APPENDIX 1

Geological Survey of Victoria

ENGINEERING GEOLOGICAL INVESTIGATION OF
PROPOSED CEMETERY SITE AT MELTON

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DEPARTMENT OF MINERALS AND ENERGY

ABSTRACT

An engineering geological investigation was carried out to assess the suitability of land at Melton for development as a regional cemetery. The works included extensive drilling, trial excavations and some soil testing.

Large areas of the site have good potential for development as a cemetery. Some portions have been designated as marginal due to a higher probability of encountering excavational difficulties. Two areas are regarded as unsuitable; the south-east section has insufficient depth of soil, and the north-west corner is not topographically or geologically suitable.

The major impediment for development of the site as a cemetery is the expansive nature of the soil. This will cause similar problems to those currently observed at the existing Melton cemetery. Some recommendations are made to minimize the severity and the extent of the problem.

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INTRODUCTION

Following a request by the Health Commission of Victoria, Public Health Division, (13-1-84) investigational works were carried out at the proposed cemetery site at Melton, Victoria.

The area examined is property under the control of the Urban Land Authority (ULA) and is located to the north-west of the City of Melton. The property was inspected on February 16, 1984 with Mr A Joseph of the Health Commission and a site with suitable terrain for a regional cemetery was selected.

Extensive drilling and trial excavations were carried out in order to determine the suitability of the site for burial purposes. Subsequent to the study of early results, the investigation was broadened to include a larger area of the ULA land to the north of the initial site.

SITE LOCATION AND TERRAIN

The site is situated approximately 40km WNW of Melbourne in the parish of Djerriwarrh. It is bounded by Bulmans Rd to the east, Harkness Rd to the west and lies 700 metres south of Porteous Rd. The area is included within the boundaries of the Melton development corridor.

The site covers approximately 265 Ha and is mostly flat land used for crop farming. The western branch of Arnold's Creek bisects the southern portion of the site and this, together with a small drainage line in the south-east corner, provides the only drainage.

In the north-west corner, depressions up to one metre deep and 3 to 10 metres across occur. This area has been designated as the "sink-hole plain" by the Soil Conservation Authority (SCA), and is largely uncleared. It is regarded both topographically and geologically unsuitable for development as a cemetery.

In general, the site is treeless apart from the sink-hole plain, parts of the central watercourse and the driveway to an abandoned house at the east. The southern part of the site has been prepared for crop farming, with the northern areas being used for sheep grazing. Presumably the recent history of the site would show similar agricultural use.

Site details are shown in figs 1 & 4.

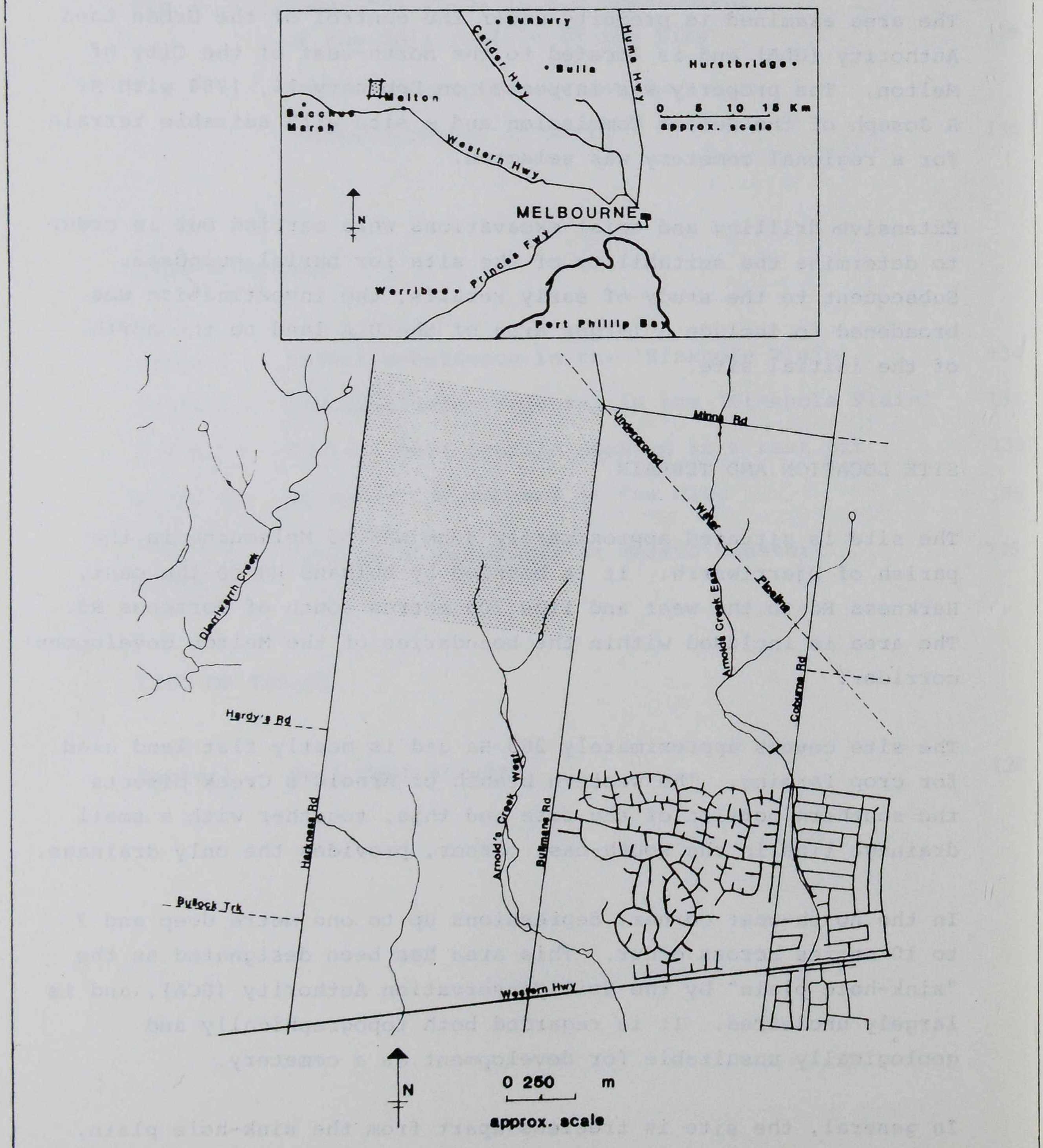


Fig. 1 LOCATION SKETCH PLAN

GEOLOGY

The surface geology of the site comprises the following two units:-

Quaternary Newer Basalt

Basalt formed by volcanic activity during the Quaternary Geological Period constitutes the bedrock of the site. This material has been weathered to a highly plastic, clayey soil which exhibits considerable shrink-swell properties. Differential weathering along joints in the rock mass has left boulders (commonly termed "floaters") scattered throughout the soil profile and these vary in size from 20cm to several metres. This form of weathering has caused an undulating rock-soil interface, thus making the depth of soil difficult to predict to within a metre.

Quaternary Gravel

A thin cover of gravels, sands and silts has been deposited over the basalt and the residual basalt soil. The probable source of this material is the Comadai Fault scarp, which forms the Gisborne Highlands approximately 3 kilometres north of the site. Material eroded from the scarp was probably washed over the plain in sheet floods, expecially before the development of Djerriwarrh Creek.

These deposits are visible as surface material in the north-west section of the site and are generally absent on the eastern side.

PEDOLOGY

Soil development over the past million years or so has produced some characteristic features in the soil profile, which reflect the physical and chemical processes involved.

The normal chemical decomposition of the basalt rock has produced a soil chiefly composed of montmorillinite clay. This clay is noted for its volumetric response to changes in moisture content and subsequently exhibits considerable variation in its seasonal behaviour. This is expressed on the surface as hard, dry, brittle soil with deep shrinkage cracks in summer and soft, wet, sticky soil in winter.

The shrink-swell nature of the soil cau: a micro-relief of broad, gently undulations or "gilgai" which are observed at the site by almost imperceptable depressions several metres across and only 200cm or so deep. In ploughed paddocks these are readily visible as darker patches and are often waterlogged in winter.

The physical process responsible for the formation of the gilgai has also allowed the outwash sands and gravels to mix with the residual soils. This is often shown in the soil profile as sand filled fissures, sand lenses and horizons of sandy and gravelly clay.

Rainwater percolating through the soil has leached some of the minerals originally present in the basalt and deposited these as calcareous nodules at lower depths. These are typically soft, crumbly, white nodules up to 15cm across generally occurring in a layer. They deliniate the depth of penetration of the winter rain and are usually found at depths between 0.5 and 1.5 metres.

Ironstone gravels, commonly referred to as "buckshot", also occur in the profile. These gravels are formed in the soil due to intermittent waterlogging and largely consist of black, subrounded sands and gravels dispersed throughout the soil profile.

On the sink-hole plain in the north-western quarter of the site, the soil surface is affected by apparent subsidence. Although the mechanism of the subsidence remains unknown, it has been observed to be still active. Since early 1983 several new "sink-holes" have been observed to subside in the treed area and in the road reserve. Several theories have been suggested to account for their origin, however none provide a complete explanation. The most likely interpretation is that they are an extension of the gilgai process. These features are shown in plates 1 & 2.

The soils covering the site show a generally uniform profile as follows:-

Surface soils: Red-brown or dark brown silty clays or clayey silts, low to moderate plasticity with a blocky or friable texture.

Subsoil : Yellow-brown, grey or mottled clays or sandy clays, highly plastic, stiff, fissured with occasional basalt floaters and calcareous nodules throughout. (plate 3)

INVESTIGATION PROGRAMME

Drilling

A drilling programme aimed at investigating the soil depth and type was carried out during May, June and July 1984.

Three types of drilling rigs were used, depending on their availability and the type of information required. The rigs are owned and operated by the Department of Minerals and Energy.

. A Gemco 210B rotary rig, equipped with modified hollow-flight augers was used to obtain continuous soil cores. This provided information on soil type and profile as well as an indication of depth to rock.

. A Gemco HS7 rotary rig, equipped with solid flight augers was used to obtain general soil depths and types.

. A Minuteman rotary rig, equipped with solid-flight augers was used to check the soil depth in areas where anomalous depths were obtained.

Fifty-eight bores were drilled in total, to an average depth of 3.1 metres. The location of these bores is shown in figure 4.

The first 30 bore locations were selected on a grid basis with the remaining ones being randomly chosen to provide coverage of selected areas. This approach reflects the change in the objectives of the investigation programme as outlined in the introduction.

Trial Excavations

A total of 32 pits were excavated using a Case 580C backhoe, with 60cm bucket. The backhoe was operated by the private contractor who usually excavates the grave-pits at the existing Melton cemetery.

The first fifteen test pits were located on a grid with the remainder randomly located to explore specific areas (figure 4). Each pit was examined carefully to assess ease of excavation and evaluate any potential problems associated with burial.

Soil Testing

Six samples were selected for testing as typical examples of the soil type found at the depth of burial. Two samples of topsoil were also selected to determine the variation in the properties of the surface material.

Index tests were carried out to determine the degree of soil plasticity which broadly indicates the potential extent for seasonal movement.

RESULTS AND DISCUSSION

Drilling

The soil core recovered by the Gemco 210 drilling rig is described in the borehole logs included as Appendix 1. The depth of soil indicated by the drilling is strictly taken as a "depth to auger refusal", since the auger penetration may stop on a cobble sized floater rather than the bedrock. Four anomalous depths were checked using the small "Minuteman" rig which showed that the anomalies were probably due to auger refusal occurring on a floater.

However, the depths generally concur with those found within the limits of the trial excavations, which was a maximum of 3 metres for this machine. The results indicate sufficient depth of soil for the burial of three or four coffins over a substantial area of the site.

Trial Excavations

The trial excavations showed that the backhoe was easily able to excavate to three metres in 14 locations and to the minimum required depth (1.4 metres) in 25 locations. This is shown graphically in figure 2, which indicates that 89% of the test pits reached the minimum depth requirement for the burial of one coffin.

Soils observed in the test pits at the depth of burial were clays, silty clays and sandy clays of high plasticity (Appendix 2). These are often jointed, sometimes fissured, with slickens ided fracture surfaces very common (Plate 4). The slickens ides are caused by shear failure and movement of the soil due to swelling

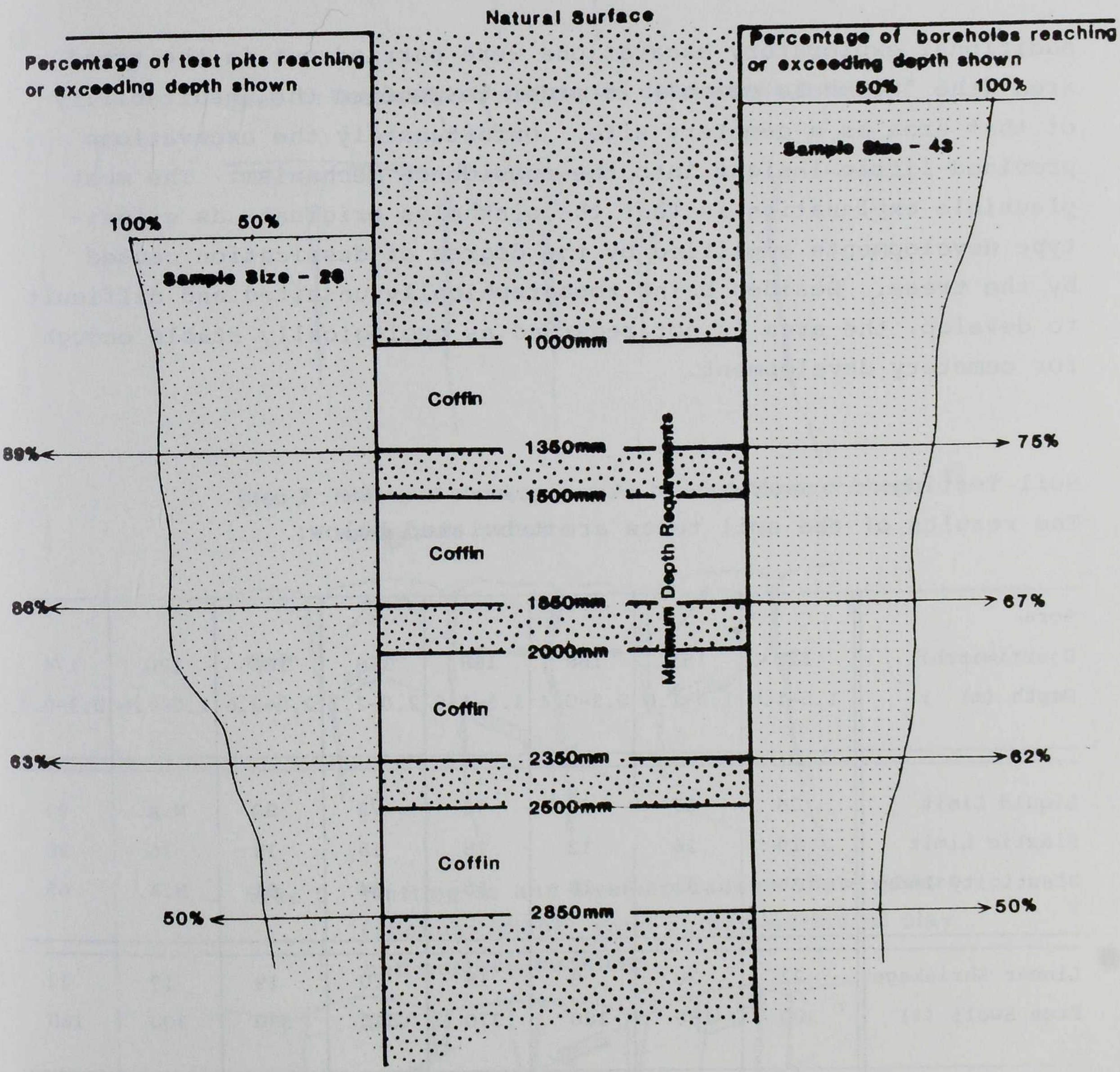


FIGURE 2. Minimum Requirements for Burial and percentage of test sites achieving the depths shown.

pressures developed in expansive clays. Some fissures are infilled with very fine quartz sand, which is presumably windblown sand deposited in surface dessication cracks formed in drier seasons. The subsequent swelling of the clays not only caused shear failure, but the assimilation of the quartz sand into the basaltic clay soil. This mechanism also causes the broad gilgai relief on the surface (figure 3).

Additional exploratory excavations were carried out in the treed area (the "sinkhole plain") in order to confirm the unsuitability of that area as a cemetery site. Unfortunately the excavations provided little insight into the subsidence mechanism. The most plausible explanation is that the sinkholes originate as gilgai-type developments amplified by the degree of dessication caused by the trees. Besides being topographically unsuited and difficult to develop, the area is not regarded as geologically stable enough for cemetery development.

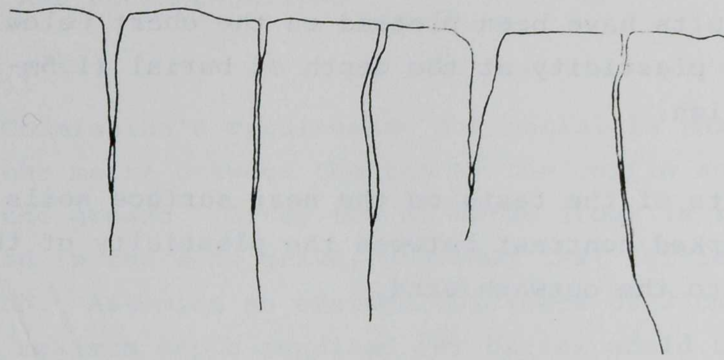
Soil Testing

The results of the soil tests are tabulated below:

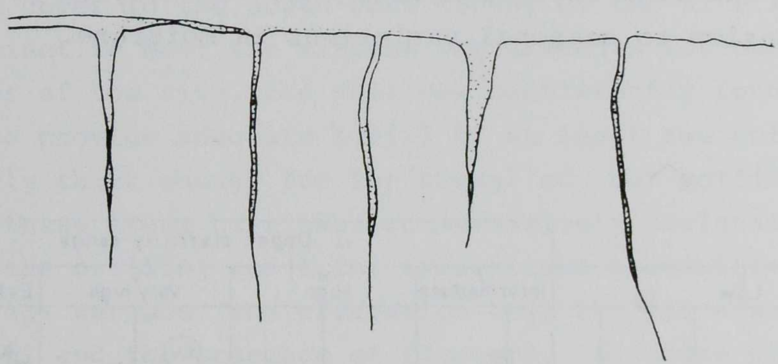
Bore Djerriwarrh: Depth (m) :	128 1.5-1.6	155 1.5-1.6	168 0.3-0.4	168 1.5-1.6	168 2.0-2.1	168 2.5-2.6	170 1.5-1.6	174 0.3-0.4
Liquid Limit	78	67	30	73	72	80	N.A.	93
Plastic Limit	19	16	12	18	18	19	16	28
Plasticity Index	59	51	18	55	54	61	N.A.	65
Linear Shrinkage	22	20	6	18	20	19	17	22
Free Swell (%)	300	180	180	370	340	330	300	160
Particle Density	2.60	2.55	2.51	2.55	2.55	2.57	2.73	2.45
Sand (%)	15	22	49	28	32	25	43	9
Silt (%)	27	29	26	18	17	17	25	22
Clay (%)	58	49	25	54	51	58	32	69

Table 1: Soil Test Results

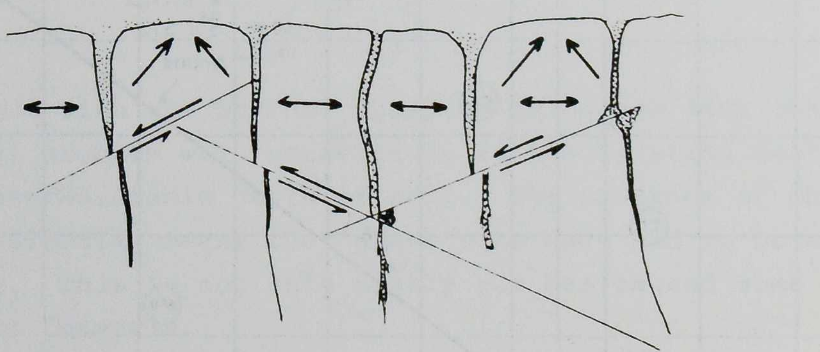
FIGURE 3. Steps in the development of the soil profile of the site.



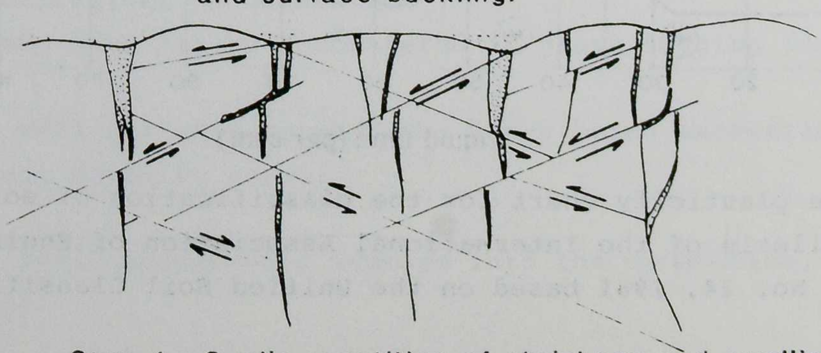
Step 1 : Dessication of soil causes deep shrinkage cracks.



Step 2 : Infilling of shrinkage cracks by wind-blown or sheet-wash sands and silts



Step 3 : Wetting up and swelling causes shear failure (slickens iding) , sand contamination of clay and surface buckling.



Step 4 : Cyclic repetition of shrinkage and swelling produces fissures , joints , sand contamination and surface undulation .

These results have been plotted on the chart below and show the degree of plasticity at the depth of burial (1.5m-2.6m) to be high to very high.

The results of the tests on the near surface soils (0.3m-0.4m) show a marked contrast between the plasticity of the residual clay compared to the outwash sand.

The high values for the liquid limit, plasticity index, linear shrinkage and free swell indicate that the soil is highly expansive and responsive to seasonal variations in moisture.

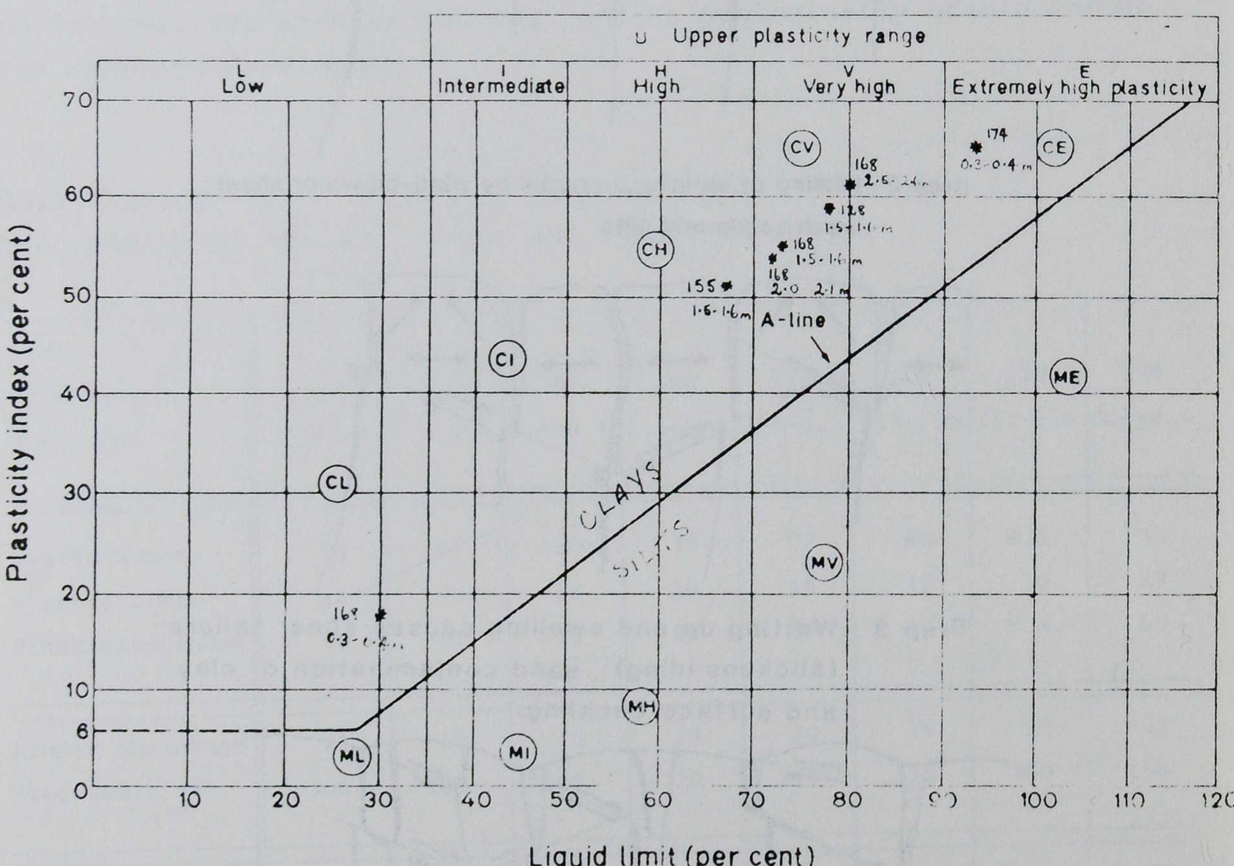


Fig 5 The plasticity chart for the classification of soils: (From: Bulletin of the International Association of Engineering Geology - No. 24, 1981 based on the Unified Soil Classification System).

CONCLUSIONS AND RECOMMENDATIONS

Depth of soil

The Health Commission's requirement for burial is that there be a minimum of one metre between the top of the coffin and the natural surface of the ground. Often two or three (four is rare) coffins may be buried in the same grave, provided that at least 15cm separate each. Assuming an average thickness of 35cm for each coffin, the maximum depth required for burial would be 2.85 metres.

The soil cover in the south-east corner of the site is generally insufficient to meet the minimum requirements for burial. Over the remainder of the site, the soil was consistently found to be thick enough to provide adequate burial of at least two coffins and frequently thick enough for the burial of four coffins. Nevertheles: some of these areas have been conservatively designated as marginal because the drilling and trial excavations encountered undulations in the rock surface (see excavation logs for pit nos. Djerriwarrh 179 & 182) and the presence of floaters. In these areas there is a higher probability of encountering problems which would require alternative excavation techniques. These areas are shown in figure 4.

Discussion with the backhoe operator disclosed that the most prevalent problem with excavations at the existing Melton cemetery is the unpredictable depth of soil. The presence of shallow rock has occasionally meant that grave pits have had to be excavated by blasting. This is not only costly but has caused some embarrassing delays at funerals.

Characteristics of Excavation

Problems that may be encountered in grave digging include:

a wall collapse between the grave being excavated and the adjacent existing grave;

b fetid groundwater seepage into the excavation, from adjacent graves;

c having to timber the sides of the grave due to lack of soil cohesion;

d excavating a neat grave pit;

e problems associated with a high water-table; and

f layers in the soil profile that are difficult to penetrate.

The trial excavations indicated little likelihood of serious problems being encountered when grave-digging on this site. The trial pits were generally very easy to excavate with the only exception being those where floaters larger than 60cm were found. During the drier months, when the soil is much harder, some minor difficulty may be experienced in creating a neat hole due to large soil clods being plucked out in the top metre or so.

None of the trial pits suffered from wall collapse, mainly due to the high cohesion of the clay soil. Although sand lenses and gravelly clays were encountered, they were in insufficient quantities to cause any instability.

Shallow groundwater was not found, and would not be expected to be encountered, since the regional groundwater bores show the depth to the water table to be approximately 40 metres. Local pooling of surface water occurs during times of heavy rainfall, especially in the gilgai depressions, since site drainage is fairly poor. Surface water may quickly percolate into the backfill and pool in the graves during times of heavy rains, since the permeability of the undisturbed soil is very low. This could lead to difficulties with fetid seepage along fissures into neighbouring excavations, especially during unusually wet years.

Soil Characteristics

A major problem facing the development of the site as a cemetery is the expansive nature of the soils. The perpetual seasonal cycle of shrink and swell sustains the mechanism which is thought to be responsible for the subsidence in the sinkhole plain. Similarily, this also seems the most likely explanation for the observed tilting of the monuments at the existing Melton cemetery (Plates 5 & 6). After a grave is backfilled with clay, the lower density of the backfill allows easier ingress of air and water, which amplifies the seasonal movement at depth. This combined with the selfmulching nature of the clay, provides a plausible explanation of the observed subsidence over the graves and the dramatic tilting of the tombstones. (Plates 5 & 6)

The following recommendations will lessen the severity of the potential problems:

* Efficient drainage should be installed to prevent the pooling of surface water. Lawn cemetery would be best located over the areas with inadequate drainage.

* Where large or high monuments are erected the sites should be levelled (by filling where necessary) and compacted. A suitably designed, wide concrete footing would help prevent the severe tilting.

* Where roads and pavements are constructed the clay sub-base should be lime stabilized to minimize distress and ultimate failure of the road surfaces. Good drainage is essential to prevent sub-grade failure since the clay soils have little strength when wet.

* All buildings should be constructed on rigid concrete slabs, with an impervious apron (such as a concrete path) at least one metre wide surrounding the structure.

* Trees will quickly dessicate the soil and should not be planted within 10 metres of any structure, including the monuments. Where this is unavoidable regular watering should be carried out, especially in dry seasons in order to minimize the damage caused by soil shrinkage.

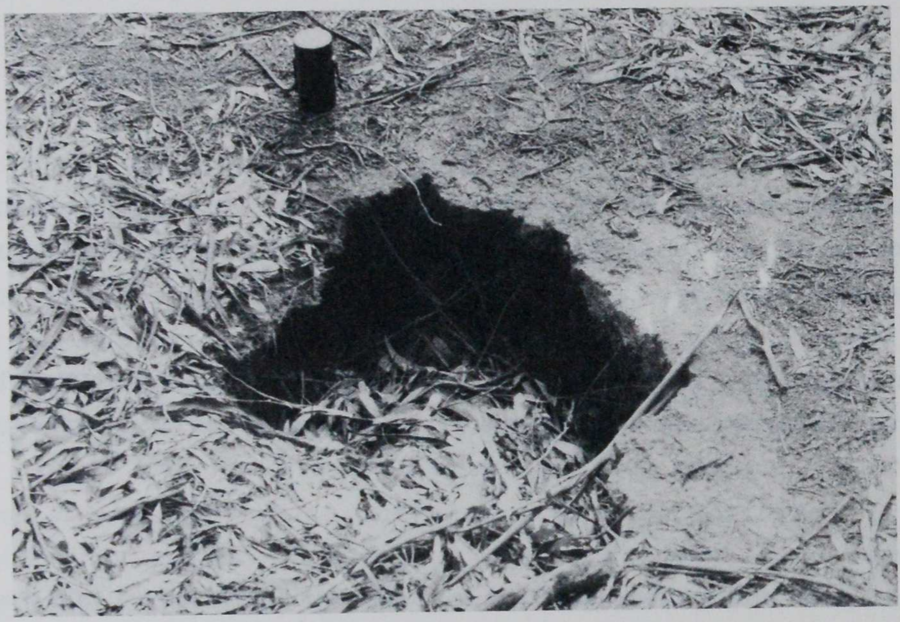


Plate 1 Recent Subsidence in the 'Sinkhole Plain'

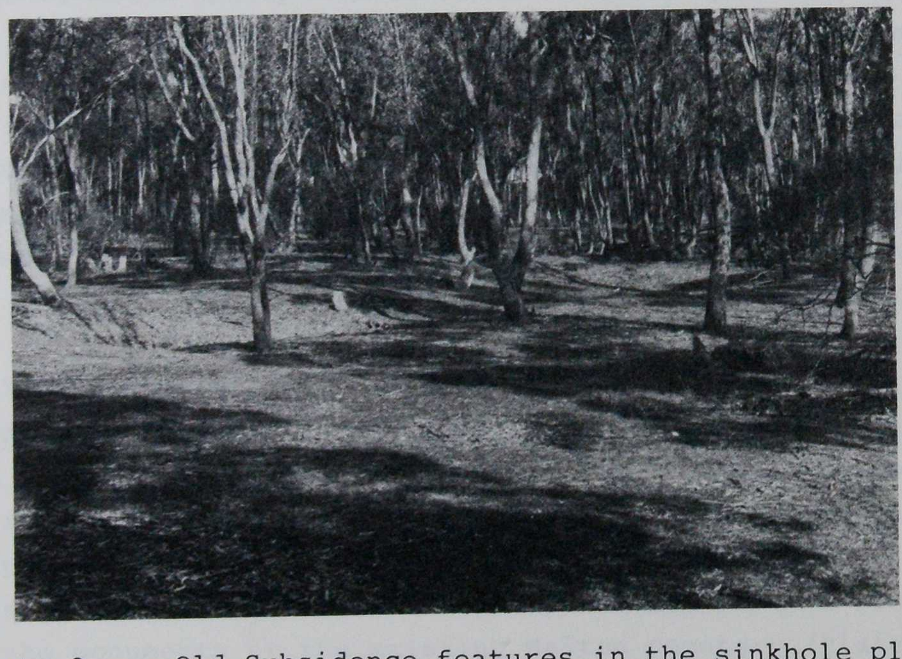


Plate 2 Old Subsidence features in the sinkhole plain

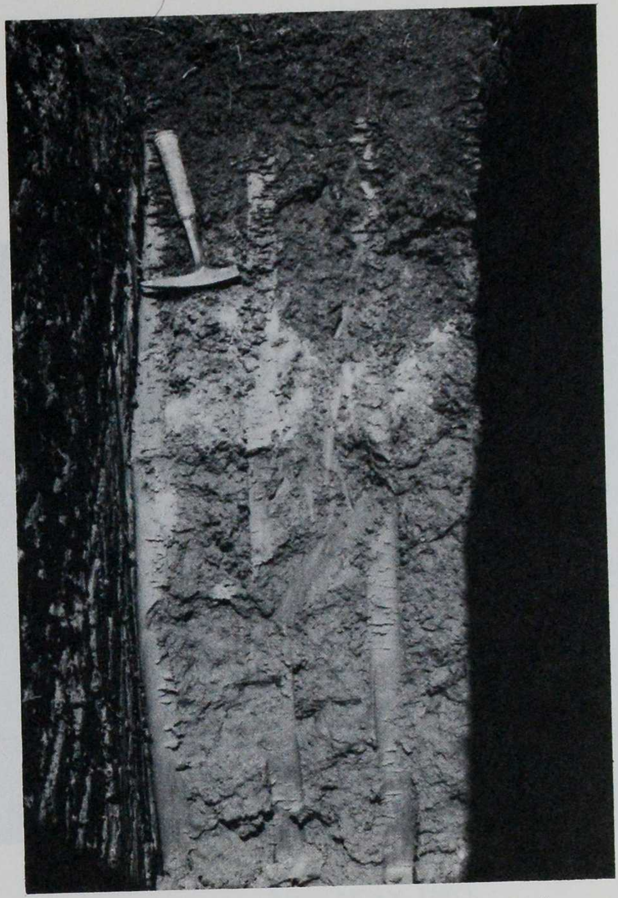


Plate 3 Typical soil profile exposed in a test pit

Plate 4 Slickenside surface in the clay

Plates 5 & 6   Tilting of Monuments at Melton Cemetery