VLAKKELAND LOW COST HOUSING PROJECT

WESTERN CAPE

COMBINED REPORT ON PRELIMINARY AND PHASE 1 GEOTECHNICAL INVESTIGATIONS

R.A. Bradshaw
& Associates cc
Consulting Engineering
Geologists

Ref. 1-89607
7 April 2008

Contents

List of Tables

List of Drawings

Appendices

Appendix A	*Description of soil profiles in trial pits and results of DCP tests*
Appendix B	*Results of laboratory tests*

Executive Summary

This report describes the results of the combined preliminary and Phase 1 geotechnical investigations for the proposed Vlakkeland Low Cost Housing Project which is located between Paarl and Wellington in the Western Cape.

The geotechnical investigations were undertaken in accordance with the requirements of the Department of Housing's Generic Specification GFSH-2, Geotechnical Site Investigations for Housing Developments, and the NHBRC, and the report can be used, in the future as supplementary, statutory information to accompany applications for subsidised low cost housing.

The current investigation comprised a desk study followed by excavation of forty-six trial pits and sampling for laboratory testing. DCP testing was also undertaken next to the all the pits except those located in the embankment walls of old, abandoned evaporation ponds which cover large area of the central and eastern parts of the site.

Numerous soil types, with weathered bedrock at varying depths, are developed throughout the site. The multiplicity of soil types reflects a complex and variable colluvial and alluvial depositional environment, with pedogenic processes also occurring.

Categorisation of the natural soils into seven groups with similar properties is possible, and three generalised, natural soil profiles and their areas of occurrence can be identified. For descriptive purposes, the areas have been named the Northern Area, the Central Strip and the Southwestern Area. The cohesionless coarse soils forming the fill in the embankment walls of the evaporation ponds are superimposed on two of the natural profiles.

Shallow seasonal perched groundwater is expected in large parts of the site in and immediately after the wet period of the year. In addition, most of the area in the southwestern corner of the site is seasonally wet, with an attendant very shallow seasonal perched water table.

The soils are relatively dense or stiff and they are not significantly compressible except in the Southwestern Area where the estimated settlement is approximately 10mm when the soils are wet.

Active soils are predominantly developed in the Northern Area and the Central Strip and a maximum soil strain up to 15mm is possible.

The soils will not be subject to significant collapse consolidation or dispersion.

Seven terrain mapping units are recognised and the associated geotechnical classifications, in general, reflect that the presence of thin collapsible surficial soils layers, the expected presence of shallow groundwater, the low erodability of the soils, the generally shallow ground slopes, the presence or absence of compressible or active soils, and the seismic environment of the area.

Based on the guidelines in the NHBRC Home Building Manual, conventional strip footings or possibly raft foundations would be appropriate for single-storey houses in parts of the site, but lightly reinforced footings with ancillary structural measures will be required in the Northern Area and reinforcement of footings in probably 60% of the houses in the seasonally wet parts of the Southwestern Area will also be required. Good drainage around the houses is essential, and service/ plumbing precautions will be required, as relevant.

The 1 in 50 and 1 in 100 year floodlines of the Dal River lie within the extreme southwestern and western part of the Southwestern Area and the construction of the flood and inundation control measures appears necessary for the long-term serviceability of this area.

Sub surface drainage measures will be required in the Southwestern Area, if that area is to be developed, and they will also be required next to roads throughout the Southwestern Area. In addition subsurface drainage next to roads in other parts of the site should be considered to prevent saturation and 'mattressing' of the surficial soils.

The evaluation of the subsidy variation should consider the costs of dewatering some trenches in winter, deep services if they run sub parallel to contours, and the cost of non normal footings for the houses. Additional costs will include removal and reworking of the existing embankment walls, handling and spoiling of mixtures of excavated soils that contain clayey material, and over-excavation in service trenches to ensure their stability. The cost of possible flood control or inundation measures and sub surface drainage should also be reflected.

With exception of parts of the Southwestern Area where encroachment of floodlines occurs, and the presence of the embankment walls of the old evaporation ponds, no significant geotechnical constraints are apparent in the study area which is therefore generally considered generally suitable for human settlement and subsidy based housing.

VLAKKELAND LOW COST HOUSING PROJECT
WESTERN CAPE

COMBINED REPORT ON
PRELIMINARY AND PHASE 1 GEOTECHNICAL INVESTIGATIONS

1. INTRODUCTION AND TERMS OF REFERENCE

The Drakenstein Municipality is planning the construction of a new low cost housing project at Vlakkeland, which is located approximately midway between Paarl and Wellington, Western Cape. The location of the site is shown on Figure 1.

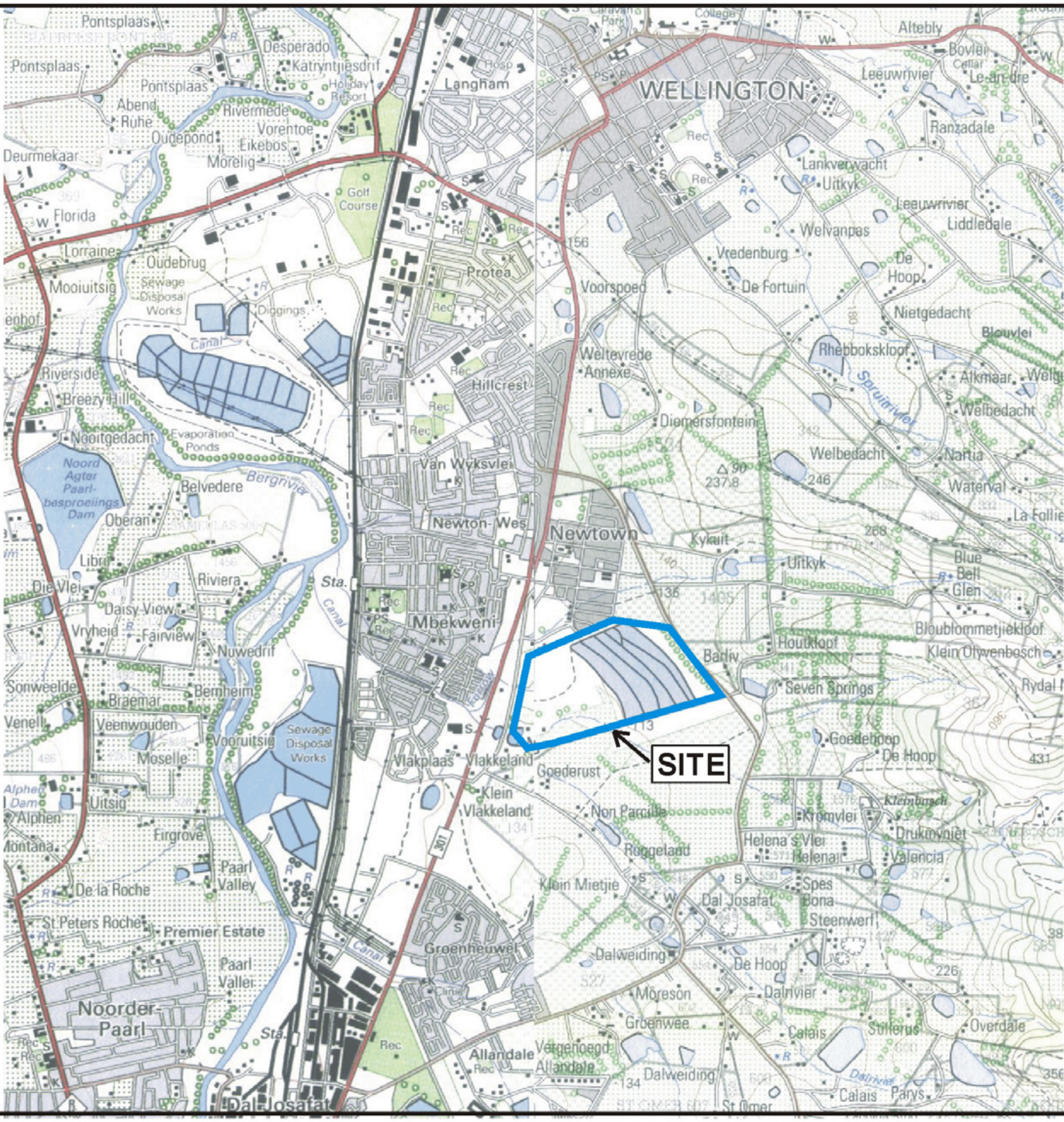
At the time the report was written, no site development plan had been presented and the number of houses/erven, the site layout and the location of ancillary structures, facilities and roads were unknown.

Mr J. Lochner of Lyners Consulting Engineers requested R.A. Bradshaw & Associates cc via an e-mail dated 9 November 2007 to undertake a geotechnical investigation of the site. The investigations were to be undertaken in accordance with the requirements of the Department of Housing's Generic Specification GFSH-2, Geotechnical Site Investigations for Housing Developments, and the NHBRC. In this regard, a combined preliminary and Phase 1 geotechnical investigation would be undertaken which would be suitable for use in the various phases of application for low cost housing.

The objectives of the preliminary geotechnical investigations, as specified in GFSH-2, are to ascertain whether the site is fit for human settlement and suitable for project linked subsidy housing development. In contrast, the Phase 1 investigations are to identify any potential hazards, to define the ground conditions, to provide Site Classifications and the geotechnical basis for safe and appropriate land use planning, infrastructure and housing design, and to formulate precautionary measures and risk management procedures.

This report presents the results of the field investigations, which were undertaken over the period 31 January to 7 February 2008, and the associated laboratory testing.

The headings in this report most closely follow the headings prescribed by GFSH-2 for Phase 1 reports. However, the overall work undertaken during this study is as per the investigation requirements of GFSH-2 for both preliminary and Phase 1 geotechnical investigations.



Source: 1:50 000 Topographical Map 3318 DB Paarl and 3319 CA Bain's Kloof

FIGURE 1

LOCALITY PLAN

SCALE 1 : 50 000

2. INFORMATION USED IN THE STUDY

2.1 List of information used in this study

The Council for Geoscience (Pretoria and Bellville) and the National Home Builder's Registration Council (Bellville) were approached for geotechnical information for this area, but no geotechnical data base exists.

Because of the location of the site, organisations such as the Government Mining Engineer and the Department of Water Affairs were not approached for information.

The following maps and associated supplementary information were used in the evaluation of the site:

- 1:50 000 topographic series maps 3319 CA Bain's Kloof and 3318 DB Paarl, Sixth Editions dated 2000.
- 1: 10 000 orthophoto maps. Published by the Director General of Surveys, Mowbray, Cape Town.
- Panchromatic aerial photographs (Job No. 1074, Strip 010, Photo No.'s 1036 and 1037 at a scale of 1:50 000, dated 12 November 2003).
- The Geological Series Map 3318, Cape Town and 3318 Worcester at a scale of 1:250 000 and the associated explanations for the maps entitled 'The Geology of the Cape Town Area' and 'The Geology of the Worcester Area', Geological Survey of South Africa, both dated 1992.
- Sub regional and local context plans were provided by Mr Lochner, including a survey plan which only covered approximately the eastern half of the site.
- A plan showing the contours at 1m intervals at the site was provided by the Drakenstein Municipality together with the 1 in 50 and 1 in 100 flood lines of the Dal River which runs through the extreme southwestern corner of the site.
- National Department of Housing. Project Linked Greenfield Subsidy Project Developments. Geotechnical Site Investigations for Housing Developments. Generic Specification GFSH-2, September 2002.
- National Department of Housing. Home Building Manual, Parts 1, 2 and 3. National Home Builders Registration Council, Revision 1, February 1999.
- A walk-over site inspection was conducted on 31 January, and the existing houses in the vicinity of the project were inspected for signs of structural distress which could be ascribed to geotechnical factors.

Discussions were also held with Mr J. Knaggs of the Drakenstein Municipality. The objectives of the discussions were to obtain information about the evaporation ponds in the eastern parts of the site, and other geotechnical and hydrological conditions at the site.

2.2 Evaluation procedures used in this investigation

The standard specifications GFSH-2 from the National Department of Housing have been followed during the investigations and associated preparatory desk study including sourcing of maps and other documentation. Guidelines from the NHBRC were also considered during compilation of this report.

The initial evaluations that were made were based on air photo interpretation and a study of the geological map and associated explanation. The planning of the investigations was based predominantly on the basic survey plan provided by Mr Lochner.

No exposures of rock outcrop generally occur on or near the site. Consequently the final geotechnical assessments in this report are based predominantly on the results of trial pitting and laboratory testing.

3. SITE DESCRIPTION

The site is located to the east of the R301 between Paarl and Wellington and approximately midway between the two towns.

The site is an irregular, polygonal shape and it is approximately 85 hectare in area. It is bounded to the west by a service road running parallel to the R301, and by vacant ground and existing housing to the north. Vacant ground abuts the northern third of the eastern boundary, with a gravel road running along the southern two-thirds. Mainly vacant ground lies to the south of the southern boundary, but the Dal River and associated dams and dam-like structures occur near the extreme western end of this boundary.

The overall slope of the ground is towards the southwest, with a typical gradient of approximately 1:75, but a strip along the northern boundary has a gradient of approximately 1:18.

Five, very large, abandoned evaporation ponds, which extend north-south almost across the entire width of the site, cover approximately 70% to 80% of the central and eastern parts of the site. Excavations for these ponds and the embankment walls themselves have changed the ground profile. The bases of the ponds, which range up to 100m in width and up to 300m long, are slightly dish-shaped and they have a very gentle fall to the east. Water is trapped in parts of these ponds in winter and reed vegetation occurs in places. The embankment walls vary in size and length, but typically they are 3m to 4m high with slopes at 1:3, and crest widths between 3m and 4m. The upper parts of the embankments have been subjected to wave erosion, and near vertical slopes, occur, in places, just below the crest. The embankment walls have been deliberately breached, in places, to ensure free outflow of stormwater.

The large diameter, cement pipes that previously formed the rising main and gravity pipelines from the sewage works to the west of the R301 to the evaporation ponds apparently run in a northeasterly direction through the centre of the site (only one was identified during site investigations). Outlets structures also occur, generally, in the southwestern corners of the ponds.

Most of the site has a grass cover, which is currently very sparse, in places, but relatively thickly developed in a floodplain or wet area in the southwestern corner of the site. Large gum trees grow along the central parts of the eastern boundary, and large pine trees grow in places in many other parts of the site outside of the evaporation pond area. Port Jackson scrub and trees grow in most areas of the site, but notably in the pond area and in the central parts of the site to the west of the ponds. Wattle and other large trees grow next to the dams and the Dal River in the extreme southwestern corner of the site.

An area, which is approximately 0.8 hectare in area and is located against the central part of the western boundary, is currently occupied by the largely abandoned shacks and informal livestock pens and paddocks of emergent farmers. Most of the structures have been abandoned, but a few of the shacks are still occupied, and livestock is still housed, in places.

Gravel tracks criss-cross many parts of the site, and there is still limited vehicular access along the tops of the embankment walls.

The remnants of old brick houses and structures occur near the southwestern corner of the property, and at least one of these is occupied. Paddocks also occur in this area.

Scattered rubble and rubbish has been dumped throughout the site, particularly in the southwestern corner and the extreme eastern parts and, in places, in the evaporation ponds.

4. NATURE OF THE INVESTIGATIONS

4.1 Desk study

Prior to conducting field investigations, a desk top study was undertaken using the information detailed in Section 2.1. In addition, discussions were held with personnel from the Municipality and a walk-over site inspection was also conducted. The contour plan provided by Mr Lochner was used to pre-plan the position of the trial pits for the current investigations.

4.2 Site investigations and associated laboratory testing

The site investigations were undertaken by Mr R. Bradshaw of R.A. Bradshaw & Associates cc during the period 31 January to 7 February 2008.

The soil testing was undertaken by Geoscience Laboratories (Pty) Ltd at their laboratory in Cape Town.

4.2.1 Trial pitting

A total of forty-six trial pits were excavated with a digger/loader at the locations shown on Figure 2. Because no site development plan currently exists, the trial pits were generally excavated on a 200m by 100m, staggered grid, but trial pits were specially excavated, in places, in the embankment walls. Some variation of this grid pattern was also required in the shack and livestock pen area where existing structures had to be avoided or access was not possible.

The objective of the trial pitting was to determine the soil profile to 3m depth as prescribed in GFSH-2, and to provide access for sampling.

The exposures in the trial pits were profiled according to the Jennings, Williams and Brink method, and the descriptions of the soil profiles in the trial pits are presented in Appendix A.

4.2.2 DCP testing

DCP (dynamic cone penetration) tests were undertaken next to all trial pits except those in the embankment walls. However, the probe commonly refused at shallow depths and the full potential depth of testing (2m) was seldom achieved.

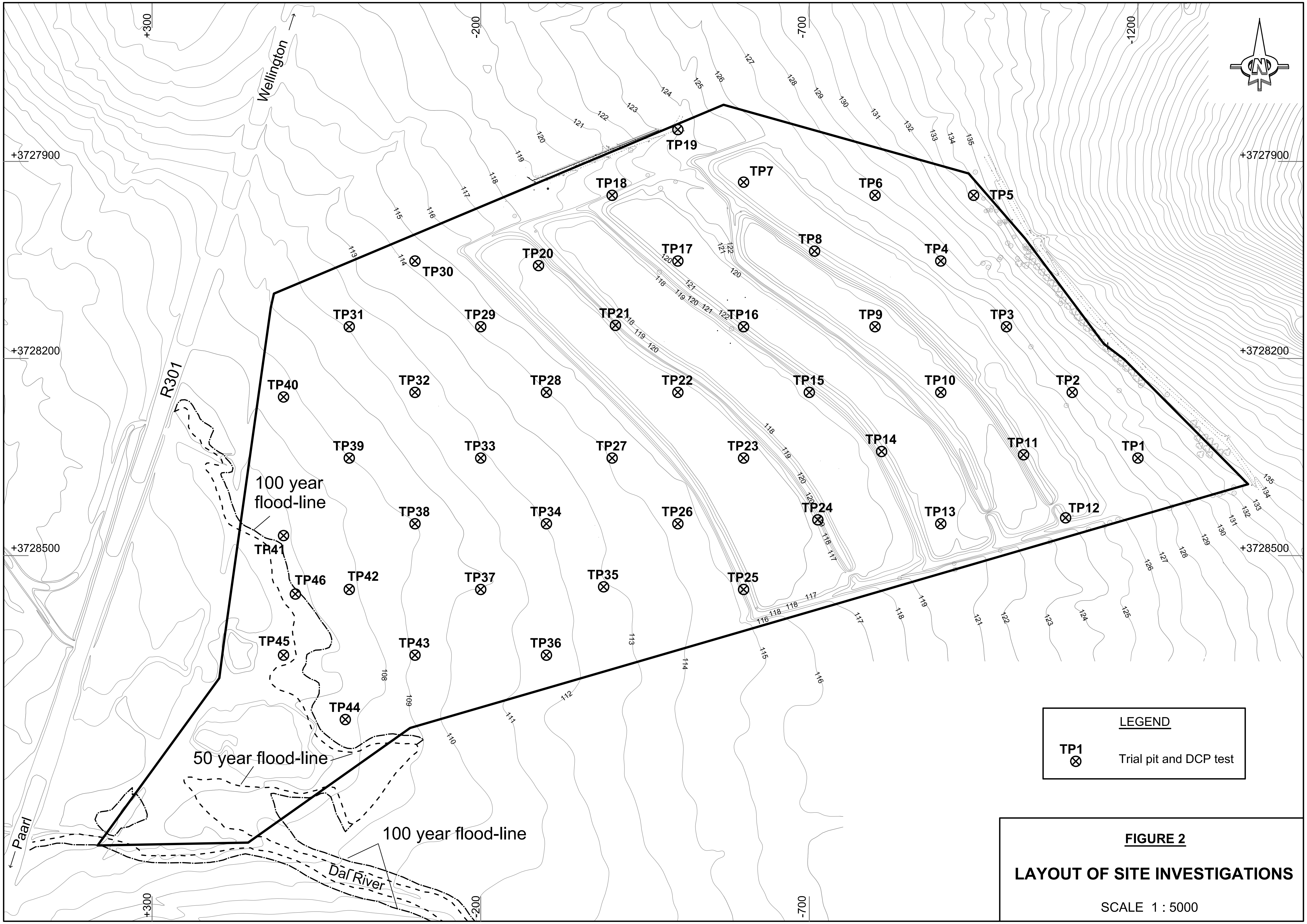


FIGURE 2

LAYOUT OF SITE INVESTIGATIONS

SCALE 1 : 5000

The objective of the testing was to determine the current relative density/consistency profile to a depth of 2m.

The plots of DCP penetration rates versus depth are also presented in Appendix A.

4.2.3 Laboratory testing

Foundation indicator tests were undertaken on seventeen representative soil samples, and mod/CBR tests were conducted on eight samples.

Oedometer tests were conducted on four undisturbed soil samples to determine the swell strain and swell pressures developed when the samples were saturated. The samples were nominally loaded, after which they were loaded to a pressure equivalent to the overburden pressure plus the expected foundation load. After consolidation had occurred at this pressure, the samples were saturated and allowed to swell freely. After swelling was complete, the samples were loaded until the sample had consolidated beyond its original height (void ratio) immediately prior to saturation.

pH and conductivity tests were also conducted on eight samples.

The results of the laboratory testing are presented in Appendix B.

5. SITE GEOLOGY AND GROUNDWATER CONDITIONS

5.1 General geology

Portions of the 1:250 000 Geological Series Maps, 3318 Cape Town and 3319 Worcester are shown at a scale of 1:125 000 on Figure 3.

Based on the Geological Series Maps, the area in the vicinity of the site is covered by undifferentiated, thin Quaternary sediments (Qs on Figure 3), overlying the Porterville Formation of the Malmesbury Group (Npo).

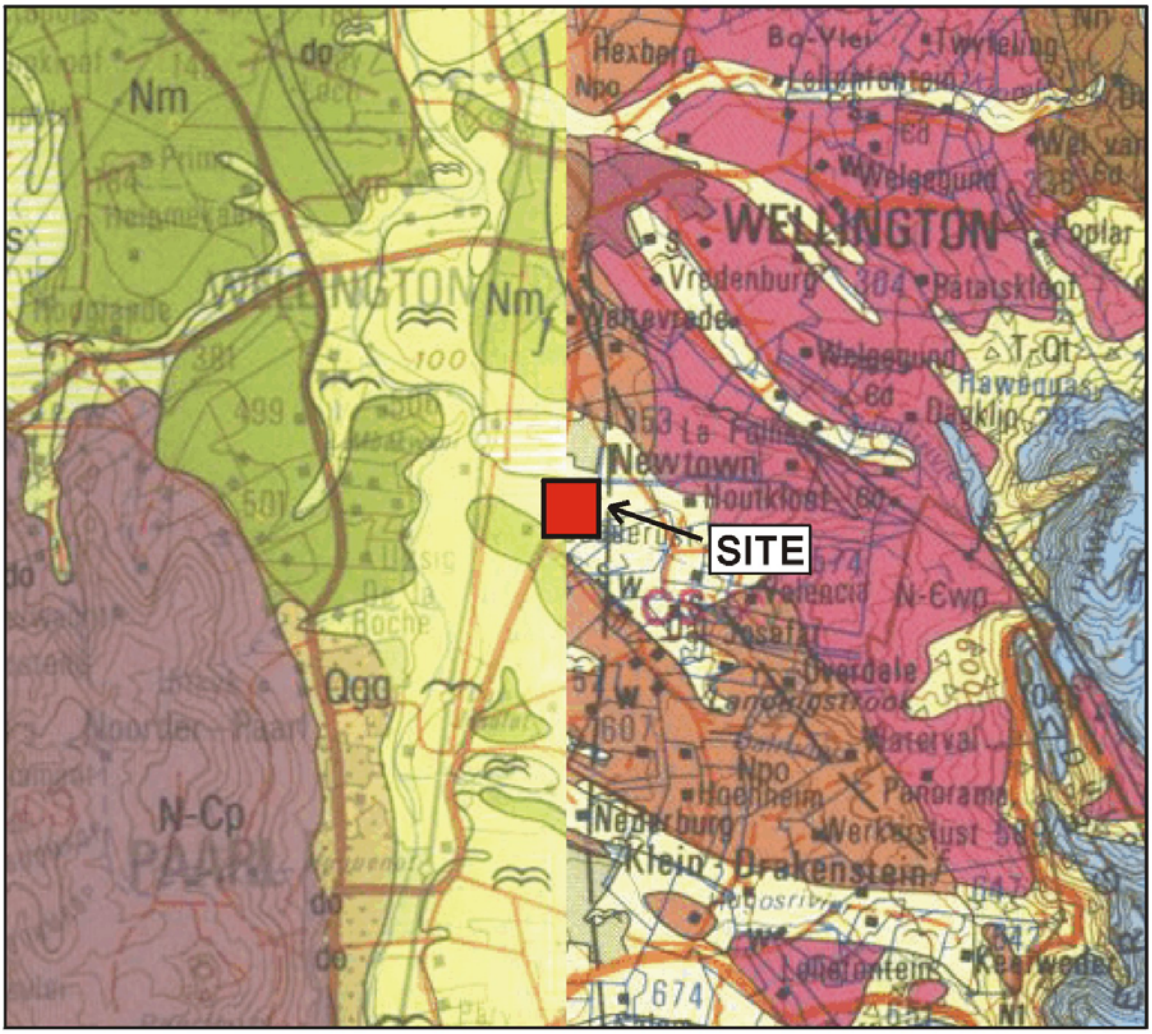
5.2 Site geology and soil profiles

Although the trial pitting confirmed the general geology described in Section 5.1, more than fifteen soil or material types were exposed in the trial pits, reflecting a complex and variable colluvial and alluvial depositional environment and pedogenic processes. Detailed descriptions of all the soil types are neither practical nor relevant, and the soils have been grouped into eight generalised soil types for descriptive purposes.

The schematic distribution of the generalized soil types in the forty-six trial pits are shown on Figures 4.1 and 4.2, and detailed descriptions of the soil profiles are presented in Appendix A. Summarised descriptions of the eight groupings of soil types are given below:

(i) Made ground

Made ground or fill material was almost exclusively encountered in those trial pits located in the embankment walls of the evaporation ponds.



LEGEND

Qgg, Qs	Undifferentiated Quaternary sediments
Ncp, Ncwp	Cape Granite Suite
Npo, Nm, Nn	Porterville, Malmesbury & Norree Formations, Malmesbury Group

Source: 1:250 000 Geological Series Maps 3318 Cape Town and 3319 Worcester

FIGURE 3

REGIONAL GEOLOGY

SCALE 1 : 125 000

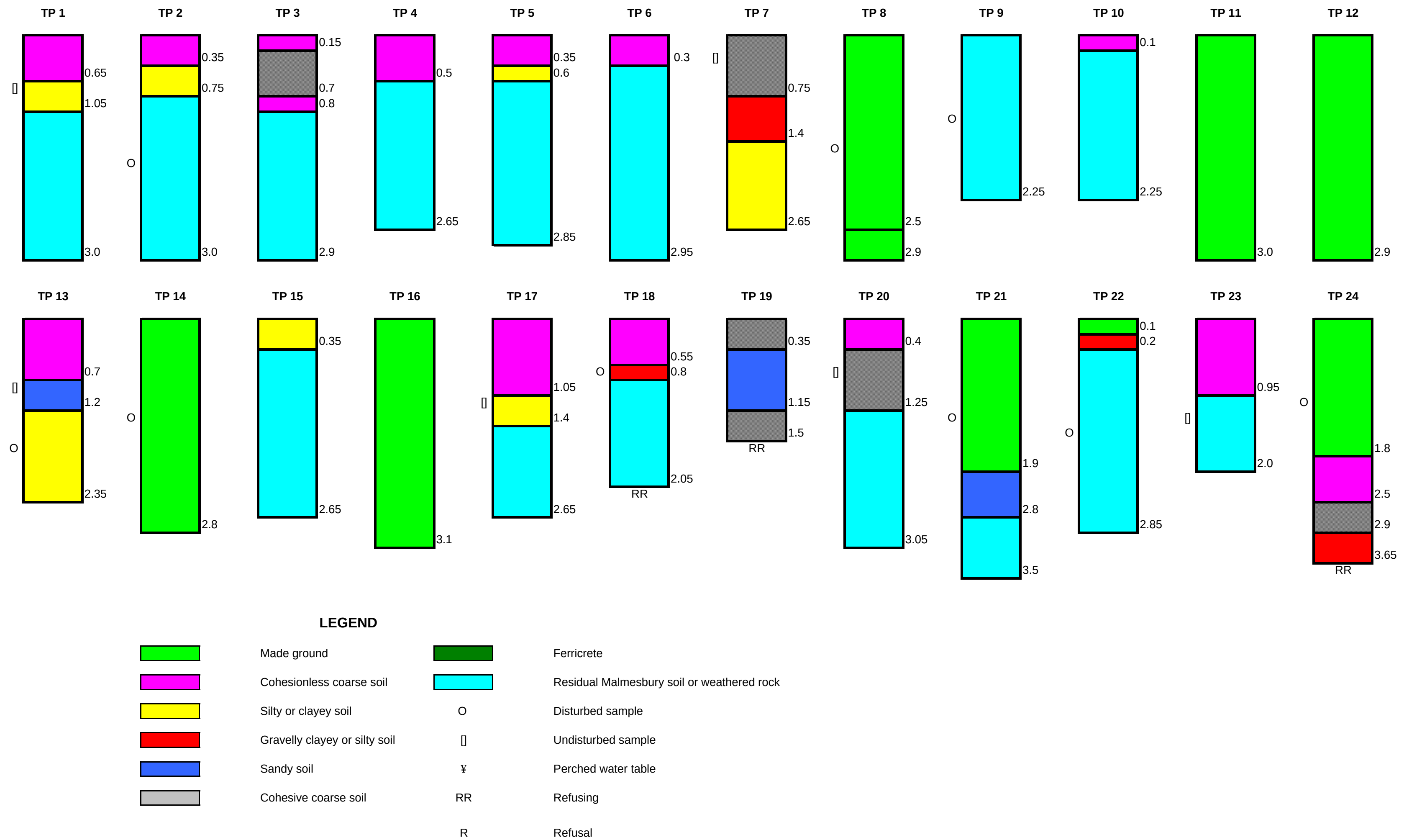


FIGURE 4.1
SOIL PROFILES IN TRIAL PITS - TP1 TO TP24

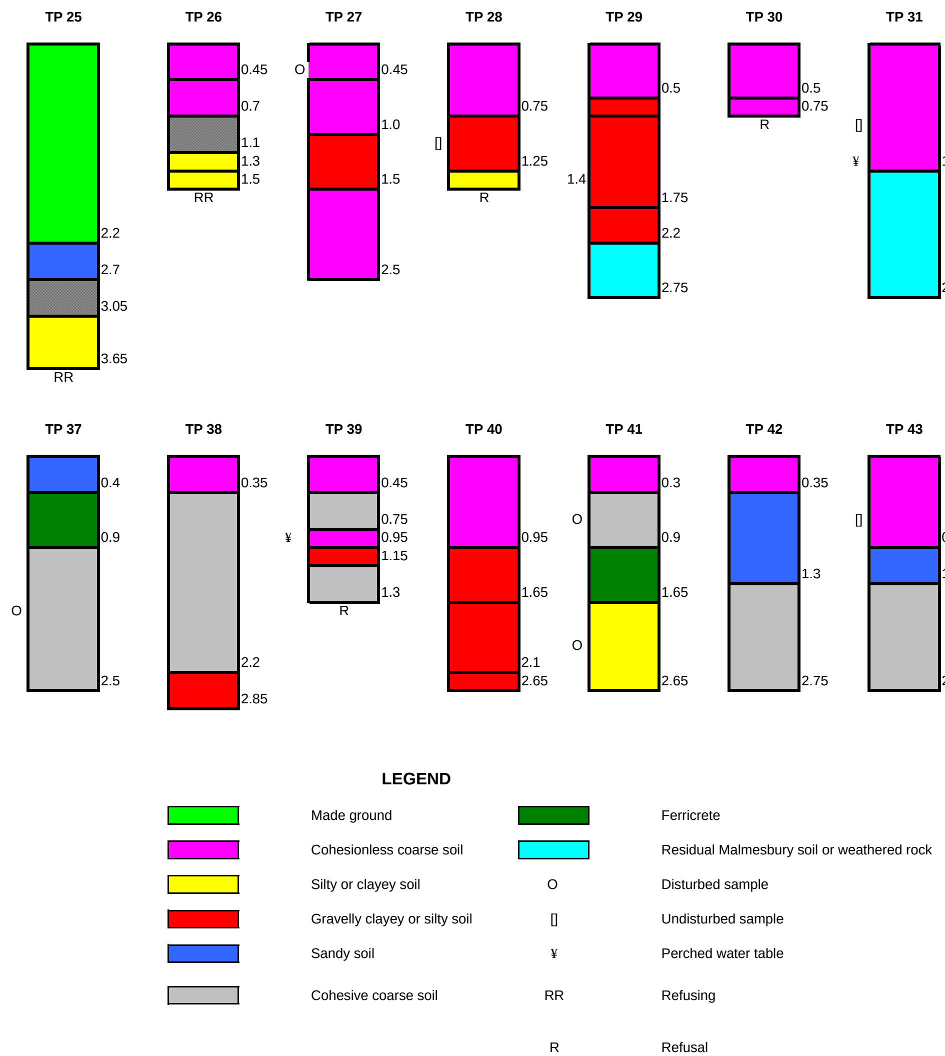


FIGURE 4.2
SOIL PROFILES IN TRIAL PITS - TP25 TO TP46

The made ground is generally layered light grey, greyish brown and orange brown. The soil generally comprises a slightly clayey, silty fine to medium sand, but coarser sands occur in places, and fine to medium gravel is also present. These fill soils were derived from the surficial soils within the pond areas, and, where deep excavation occurred, some finer soils were also excavated which now occur as thin layers of cohesive fill within the general fill.

The thickness of the fill in the embankment walls is variable, but the contour plans indicate a thickness up to 4m.

(ii) Cohesionless coarse soils

These soils mask or masked most of the site with the exception of the southwestern corner.

They generally comprise slightly clayey silty sand with variable proportions of fine to medium sub rounded ferruginised gravel. These gravelly silty sands or silty sandy gravels are brownish grey and the gravel is concentrated towards the basal contact. The soils, which are colluvial in origin in the upper parts of the site and alluvial or alluvial wash in the lower parts, range in thickness from 0.3m to 1.3m. They are weakly cemented in places.

(iii) Silty or clayey soils

These soils are of colluvial origin in the upper parts of the site and alluvial in the lower parts.

They commonly occur below the surficial cohesionless coarse soils in the former areas where they are khaki brown and generally less than 0.4m thick. The alluvial varieties are commonly khaki grey and at least 1m thick, in places.

(iv) Gravelly silty or clayey soils

These slightly gravelly soils occur as thin layers (0.1m to 0.65m) in places in the upper and central parts of the site, but they are more strongly developed in the western central and northwestern parts of the site.

The soils display variable colours, but they are commonly characterised by blotching and mottling. They are often weakly cemented and contain very minor quantities of fine to medium gravel.

(v) Sandy soils

These soils are not strongly developed in the central and northern parts of the site, but they are concentrated in the southwestern parts where the sand layers range in thickness from 0.4m to 1m in the trial pits. The composition ranges from silty sand to sand, with the sand component commonly medium to coarse.

(vi) Cohesive coarse soils

This grouping includes clayey sandy gravel, gravelly clayey sand, clayey gravelly sand, clayey silty gravel, gravelly silty sand and clayey silty sand.

The soils are almost exclusively developed in the southern central and southwestern areas of the site, with the gravelly clayey silty and their slightly gravelly derivatives occurring exclusively in the Southwestern

Area. The gravel component of all the soils is commonly, but not exclusively scattered and fine to medium sized. The thickness of the soils varies from 0.35m to more than 1.85m.

(vii) Ferricrete

Dark orange brown and brownish grey, layered, coarse gravel-sized blocks of hardpan ferricrete in a minor coarse sandy matrix were encountered in TP 37 and TP 41 in the southwestern parts of the site. These layers of pedogenic soil were 0.5m and 0.75m thick respectively. It should be noted that fine ferricrete or ferruginised gravels occur in the cohesionless coarse soils in the other parts of the site, particularly the eastern parts.

(viii) Malmesbury soil and weathered rock

Residual Malmesbury soil (sandy clayey silty or sandy silty clay) was encountered in TP 1 where it occurred together with patches of very soft, generally ferruginised greywacke.

Grey, stained and mottled or blotched red or orange brown, highly weathered, very closely to closely jointed (sub vertical foliation and joints), very soft to generally soft greywacke occurs at shallow depth (generally less than 0.8m) in the eastern and northern parts of the site. The weathering is more extensive in places so that very soft rock to very stiff residual soil-like material occurs within the highly weathered rock mass.

Based on the above descriptions and the distribution of soils shown on Figure 4.1 and 4.2, the site can be broadly divided into three areas where the following generalised soil profiles occur:

Northern Area

The generalised soil profile comprises:

- thin cohesionless coarse soils
- over, in places, thin clayey or silty soils,
- over residual Malmesbury soil and mainly highly weathered Malmesbury greywacke

Central Strip

The generalised soil profile comprises:

- cohesionless coarse soils,
- over gravelly silty or clayey alluvium
- over highly weathered Malmesbury greywacke generally at depths of more than 1.5m

Southwestern Area

The generalised soils profile comprises:

- cohesionless coarse soil
- over cohesive coarse alluvial soils with layers of sand, clayey or silty soil and minor hardpan ferricrete

The interpreted distributions of these profiles are shown on Figure 5 from which it is apparent that the areas run sub parallel to the Dal River. The soils were probably deposited by that river and probably also by the Berg River whose broad ancient floodplain extends into the site.

Superimposed on the first two of the generalised soil profiles are the strips of fill that form the embankment walls of the old evaporation ponds. The soils were generally derived from the cohesionless coarse soils that previously masked the footprint of the pond area.

5.3 Water table

Site investigations were conducted towards the end of a dry summer and perched groundwater was only encountered in three trial pits (TP 31, TP 39 and TP 46).

The presence of weakly cemented layers, ferricrete and the juxtaposition of coarse soils over clayey or silty transported soils or weathered bedrock suggests that perched groundwater will be more widespread in and immediately after the wet period of the year.

Anecdotal information plus the vegetation evidence suggests that most of the area in the southwestern corner of the site is seasonally wet, with an attendant very shallow seasonal perched water table.

6. GEOTECHNICAL EVALUATION

6.1 Engineering and material characteristics and constraints

6.1.1 Site topography

Field observations

There is a 27m fall westwards across the site with gradients of approximately 1:18 along the eastern boundary, reducing to approximately 1:75 in the central and particularly western parts of the site.

The overall natural gradient of the site is interrupted by the embankment walls of the evaporation ponds which typically slope at 1:3.

Effect on the development

Because of the shallow ground gradient and the occurrence of local low areas, surface run-off will be poor and local ponding and flooding could occur, particularly in the southwestern part of the site. Shaping of the ground will be required to improve drainage and encourage run-off.

Deep stormwater and sewer lines will probably also be required in many areas to ensure that the pipelines have an adequate fall.

6.1.2 Soil profiles

Field observations

From the soil profiles in Appendix A and Figure 2, it is apparent that there are numerous soil types, with weathered bedrock at varying depths. However, it is possible to categorise the soils into groups with similar properties and to identify three generalized, natural soil profiles and their areas of occurrence (see Figure 5). The embankment fill is superimposed on the two of these natural profiles.

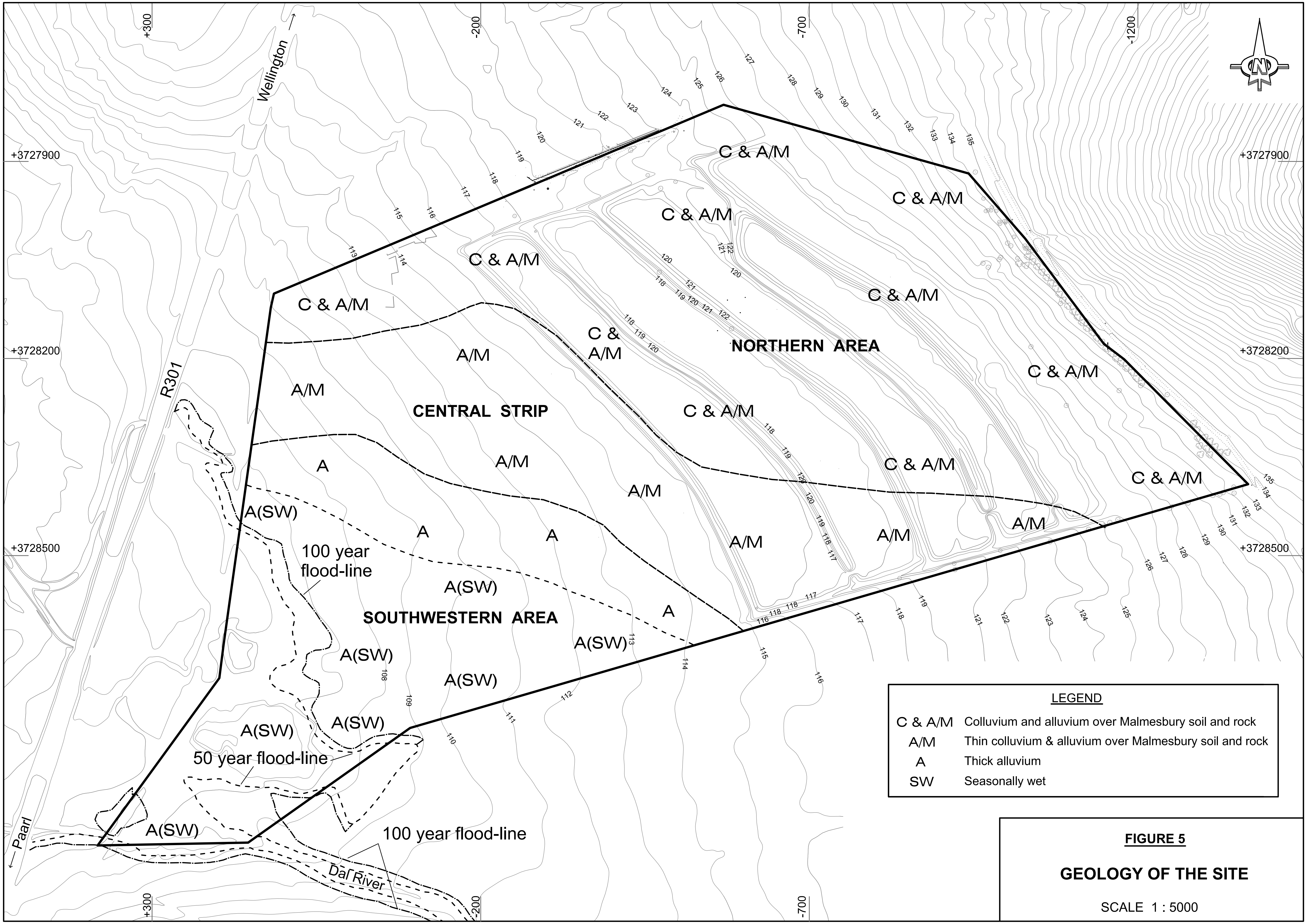


FIGURE 5

GEOLOGY OF THE SITE

SCALE 1 : 5000

Effect on the development

The following properties of the soil profile could potentially significantly influence the design and construction of houses for this project:

- The engineering properties and specifically the compressibility or heave characteristics of the silty or clayey soils and their slightly gravelly derivatives.
- The engineering properties and specifically the compressibility of the cohesionless and cohesive coarse soils and the sandy soils.
- The occurrence of weakly cemented layers, particularly in the Central Strip.
- The occurrence of bedrock and residual soils and specifically the potential swell characteristics of the latter.
- The occurrence of groundwater.

The above factors are discussed in the following sections.

6.1.3 Grading and Atterberg Limits

Laboratory results

The results of the foundation indicator tests on seventeen samples are presented in Table 1.

The made ground and the cohesionless coarse soils from which the made ground is derived have very low or negligible cohesion and are classified as SC, SW, SP-SW and SP soils.

The silty or clayey soils and their slightly gravelly derivatives are classified as CH and SC. They generally have high fines content (silt and clayey) and high liquid limits, plasticity indices and linear shrinkages.

The cohesive coarse soils are generally classified as SC or CL soils. From Figure 6, they generally display medium plasticity.

The residual soils and highly weathered Malmesbury greywacke bedrock have a fines content of more than 50%, and they display medium to high plasticity with moderate to high linear shrinkages.

Effect on development

Figure 6 also suggests the silty or clayey soils and their slightly gravelly derivatives, the cohesive coarse soils and the residual soils and weathered bedrock display medium potential for expansiveness. Heave and compressibility of the soils could therefore influence founding conditions and the foundation layout for the houses.

Compressibility and heave are addressed in Sections 6.1.6 and 6.1.7.

TABLE 1: SUMMARY OF GRADING ANALYSES

Soil Type	*Trial Pit*	*Depth (m)*	*Particle Size Distribution (%)**				*USC Classif.*	*Atterberg Limits*		
			Gravel	*Sand*	*Silt*	*Clay*		*LL*	*PI*	*LS*
Made Ground	TP8	0-2.5	7	71	9	12	SC	24	9	4.7
	TP21	0-1.9	4	87	6	4	SW		SP	
	TP24	0-1.8	9	80	7	4	SW		SP	
Cohesion less gr sand & sa gr	TP17	0-1.05	1	82	10	8	SP-SW	17	4	2.2
	TP31	0.6	3	90	5	2	SP		NP	
Silty & clayey soils	TP13	1.1-2.7	25	36	19	20	SC	33	14	7.1
	TP17	1.2	0	5	38	57	CH	54	30	9.5
Gr silty or clayey soil	TP28	1.0	3	28	12	58	CH	63	38	9.3
Cohesive or slightly cohesive gr sa, sa gr & sa soils	TP13	1.0	0	57	17	26	SC	50	30	9.2
	TP20	0.4-1.25	3	76	6	15	SC	23	9	4.8
	TP32	1.5	0	49	11	40	CL	44	26	9.0
	TP37	0.9-2.45	3	66	10	21	SC	34	18	4.9
	TP45	1.4-2.6	0	27	33	40	CL/CH	50	24	13.2
	TP46	0.8-2.6	0	45	24	31	CL	32	17	6.1
Residual soil & weath. rock	TP2	0.75-3.0	3	43	40	15	CL	36	14	6.7
	TP9	0.3-1.25	1	30	49	20	ML	44	12	5.7
	TP23	1.3	0	8	30	62	CH	62	36	11.3

** Percentage of the soil by weight   NP Non plastic   SP Slightly plastic   USC Unified Soil Classification System*

6.1.4 Moisture-density relationship and CBR

Laboratory results

The results of the mod/CBR tests on the soils are presented in Table 2.

The cohesionless coarse soils and the made ground derived from it have high maximum dry densities and low optimum moisture contents. According to COLTO, the soils would be classed as G6 or G7 soils.

Variable maximum dry densities and optimum moisture contents were recorded for the cohesive soils and their classification ranges from G7 to G10 materials.

The weathered Malmesbury greywacke rock and presumably the residual soils derived from it have negligible CBR strength on saturation.

TABLE 2: RESULTS OF CBR TESTS

Soil Type	*Trial Pit*	*Depth (m)*	*Mod. A.A.S.H.T.O. Data*		*C.B.R. at*					*Maximum Swell (%)*
			M.D.D. (kg/m^3)	**O.M.C. (%)**	**100%**	**98%**	**95%**	**93%**	**90%**	
Made ground	TP8	0-2.5	2144	7.0	60	42	26	18	10	0.2
	TP21	0-1.9	2145	6.6	178	108	56	36	18	0.0
	TP24	0-1.8	2251	5.5	109	86	55	44	30	0.2
Cohesionless coarse soils	TP17	0-1.05	2210	5.2	198	141	82	57	33	0.0
	TP27	0-1.0	2172	4.4	255	149	67	39	17	0.0
Cohesive coarse soils	TP20	0.4-1.25	2150	6.3	55	42	28	22	16	0.9
	TP45	1.4-2.6	1802	15.3	1	1	1	0	0	11.2
Weathered rock	TP9	0.3-1.25	1698	15.6	1	1	1	1	0	11.9

Effect on development

The cohesionless coarse soils in the Northern Area are thinly developed and the low saturated CBR of the underlying residual soils and bedrock will influence the design of the roads in that area.

Similarly, the cohesionless coarse soils are thinly developed in the Central Strip and in the Southwestern Area and the low CBR of the cohesive coarse soils will also influence layerwork design even though areas of sand or thicker cohesionless coarse sands with relatively high CBR also occur.

6.1.5 Conductivity and pH

Test results

The results of the chemical tests on eight soil samples are presented in Table 3.

TABLE 3: RESULTS OF CHEMICAL TESTS

Soil Type	*Trial Pit*	*Depth (m)*	*pH*	*Conductivity (mS/m)*
Silty & clayey soils	TP13	1.1-2.35	6.0	14.78
Cohesive coarse soils	TP20	0.4-1.25	6.5	40.40
	TP32	0.8-1.8	4.0	23.10
	TP37	0.9-2.45	6.2	55.00
	TP45	1.4-2.6	6.4	537.00
	TP46	0.8-2.6	5.3	40.60
Residual soil & weath. rock	TP2	0.75-3.0	5.0	22.90
	TP9	0.3-1.25	5.7	53.60

The results indicate that all the soils are acidic, generally with low to moderate conductivity.

Effect on development

In general, corrosion of metallic subsurface services is affected by the following physio-chemical properties of the soil: pH, conductivity and moisture content of the soil.

The combination of acidic soils and low to moderate conductivities indicates that mild corrosion of buried metallic services could occur with time.

6.1.6 Compressibility of the soils

Field observations and test results

The results of the DCP tests, which were conducted during summer when soil moisture contents were low, indicate that the soils are currently generally medium dense to dense or very stiff. However, loose conditions extended to more than 1m depth in places in the Central Strip and Southwestern Area.

The soils are likely to loosen/soften with increases in soil moisture content in winter.

Consolidation tests indicate that heave or swell of the cohesive soils is more likely than consolidation.

Effect on development

Consolidation settlement of engineered fill derived from soil from the embankment walls and the cohesionless coarse soils will occur, but the thickness of the soils is generally considerably less than 1m and settlements of less than 5mm are therefore expected.

Consolidation of the cohesive coarse soils in the Southwestern Area and particularly the seasonally wet parts of this area will occur and the estimated settlement of these soils when wet is approximately 10mm.

6.1.7 Heave

Field observations and test results

The silty or clayey soils and the cohesive coarse soils are fissured, but no widespread slickensiding was observed. However, linear shrinkages of the soils are commonly large, and Figure 6 suggests that they display medium potential for expansiveness.

TABLE 4: RESULTS OF SWELL STRAIN AND PRESSURE TESTS

Soil Type	*Trial Pit*	*Depth (m)*	*Swell Strain (%)*	*Swell Pressure (kPa)*
Silty or clayey soil	TP17	0.9	2.4	>219
Gravelly silty or clayey soil	TP28	1.0	1.8	110
Cohesive coarse soil	TP13	1.0	2.9	180
	TP32	1.5	5.5	420
Weathered rock	TP23	1.3	2.7	295

The results of swell strain and pressure tests on four undisturbed samples are presented in Table 4. The tests indicate that, for typical foundation plus overburden pressures of approximately 40kPa, soil strains of 2% to 3% are likely but this could increase to 5.5% in places. The swell pressures are in excess of 100kPa.

Effect on development

The active soils include the silty or clayey transported soils and their slightly gravelly derivatives, cohesive coarse soils, and the weathered greywacke bedrock and its residual soils. The latter soils are predominantly developed in the Northern Area and the Central Strip, with residual soil and bedrock at shallow depth in the former area and parts of the latter.

Assuming initially that significant seasonal changes in moisture content extend to depths of 2m, the theoretical heave could be of the order of 40mm. In practice, the soils even in mid to late summer are moist at depth (see Appendix A) and they are partially saturated. The entire 2m theoretical depth is therefore unlikely to become saturated, and maximum soil strains up to 15mm are more likely, given that the upper part of the profile generally comprises relatively inactive cohesionless coarse soils.

6.1.8 Collapse Potential

Field observations and test results

The surficial cohesionless coarse soils are pinholed in places, but these layers are generally less than 0.7m thick and the most open fabric occurs in the upper 0.5m. No laboratory collapse potential tests were therefore undertaken.

Effect on development

The pinholed soils occur at surface and are thinly developed, and collapse consolidation of the soil is not considered a significant factor influencing the design and construction of houses.

6.1.9 Dispersivity

Field observations

Despite having impounded untreated sewage water, no evidence of dispersivity was observed in the embankment walls of the evaporation ponds. The walls are constructed with cohesionless coarse soils.

Effect on development

The silty or clayey soils and the cohesive coarse soils display no characteristics associated with dispersivity. No dispersivity testing was therefore undertaken.

6.1.10 Permeability

Field observation and laboratory results

The cohesionless coarse soils contain a small but significant proportion of fines and, in general, they would be classed as slightly to possibly moderately permeable with permeabilities probably less than 10^{-4}cm/sec.

All other soils, with the exception of the very minor occurrences of silty sand and sand, contain high proportions of fines and they are therefore slightly to effectively impermeable.

Effect on development

Some infiltration of surface water will occur but the majority will disperse through surface run-off and drainage measures will be required to control surface flows of stormwater.

Conditions also exist for the development of perched water tables where cohesionless coarse soils overlie less permeable soils.

6.1.11 Condition of houses in the adjacent developments

Field observations

Inspection of houses to the north of the site indicates that cracking is not generally developed. The houses do not appear to have been constructed as part of a group scheme and it is assumed that, in the absence of control joints, no extensive structural measures or non conventional foundation layouts were used to counter adverse ground conditions.

Effect on development

The general lack of extensive cranking in the houses to the north of the development contradicts the results of the laboratory testing and the assessments above which indicate that active soils could lead to structural problems in the houses. The lack of widespread cracking suggests that either comprehensive foundation design and ancillary structural measures were used to minimise the affects of heave (unlikely) or that, despite the evidence from testing and observations on the site itself, the soils in the existing residential area are only mildly active, or the soil profile below the existing houses differs from that in the Northern Area and Central Strip.

6.2 Slope stability, erosion and inundation

No natural, large-scale instability can occur on the relatively shallow sloping ground at the site.

Deep vertically excavated slopes in service trenches will be unstable and the following cut slope batters can be considered:

- 0 to 1.5m depth - vertical
- 1.5m to 2.5m - 1:0.75
- >2.5m - 1:1

These batters should be confirmed on site during construction and statutory provisions will be required to ensure the safety of workers in the trenches. These recommendations should be reviewed if groundwater is encountered, because flatter slopes and/or lateral support will be required.

Exposed surficial cohesionless coarse soils are potentially erodable by water and small shallow eroded channels occur in the mid central and western parts of the site. However, the extent of erosion is minimal and erosion of the surficial soils is not considered a significant factor in the construction of this project.

The 1:50 and 1 in 100 year floodlines are shown on Figures 2, 4, 7 and 8. The information, which was obtained from the Drakenstein Municipality, indicates that inundation of a significant portion of the southwestern corner of this site will occur. Floodlines for the 1 in 10 and 1 in 20 year events were not available, but the Dal River will presumably also cause more frequent inundation of smaller areas during those events.

6.3 Excavation classification with respect to services

According to Tables 2.1 and 2.2 of the Generic Specifications, excavation in the various soil types would be classified according to SABS 1200 D as follows:

Soft Excavation Class:	Made ground, cohesionless coarse sands, silty or clayey soils, slightly gravelly silty or clayey soils, sandy soils and cohesive coarse soils
Intermediate Excavation Class	Weakly cemented cohesive coarse soils, weakly cohesive coarse soils, ferricrete and weathered bedrock

In practice, excavation to 3m depth in the typical soil profile in the Northern Area would generally be classified as Soft Excavation Class with possibly 10% to 15% categorised as Intermediate Excavation.

Weakly cemented layers are commonly developed in the Central Strip and the percentages of Soft and Intermediate Excavation are probably of the order of 70% to 30% respectively.

Weakly cemented layers also occur in places in the Southwestern Area and the percentages of Soft and Intermediate Excavation are probably approximately 85% to 15% respectively.

The surficial sandy soils and possibly the cohesionless coarse soils in winter can be efficiently excavated manually, but all other soils will be difficult to excavate manually, particularly when the soils dry out in summer.

6.4 Impact of the geotechnical character of the site on subsidy housing development

6.4.1 Land usage

There is minimal vegetation cover, and with the correct preparation, site clearance and founding methods and removal of the embankment walls, the entire study area will be suitable for human settlement and subsidy based housing with the exception of the area in the extreme southwestern corner of the site which will be subject to periodic inundation and flooding, and also possibly the seasonally wet parts of the Southwestern Area.

6.4.2 Subsidy variations

In considering the entire site and using Annexure 1 of the General Specification, the following generic subsidy variations for the site and founding conditions are applicable:

II SITE CONDITIONS

1 Seepage/Groundwater

1. Category1 - Permanent or perched water table less than 1m below ground surface.

This condition is expected seasonally in the southwestern corner of the site, and probably in places, in other areas.

Service trenches would have to be dewatered during construction.

3 Difficulty of servicing land due to slopes

3.1 Type 1 site - average slope measured along a 100m line in any direction from any of the boundaries of the erf is flatter than 1:100

Because the ground contours run consistently northwest-southeast, any services that run consistently parallel or sub parallel to the contours will be located at depth, in places to facilitate free flow in the services.

III FOUNDING CONDITIONS

1 Expansive soils

1.1 Class H1

This condition occurs in the Northern Area. The masonry houses will require foundation design, building procedures and precautionary measures to be in accordance with Table 5 of Part 1, Section 2 of the NHBRC Coal Home Building Manual.

Additional factors that are not categorised in Annexure 1 but will affect construction costs include:

- The embankment walls for the old evaporation ponds must be removed and the soils placed as engineered fill within the basins of the ponds. The quantity of material to be moved is unknown to the Author. The cost of excavation and placing this material should also be reflected in the costing and subsidy variation.

- Material that is excavated from road beds, foundation trenches and some foundation trenches in the Northern Area might comprise a mixture of sandy and cohesive soils. Excavated material from deep (>1.25m) service trenches in all areas will also contain a mixture of soils. This material is unsuitable for structural fill and it should not be placed on adjacent erven or under surface beds. The cost of handling and spoiling the materials should be included in the assessment of subsidy variation.

- Over-excavation of trenches in the gravelly soils will be required to ensure stability of the sidewalls of the service trenches, particularly where groundwater is encountered. The cost of the extra excavation, the spoiling of additional quantities of material unsuitable for backfill and the additional importation of selected material for backfilling service trenches should be reflected in the costing and subsidy variation.

Although the site investigation coverage was extensive, the soil conditions may vary between trial holes. Consequently, subsidy variations could also vary depending on the ground conditions actually encountered.

7. SITE CLASSIFICATION

7.1 NHBRC Classification

According to Table 5 in the Generic Specifications and Table 1, Section 2 of the NHBRC Home Building Manual, Part 1, and based on the assessments given above, the following NHBRC classifications, whose distributions are shown on Figure 7, are applicable to the site:

Northern Area A:	Site Class H1 and H1 with S
Central Strip:	Site Class H and H with S
Southwestern Area:	Site Class S/S1

The 'S' classification in the first two areas currently refers to the fill in the embankment walls, but the classification will largely fall away when the walls are flattened and the material placed in engineered fill.

7.2 Geotechnical Classification for Urban Development

The areas containing the three generalised soil profiles described in Section 5.2, plus the seasonally wet area in southwestern corner, areas with different slope gradients and the area that will be subject to the 1 in 100 year flooding have been classified using the Geotechnical Classification for Urban Development in Table 3 of the GFSH-2 Generic Specifications. For ease of reference, the table from GFSH-2 is presented on the next page as Table 5 of this report.

The terrain mapping units were derived from the results of the site investigation and other data or activities referenced in Section 2 of this report. The extent of the mapping units was determined by extrapolation of information from the trial pits.

The distributions of the terrain mapping units are shown on Figure 8, and the mapping units can be described as follows:

(i) Thin colluvium and alluvium over Malmesbury soils and weathered rock – 1ABEI 2C 3K:

This mapping unit lies between the eastern edge of the evaporation pond area and the eastern boundary.

The classification reflects the presence of potentially slightly collapsible thin soils, perched groundwater more than 1.5 m below ground surface, the low erodability of the soils and ground sloping between 2° and 6°, all of which represent most favourable conditions.

Intermediate constraints include the moderate heave potential of the soil profile and the least favourable constraint is that the site occurs close to the epicentre of the 1969 'Tulbagh' earthquake and a natural seismicity of more than 100 cm/sec^2 will occur.

(ii) Thin colluvium and alluvium over Malmesbury soil and weathered rock – shallower slopes – 1ABE 2CI 3K

This unit is developed in the area between the northern side of the evaporation ponds and the northern boundary, and the remainder of the Northern Area to the west of the ponds.

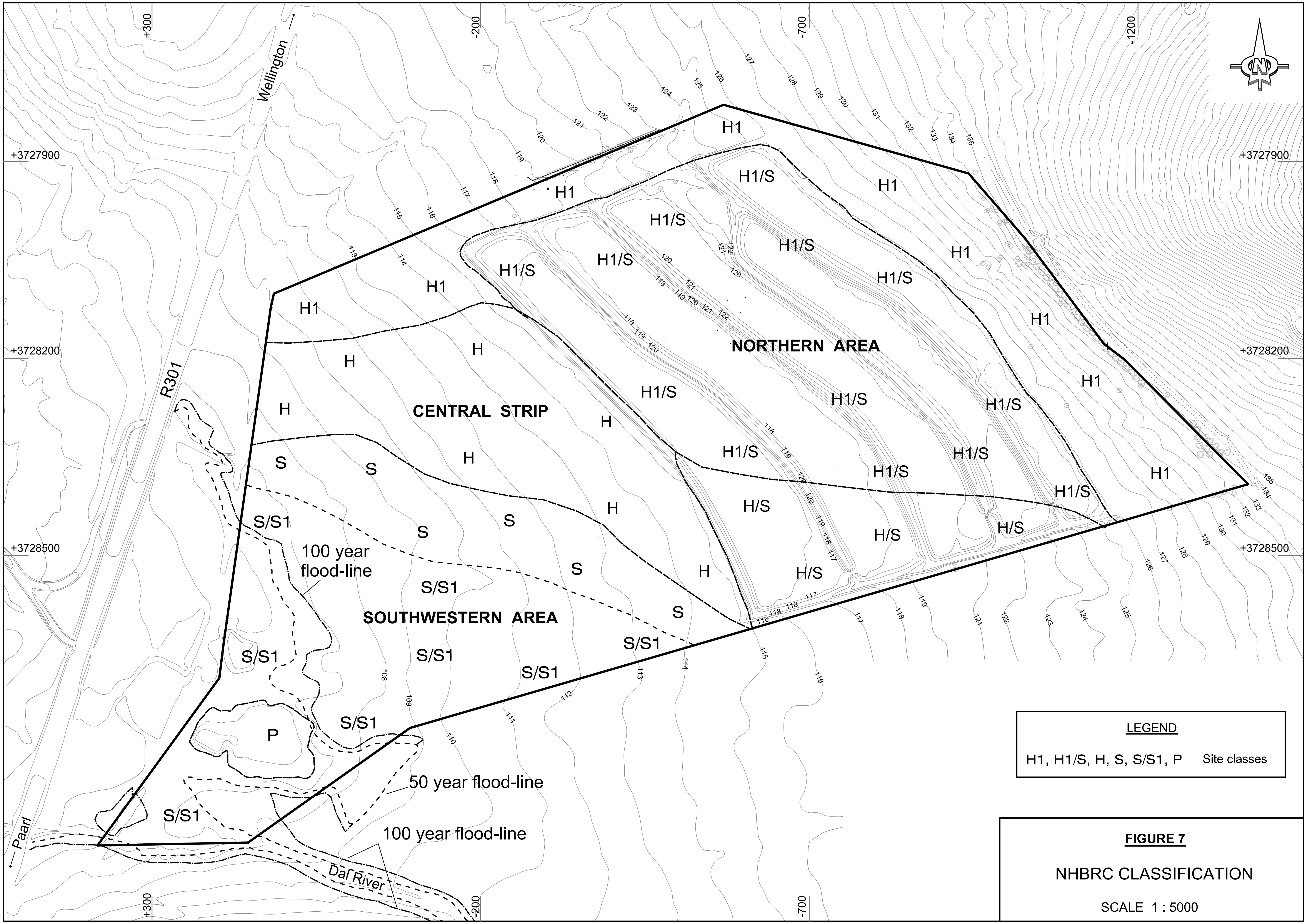


FIGURE 7

NHBRC CLASSIFICATION

SCALE 1 : 5000

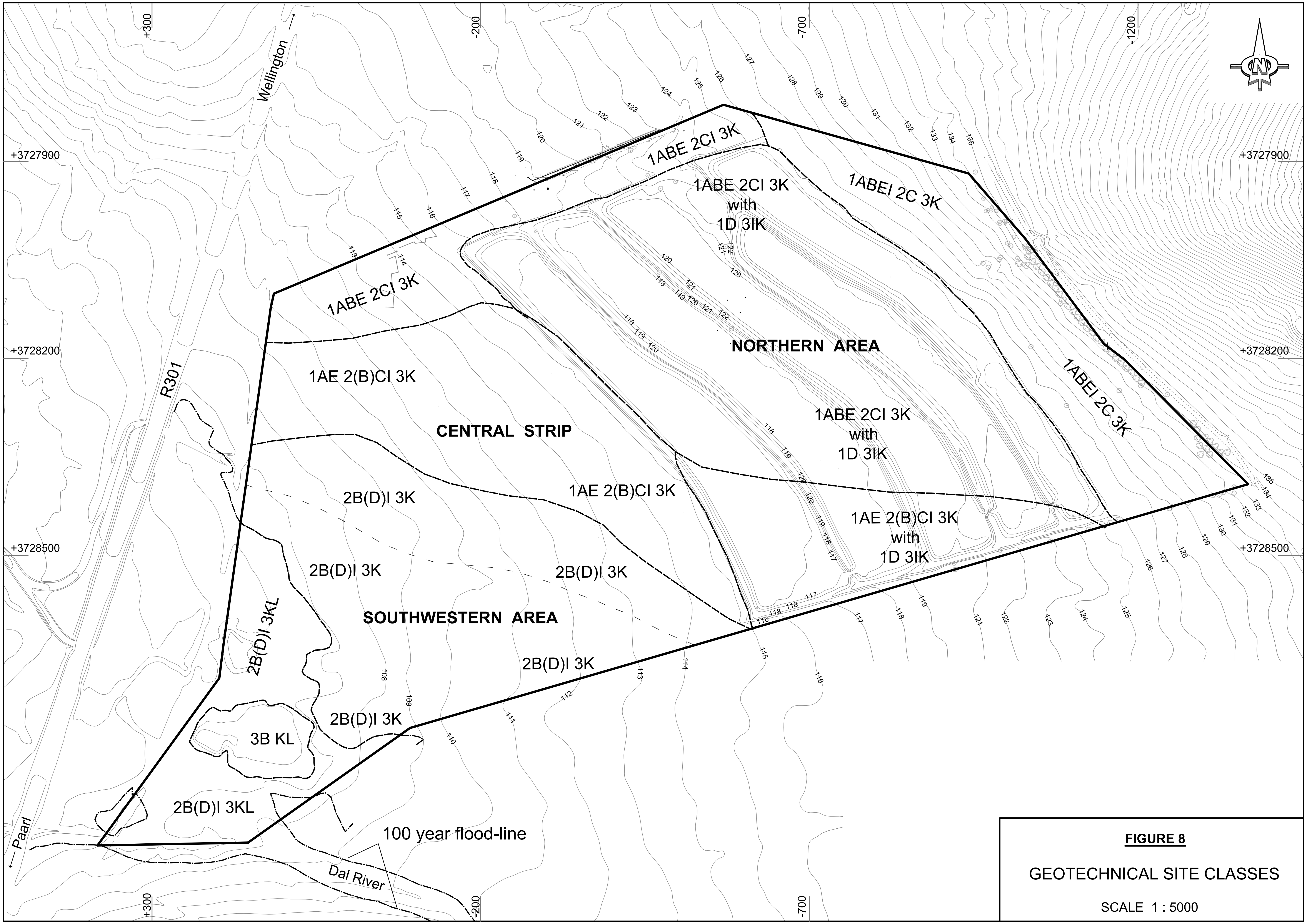


FIGURE 8

GEOTECHNICAL SITE CLASSES

SCALE 1 : 5000

The classification reflects the same features described in (i) above, but ground slopes of less than 2° represent an intermediate constraint.

(iii) Thin colluvium and alluvium over Malmesbury soils and weathered rock – evaporation pond area – 1ABE 2CI 3K with 1D 3IK

This unit occurs in that part of the Northern Area that falls within the evaporation ponds.

The 1ABE 2CI 3K classification reflects the conditions in the basal areas of the ponds and the explanation was presented in (ii) above.

The classification for the embankment walls is currently 1D 3IK which reflects low soil compressibility, but steep slopes and the seismicity of the region are also considered.

TABLE 5: GEOTECHNICAL CLASSIFICATION FOR URBAN DEVELOPMENT

CONSTRAINT		Most favourable (1)	Intermediate (2)	Least favourable (3)
A	Collapsible Soil	Any collapsible horizon or consecutive horizons totaling a depth of less than 750mm in 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 anticipated*	Moderate soil heave potential anticipated	High soil-heave potential Anticipated
D	Highly compressible Soil	Low soil compressibility anticipated*	Moderate soil compressibility anticipated	High soil compressibility Anticipated
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 and 40% of the total volume	Rock or hardpan pedocretes more than 40% of the total volume
G	Undermined ground	Undermining at a depth greater than 240m below surface (except where total extraction mining has not occurred)	Old undermined areas to a depth of 90-240 m below surface where stope closure has ceased	Mining within less than 90-240m of surface or where total extraction mining has taken place
H	Stability: (Dolomite & Limestone)	Possibly stable. Areas of dolomite overlain by Karoo rocks or intruded by sills. Areas of Black Reef rocks. Anticipated Inherent Risk Class I	Potentially characterised by instability. Anticipated Inherent Risk Classes 2 – 5.	Known sinkholes and dolines. Anticipated Inherent Risk Classes 6 –8.
I	Steep slopes	Between 2° and 6° (all regions)	Slopes between 6° and 18° and less than 2° (Natal and Western Cape) Slopes between 6° and 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 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 know drainage channel or floodplain with slope less than 1%	Areas within a known drainage channel or floodplain

* These areas are designated as 1A, 1C, 1D, or 1F where localised occurrences of the constraint may arise.

Example: A sub-area designated as Zone 2BF would be an intermediate class with anticipated seepage and excavation problems.
A sub-area designated as Zone 3B would be designated as least favourable and not recommended for development due to surface water inundation.

(iv) Thin alluvium over Malmesbury soils and weathered rock – 1AE 2(B)CI 3K

This unit occurs in the Central Strip.

The classification reflects similar conditions to those discussed in (ii) above, but there is greater likelihood of encountering shallower perched groundwater conditions in winter.

The classification for the embankment walls is currently 1D 3IK which reflects low soil compressibility, but steep slopes and the seismicity of the region are also considered.

(v) Thick alluvium – 2B(D)I 3K

This unit occurs in those parts of the Southwestern Area to the east (downstream) of the 1 in 100 year floodline.

The classification reflects the fact that there will be a perched water table less than 1.5m below ground surface, that the soils have borderline moderate compressibility when wet and the ground slopes are shallow, all of which are intermediate constraints. The seismicity of the region is also reflected.

It should be noted that the southern two-thirds of this area is seasonally wet and that it has a marginal 2L 3B classification.

(vi) Thick alluvium within the 1 in 100 year flood line – 2B(D)I 3KL

This unit occurs in those parts of the Southwestern Area to the West (upstream) of the 1 in 100 year floodline.

The explanation is as per the relevant parts of (iv) above, but the area has lies within a known floodplain.

(vii) Dam area – 3BKL

This unit occurs in the small dam in the extreme southwestern part of the Southwestern Area.

The classification indicates most unfavourable conditions including marshy conditions, its location within a floodplain and the seismicity of the area apply to this dam area.

8. FOUNDATION RECOMMENDATIONS AND SOLUTIONS

Based on the general NHBRC classifications in Section 7.1, and Part 1, Section 2, Tables 5 and 7 of the NHBRC Home Building Manual, the following foundation types are considered appropriate for the houses in the various areas:

(i) Northern Area – Site Class H1

Lightly reinforced strip footings with articulation joins at all internal/external doors and openings and light reinforcement in the masonry.

Site drainage and plumbing/service precautions will be necessary.

(ii) Northern Area – evaporation pond area – Site Class H1 with S

Once the material from the embankment walls has been removed and placed as thin engineered fill in the basal parts of the ponds, H1 conditions will occur, and the layout and measures described for (i) above are again considered appropriate.

(iii) Central Strip – Site Class H

Normal construction comprising strip footings founded at 0.6m depth are considered appropriate.

Site drainage and plumbing/service precautions are recommended.

(iv) Central Strip – Site Class H/S

Provided that the material from the embankment wall is placed and compacted according to specifications, normal strip footings founded at 0.6m depth are considered appropriate.

Site drainage and plumbing precautions are recommended.

(v) Southwestern Area – non seasonally wet sub area – Site Class S

Normal strip footings founded at 0.6m depth with foundation pressures not exceeding 50kPa are considered appropriate.

Good site drainage is essential.

(vi) Southwestern Area – seasonally wet sub area – Site Class S/S1

The soils are likely to soften/loosen seasonally with increases in soil moisture and the classification would be borderline Site Class S/S1.

Normal strip footings typically founded at 0.6m depth with foundation pressures not exceeding 50kPa will be appropriate for this area. However, allowance should be made for modified normal, lightly reinforced footings in, say, 60% of the houses.

It should be noted that special drainage measures and/or raising of the ground levels are essential in this seasonally wet area.

(vii) Southwestern Area – sub area within the 1 in 100 year floodline – Site Class S/S1

Unless special measures such as protective berms or raising ground levels are instituted, no construction should occur in this area. This restriction should also include the pond or dam in the extreme southwestern corner where the Site Class P (marshy area) occurs.

Raft foundations could be used in all the sub areas of the site with the exception of the seasonally wet parts of the Southwestern Area. The rafts should be carefully designed and constructed to ensure that settlement or heave of the soils are handled by the raft.

9. DRAINAGE

The general slope of the site is very shallow particularly in the Southwestern Area and most parts of the Central Strip. Careful attention to general surface drainage will therefore be required during design and construction. In this respect, extensive drainage measures will be required in the Southwestern Area if that area is to be developed.

Good drainage around the houses is also essential and careful local shaping of the ground and design of stormwater will be required to ensure that drainage is efficient and no ponding of stormwater occurs.

Subsurface drainage will be required next to roads throughout the Southwestern Area. In addition, because the surficial cohesionless coarse soils contain small amounts of fines and are underlain by less permeable soils, subsurface drainage next to roads in other parts of the site should be considered to prevent saturation and 'mattressing' of the surficial soils.

10. SITE CLEARANCE AND PREPARATION AND EARTHWORKS

Site clearance will be extensive and include the following:

- Removal of the large trees that grow in several parts of the site, particularly along the eastern boundary.
- Removal of the Port Jackson bush and trees.
- Demolition and removal of the shacks and livestock pens on the western side of the site.
- Demolition and removal of the old house and other structures in the Southwestern Area.
- Removal of the old feed and gravity lines from the neighbouring sewage works to the evaporation ponds.
- Removal of the outlet/inlet works structures in the ponds.
- Removal and spoiling off the site of the piles of rubble and rubbish scattered throughout most of the site.

Because the site layout is unknown, no specific comment can be made with regard to earthworks requirements with the exception and that the embankment walls will have to be removed and reworked.

It is assumed that the soils from the walls will be placed in the basal areas of the ponds. Irrespective of where it is placed, the areas to be filled must be cleared of vegetation and the small areas where the bases of large trees should be carefully cleared of remnant roots and loose material. The subgrade throughout the cleared areas should then be compacted to at least 90% of mod AASHTO maximum dry density with a ten-tonne, smooth drum, vibratory roller. The material from the embankment walls can then be placed in layers not exceeding 250mm in thickness, moistened to within 2% of optimum moisture content and rotivated, if necessary, to mix the soil and water, and then compacted to 98% of mod density.

Nuclear densimeter (troxler) tests should be undertaken on a routine basis as the layers are placed and at the intervals prescribed in SABS 1200 D.

It should be noted that the soils are moisture sensitive, and it will not be possible to achieve satisfactory compaction in, for example, winter when the soils are wet of optimum or when they are dry towards the end of summer.

Mixtures of sandy and clayey soils should not be placed in the engineered fill.

11. USE OF ON-SITE MATERIALS FOR CONSTRUCTION PURPOSES

The cohesionless coarse soils and the soils in the embankment walls will be suitable for engineered fill provided that the moisture content lies within 2% of optimum moisture content. If not they must be spoiled and imported materials substituted or they must be allowed to dry out.

It is unlikely that they will be suitable for pipe bedding, but they will be suitable for general fill in service trenches and for backfill below surface beds, provided that the soils are neither too wet nor too dry.

In general, the silty or clayey soils and their slightly gravelly derivatives, and the cohesive coarse soils will not be suitable for use as fill, and this material and particularly mixes of the soil types must be spoiled.

The residual and Malmesbury soil and weathered rock could probably be used in engineered fill where it should be compacted to 95% of mod density with a pad foot vibratory roller. It could also be used in the wide service trenches where a sufficiently large compactor can be used. These materials are also moisture sensitive, and mixtures of Malmesbury materials and other soils must be avoided.

Clean sand for bedding, and sub base and basecourse for road layer works should be imported.

12. ROAD CONSTRUCTION

Site preparation for the roads should include excavation of the road bed and removal of any vegetation (roots etc.). The subgrade conditions will then comprise thin remnant cohesionless coarse soils in the Northern Area, thin remnant cohesionless soils over silty or clayey soils in the Central Strip, and silty or clayey soils and cohesive coarse soils in the Southwestern Area.

Based on the results presented in Table 2, the cohesive coarse soils and the Malmesbury materials have very low, saturated CBR’s, whereas the other materials have relatively high CBR’s and fair to good subgrade properties.

The subgrade in the road bed should be compacted to at least 93% of mod density. The design of the roads and the road layer works should take cognisance of the very low saturated CBR’s of the shallow oils in the Northern and Southwestern Areas.

Subsurface drainage will be required next to and probably below the roads in the Southwestern Area, and particularly in the seasonally wet parts. The comment in Section 9 on subsurface drainage next to roads in the other parts of the site should also been noted.

It should be noted that the trafficability over the cohesionless coarse soils will be difficult in winter because these soils will become saturated. Provision should therefore be made to pioneering temporary access roads with a gravel surfacing.

13. SPECIAL PRECAUTIONARY MEASURES

Special precautionary measures should include the following:

- Inspection of all foundation trenches and DCP testing in the trenches to ensure that the structural design is in accordance with the ground conditions actually encountered.
- Measures should be instituted to safeguard workers in service trenches from collapse of the sidewalls of the trenches.
- The ground should be shaped so that no ponding occurs against the houses.
- Subsurface services should be designed and constructed so that they are located sufficiently far from buildings that their backfilled trenches do not interfere with the foundations for houses and other structures.
- Excess soils from, for example, the road bed or service trenches should not be spoiled on the general site area otherwise the subgrade for the surface beds and possibly for footings will be adversely affected.
- The trial pit positions should be identified during the initial phases of development and special compaction or other special founding measures may be required to ensure the founding conditions for the future houses or roads are adequate.

14. CONCLUSIONS

a) Numerous soil types, with weathered bedrock at varying depths, are developed throughout the site. The multiplicity of soil types reflects a complex and variable colluvial and alluvial depositional environment, with pedogenic processes also occurring. Categorisation of the natural soils into seven groups with similar properties is possible and three generalised, natural soil profiles and their areas of occurrence can be identified. For descriptive purposes, the areas have been named the Northern Area, the Central Strip and the Southwestern Area.

b) The cohesionless coarse soils forming the fill in the embankment walls of the old evaporation ponds, which cover large parts of the central and eastern areas of the site, are superimposed on two of the natural profiles.

c) The presence of weakly cemented layers, ferricrete and the juxtaposition of coarse soils over clayey or silty transported soils or weathered bedrock suggests that seasonal perched groundwater is widespread in and immediately after the wet period of the year. In addition, most of the area in the southwestern corner of the site is seasonally wet, with an attendant very shallow seasonal perched water table.

d) Laboratory testing and field testing indicate that the soils are relatively dense or stiff and they are not significantly compressible except in the Southwestern Area where the estimated settlement is approximately 10mm when the soils are wet.

e) Active soils are predominantly developed in the Northern Area and the Central Strip and a maximum soil strain up to 15mm is possible.

f) The soils will not be subject to significant collapse consolidation or dispersion.

g) Seven terrain mapping units are recognised and the associated geotechnical classifications, in general, reflect that the presence of thin collapsible surficial soils layers, the possible presence of shallow groundwater, the low erodability of the soils, the generally shallow ground slopes, the presence or absence of compressible or active soils, and the seismic environment of the area.

h) Based on the guidelines in the NHBRC Home Building Manual, conventional strip footings or possibly raft foundations would be appropriate for single-storey houses in parts of the site, but lightly reinforced footings with ancillary structural measures will be required in the Northern Area and reinforcement of footings in probably 60% of the houses in the seasonally wet parts of the Southwestern Area will also be required. Good drainage around the houses is essential, and service/ plumbing precautions will be required, as relevant.

i) The 1 in 50 and 1 in 100 year floodlines of the Dal River lie within the extreme southwestern and western part of the Southwestern Area and the construction of the flood and inundation control measures appears necessary for the long-term serviceability of this area.

j) Careful attention to general surface drainage will be required. Sub surface drainage measures will be required in the Southwestern Area, if that area is to be developed, and they will also be required next to roads throughout the Southwestern Area. In addition, because the surficial cohesionless coarse soils contain small amounts of fines and are underlain by less permeable soils, subsurface drainage next to roads in other parts of the site should be considered to prevent saturation and ‘mattressing’ of the surficial soils.

k) The evaluation of the subsidy variation for low cost housing should consider the costs of dewatering some trenches in winter, deep services if they run sub parallel to contours, and the cost of non normal footings for the houses. Additional costs will include removal and reworking of the existing embankment walls, handling and spoiling of mixtures of excavated soils that contain clayey material, and over-excavation in service trenches to ensure their stability. The cost of possible flood control or inundation measures and sub surface drainage should also be reflected.

l) With exception of parts of the Southwestern Area where encroachment of floodlines occurs, and the presence of the embankment walls of the old evaporation ponds, no significant geotechnical constraints are apparent in the study area which is therefore generally considered generally suitable for human settlement and subsidy based housing.

R.A. BRADSHAW Pr.Sci. Nat.
for R.A. BRADSHAW & ASSOCIATES cc