depth and the reason why the test pit was stopped, stability of the test pit side-walls, the depth at which soil samples were taken, date of recording and the name of the profiler. Geotechnical problems identified during the field work stage should be noted to aid in the compilation of the final geotechnical map.

4.5 LABORATORY ANALYSIS

Laboratory analysis are carried out on disturbed and/or undisturbed soil samples to determine material and engineering properties of the various soil horizons present in the area of investigation.

Laboratory analysis on undisturbed soil samples are not considered as part of the normal sampling and testing procedure for regional geotechnical mapping, due to the scope of such a mapping exercise and the high costs involved with these tests. A number of undisturbed soil samples may be collected for analysis to determine a quantitative value for a specific problem that may occur in the area of investigation. These tests may include consolidation, tri-axial, shear-box, permeability and moisture-density tests/compaction (modified AASHO).

Disturbed samples are used to conduct foundation indicator tests, included grading analysis, determination of the Atterberg limits and Emerson crumb test.

Grading (particle size distribution) of the soils are determined by means of sieve analysis and hydrometer tests (to determine the clay percentage), resulting in cumulative grading curves. Samples are classified according to the A.S.T.M. standard, using the Unified Soil Classification System (Craig, 1997). This system is used to classify the material in each land facet, as well as determining its suitability as a construction material resource.

The mechanical or physical properties of a soil are described in terms of the liquid limit and plasticity index (determined by means of the Atterberg Limit test) and the linear shrinkage. The expected maximum probable heave and expansiveness can be evaluated according to the method of Van der Merwe (1964). This method is a development of the unit heave approach, which allows for the heave of profiles with layers exhibiting different potential expansiveness with a depth factor to be calculated. However, the use of unit heave under no load for the various classes of potential expansiveness does not take into account the influences of either initial moisture content or density and therefore gives a partial estimation of expansiveness. The degree of saturation would influence the potential expansiveness of the soil. For example, a partially saturated soil could show moderate expansiveness, whereas the same soil in a saturated condition will show little or no expansiveness. The method of van der Merwe is an empirical method and should be used with care. It is however a good indication of expected heave conditions on a regional scale.

The permeability of the material is classified in centimetres per second and can be calculated with Hazen's permeability equation, which uses the grading of the material (Hazen, 1982):

$$k = 100.\ D_{10}^2$$

where k - Coefficient of permeability in centimetres per second

D_{10} - Effective size (10% of particles are smaller than the size denoted by D)

It should be noted that this method is only applicable for clean sandy soils and not very reliable for permeabilities of clay and silty soils, which normally have permeabilities below 10^{-4}cm/s. Although not applicable for silty and clay soils, it could be useful as a first indicator at an early stage of the investigation.

The potential erodibility of soils could be determined by means of the Emerson Crumb test. According to Elges (1985), the test involves the submerging of a 15 mm cubical moist soil sample in 250 ml distilled water. As the soil crumb begins to hydrate the tendency for colloidal-sized particles to deflocculate and go into suspension is observed, in terms of different reaction grades.

XRD analyses could be conducted on disturbed soil samples to determine the mineral composition of the soil. This can be useful to establish the presence of a 1:1 lattice clay like kaolinite, to confirm the presence of a potential clay resource for construction purposes or to determine the presence of montmorillonite clays with a 2:1 lattice structure, that will be potentially expansive.

A method that is commonly used during regional geotechnical investigations to determine the potential collapse of undisturbed soil samples is the Collapse Potential test (Jennings and Knight, 1975). The percentage of collapse will depend on the initial dry density (mass of solids per unit volume of soil) and the initial moisture content (ratio of the mass of water to the mass of solids) of an undisturbed soil sample (Craig, 1997).

In the Collapse Potential test an undisturbed sample is cut to fit into an oedometer ring, followed by a consolidation test with the sample at natural moisture content. Loads are applied, incrementally, until 200kPa. When no further change in volume occurs at 200kPa the specimen is inundated with water and allowed to stand for 24 hours. Thereafter the consolidation test is continued to its normal final load. A pronounced reduction in void ratio will be experienced by collapsible material upon inundation (Jennings and Knight, 1975). The Collapse Potential (CP) is then defined as:

$$CP = \frac{\Delta e_c}{1 + e_0} \times 100$$

where Δe_c change in void ratio, at 200kPa, upon wetting.

e_0 original void ratio

This is only a first indication of collapse and no value for the amount of collapse can be obtained. A double oedometer test is necessary to quantify the collapse of a soil.

4.6 COMPILATION OF THE GEOTECHNICAL MAP

The soil profiles obtained in the field, the laboratory results, the land form map and the geology are used to compile a geotechnical map of the area. The following procedure is followed:

- If the primary mapping and data collation has been done at a 1:10 000-scale, the relevant information should be compiled at a 1:50 000-scale, either through means of a scanning and vectorising process or digitizing by hand.
- Test pit positions are plotted on an overlay and captured digitally or could be recorded and stored by using a GPS.
- Laboratory results and observations during the fieldwork stage are analysed to assess the geotechnical properties of an area.
- The corresponding geotechnical factors are then written down next to each plotted test pit.
- This overlay is then placed over the transparent land form overlay and both are placed on top of the geology map. It is then possible to identify areas with the same geology, landform and geotechnical properties and to extrapolate geotechnical properties to other areas with similar geology and landform where test pits may not have been sited.
- Geotechnically distinct areas are then identified and boundaries drawn dividing the area into mapping units with their specific geotechnical properties.

- Coding of mapping units follows. A table is then drawn, where each unique code represents a specific combination of geotechnical properties.
- The geotechnical map is then traced onto a chrona (topographical map printed on transparent polyester) and captured digitally for GIS processing. The final map printed with the codes and colours is then submitted to the drawing office.
- This mapping process could lead to the formation of a stack of layers of information or data sets, which could be stored in a data base. The data from these coverages can in turn be manipulated and integrated by computer software to create different types of maps, for instance a development potential map or a land-use map, by combining the geology, landform and geotechnical coverages.
- Other data coverages (apart from geology, land form and geotechnical properties) that will be useful for an engineering geological GIS data model include (Croukamp, 1996): Instability features, slope-grade, land-use, outcrop-nature (soil depth and outcrop), construction materials, cadastral data and infrastructure.

4.7 REPORT WRITING

A report or explanation should accompany the produced geotechnical map, outlining the methodology and reasoning behind the production of such a geotechnical map, as well as an explanation and discussion of the conditions found during the study. The following should be portrayed:

- **Introduction:** Should explain the purpose and scope of the mapping project and discuss previous investigations conducted in the study area, as well as information available in databases that could be used.
- **Methodology:** Describe the way information has been gathered and interpolated and how the geotechnical map has been compiled.
- **Physiography:** Define the study area in terms of locality, scale and size. Description of the geomorphology including drainage, relief and landform that can influence new developments.

- **Climate and vegetation:** The climate of the region is described by means of the average annual rainfall, minimum and maximum temperatures, prevailing wind direction and speed (Weather Bureau). These aspects are important during the selection of potential waste disposal and cemetery sites. Weinert's climatic N-value for the area is indicative of weathering predominance (mechanical breakdown or chemical decomposition), therefore expected depth to bedrock can be estimated (Weinert, 1980). The description of the area's vegetation is an important environmental consideration, this is to assure that endangered species are protected if new development should take place. It is also a good indication of the underlying geology, because certain vegetation species are associated with certain geology (Acocks, 1988; Low and Rebelo, 1998).
- **Geology:** A description of the geological Supergroups, Groups, Formations and lithologies, obtainable from an existing 1:50 000-scale geological map and explanation or published 1:250 000-scale geology maps.
- **Geohydrology:** Information regarding ground water movement and direction, compartments, quantity and quality should be discussed.
- **General engineering geological properties based on geology and land form:** The four volumes of Brink (1979-1985), as well as existing studies conducted in the area, should be used to discuss the kind of conditions to expect on transported and residual soils derived from different rock types in the study area.
- **Terrain evaluation:** Each geotechnical property should be described in detail in terms of physical parameters, classification (severity class), area covered, associated problems that could have an effect on development as well as recommended construction methods.
- **Potential construction materials:** Potential natural resources should be defined in terms of suitability, quality and available reserves. All existing quarries (non-operational and operational), as well as potential resources should be indicated and described in the report to reduce the risk of sterilisation of these resources.
- **Environmental considerations:** This include developments such as cemetery sites, waste disposal sites and ground based sanitation systems (pit latrines and septic tanks), that will have a negative impact on the environment. The

requirements should be listed and potential areas should be defined and described.