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DAIRY FLAT, A.C.T.

REPORT ON SAND AND GRAVEL INVESTIGATIONS 1973-76

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SUMMARY

A geological and geophysical investigation has been carried out at Dairy Flat, A.C.T., with the aim of delineating reserves of sand and gravel as part of an overall planning study of the area for NCDC.

The BMR augered 85 boreholes to an average depth of 9 m and core samples were tested in the laboratory. Results showed three main deposits in the area. In the northeast a deep flood channel contains up to 8 m of well-graded sand. Sub-alluvial sand and gravel lie beneath up to 4 m of clay and topsoil through the central area. In the south the most promising recoverable reserves occur as terrace sand and gravel beneath a thin cover of topsoil, with aeolian sands in low dunes in some places.

Geophysical surveys carried out over a number of years involved a seismic and resistivity traverse in 1973 and a reconnaissance seismic survey covered the river flats in 1974. Finally, Wenner resistivity soundings were carried out in 1975 to assist in planning the augering program. Uncertainties of definition of weathered bedrock from overlying alluvium made seismic estimates of alluvium thickness difficult. In view of this and blindzone problems, the resistivity method is considered more effective for this type of environment than seismic refraction.

Estimates of economically recoverable reserves were based on the thicknesses of sand and gravel deposits as found by augering and geophysical methods, the thickness of overlying clay and topsoil, and the laboratory grading curves. On the basis of this information, preliminary estimates of reserves are about 5 million m^3; and the mean gradings of these reserves showed there is probably 0.5 million m^3 of gravel, 3.6 million m^3 of sand with 0.8 million m^3 of fines. About 0.7 million m^3 of topsoil may be won in selected areas.

INTRODUCTION

In 1974 the National Capital Development Commission (NCDC) requested the Bureau of Mineral Resources (BMR) to carry out a sub-surface investigation of the Dairy Flat area, ACT, with an emphasis on locating sand and gravel deposits. An augering program was devised, and the Drilling Section of BMR made available a Gemco auger rig which was in Canberra between field seasons.

Eighty-five boreholes were augered and sampled over a total depth of 758 m from October 1975 to June 1976. Average depth of the holes was 9 m.

The Engineering Geophysics Group of the BMR did a seismic and resistivity test traverse in 1973, seismic surveys in 1974, and further resistivity traversing in 1975. The results of these investigations have been written by G.R. Pettifer.

General geological mapping covered Dairy Flat and the surrounding higher areas. Airphoto interpretations proved most valuable in mapping the surface features of the alluvial flats.

The location of the area investigated is shown in Figure 1.

PREVIOUS INVESTIGATIONS

Investigations for sand and gravel along the Molonglo River have been going on throughout the development history of Canberra. Early studies by BMR covered general sources of sand in the Canberra area (Gardner, 1958), dune sands in the Molonglo River valley (Gardner, 1966) and investigations adjacent to Dairy Flat; to the east (Gardner, 1967) and to the west in the present East Basin (Gardner, 1965).

The first investigation in the Dairy Flat area was an augering program in 1969 by Coffey and Hollingsworth for Maunsell and Partners, consulting engineers in the East Lakes Development (a plan by NCDC to develop the area between Fyshwick and Lake Burley Griffin). A total of 20 boreholes were augered and their location and summary logs are shown in Plate 2.

LOCATION MAP

FIGURE 1

(Record No. 1977/54)

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GEOLOGICAL INVESTIGATIONS 1975-76

GENERAL GEOLOGY

The Dairy Flat area is an alluvial plain bounded on three sides by the Molonglo River and is traversed by numerous prior stream channels up to 3 m deep. Alluvium ranges in thickness from 7 to 8 m in the south and northeast to 25 m in the centre and north, and overlies Silurian mudstone, siltstone, and sandstone of the Canberra Group. The general geology is shown in Plate 1.

Prior stream channels

Prior stream channels (Plate 1) were delineated from aerial photographs (C. Simpson, pers. comm.) and have been classified into three types:

1. Most recent floodways with up to 3-m deep channels and some lagoons. One channel traverses the flood plain from east to west. Channels on the western side have been permanently flooded since 1964 by the waters of Lake Burley Griffin, where a south-trending channel washconstructed to divert them into the mouth of Jerrabomberra Creek.

2. Older mostly abandoned channels, infrequently flooded. Most channels are topographic depressions about 1 - 2 m deep. They are most common through the centre and southwest of the area.

3. Oldest recognisable channels, with generally no topographic expression. (seen only on aerial photographs).

Most of the channels are probably flood-scour channels rather than major prior courses of the Molonglo River. This is suggested by the narrowness of the channels compared to the present river size.

Alluvium

Dissection of terraces by flood-scour channels and transgressive sequences of terraces and channels have resulted in narrow lenses of sand and gravel with interbedded clay layers of irregular lateral and vertical extent.

The alluvium is thickest in the centre of Dairy Flat and adjacent to the Molonglo River west of Dairy Flat Road but it is not known if this is of uniform depth (see section Plate 3). The northeast corner of the area near Dairy Flat Bridge, inside the horseshoe bend in the river, has a thinner cover of alluvium.

The alluvium consists of a fairly uniform cover of about 2 m of dark brown silty topsoil that ranges in thickness to 5 m, overlying variable thicknesses of silt, sand, and gravel (Plate 6).

The southern flank of the plain is underlain by an extensive terrace in which sand and gravel thickens from 2 m to more than 8 m towards the north. This may become thicker under the flood channel near auger hole 23 on Traverse AA[1] (Plate 2), as indicated by the lower resistivity values (Plate 3). Overlying the terrace is a system of low relief sand dunes up to 2 m high and trending northwest (Plate 7). Augering indicated this fine aeolian sand was about 2 m thick (holes 1-4, 34-39, 10, 11, 61-63).

Through the middle section of the plain, dissection of the present and past land surfaces by flood channels has modified the land surface and deposited additional sediments. Generally 2 to 6 m of clay and topsoil overlies irregular lenses of sand, gravel, and glay. Overlying this is a layer of sandy silt less than 1 m thick which is deposited by floodwaters whenever they pass over the plain, and this material constitutes the floodplain terrace of today.

Along the bank of the Molonglo River in the north of the area the alluvium consists of 5 m of dark brown organic-rich silt and clay, of high plasticity, overlying clayey sand with some less common clean sand and lenses. This dark silt and clay wedges out about 200 m south of the river (holes 16 and 26, Plate 2).

High-level gravels of Tertiary or Permian age (Öpik, 1958) occur on the elevated area to the south of Dairy Flat and at the Causeway. They are known as the Fyshwick Gravels and consist of consolidated coarse quartz-rich sand and gravel with some large boulders and are found as residual patches in the Fyshwick area and in the Canberra City area.

Bedrock

Underlying the alluvium are rocks of Silurian age. Mudstone, siltstone, and sandstone of the Canberra Group underlie most of Dairy Flat, but similar lithologies of the Fairbain Group may lie beneath the southeast section. Ainslie volcanics, which crop out on Mount Pleasant to the north, may extend under the northwest corner of the alluvial plain.

Excavation for the Googong Pipeline across Dairy Flat exposed mudstone of the Canberra Group at 1-2 m just west of the sewerage works, but the rock does not crop out (Plate 1).

Groundwater

The water-table is relatively close to the surface as the floodplain is only a few metres higher than the river level. Water levels in the boreholes (Plate 2) were only measured at the time of augering so the extent of fluctuations in the water-table are not known. However the water-table was lower, at depths of 3 - 5 m, in 1974. Generally the water-table is at 556-558 m RL;;this is at 2-4 m depth on the eastern side and at 1-2 m depth on the western side because the eastern side is topographically higher by 1-2 m. Groundwater recharge is from both sides; the permanently inundated channels are fed from the west by Lake Burley Griffin. The eastern side is supplied by seepage from the Molonglo River.

Conductivity* of the groundwater was measured at 13 sites (see Plate 2). The results can be classified into three groups: the northwestern area adjacent to the Molonglo River gave results of 1000-1400 micro/mho cm-1, indicating some pollution from the river or generally organic-rich soil; the main central area with fairly low conductivity of 345-490 micro/mho cm^{-1}; and one result in a channel just downstream from the sewage treatment plant (760 micro/mho cm^{-1}). No conductivity readings were obtained from the eastern side. It is possible that the groundwater contains contaminants derived from the Fyshwick sewage treatment works as well as dissolved pollutants from the Molonglo River.

DRILLING RESULTS

Drilling was carried out with a Gemcodrill, model 210B rotary drilling rig. A hollow flight auger with an outer diameter of 5½" in 4' lengths was used. Sampling was carried out with a 2" internal diameter split inner tube which penetrated the soil as the auger bit advanced. The auger flights doubled as casing for the hole while the sample tube was retrieved.

Holes were augered to 30 feet (9.2 m) or less if auger refusal occurred. Some holes went to a greater depth to determine the thickness of the alluvium, but generally auger refusal occurred in gravel beds.

Location of auger-holes and summary logs are shown in Plate 12 and logs of ten selected holes are given in Appendix 1. The material was classified according to the Unified Soil Classification system (Plate 2).

Problems in sampling were encountered, especially in the sand layers. Clays and silts were easy to sample as their cohesion held them in the sample tube. The sands however tended to drop out of the tube as it reached the surface and only small amounts were retrieved; however core-loss was considered an indication of well-graded sand.

LABORATORY TESTING RESULTS

Samples of drill-core were tested in the BMR Engineering Geology soils laboratory. Results of these tests are given in Appendix 2. A total of 62 samples were graded and the plasticity index (PI) was measured in 7 samples. As very low PI values were obtained this test was discontinued. Colorimeter tests proved negative in all cases.

Samples chosen for testing were those which visibly contained a considerable amount of sand and/or gravel. All samples were dry-sieved following the Australian Standard A.77-1957. Samples were taken from the complete lifts at the drillsite and subsequently split to a size suitable for testing.

Summary grading surveys for particular areas and depths are given in Appendix 3. These curves can be compared with specified grading curves for fine aggregate, ½ inch (12.5 mm) aggregate, 1 inch (25 mm) aggregate and pavement material (p. 6. Appendix 3).

COMPOSITION OF THE SAND AND GRAVEL DEPOSITS

The potentially workable sand and gravel in the Dairy Flat area is generally confined to three broad areas: point bar and channel deposits in the northeast; sub-alluvial sand and gravels in the centre; dune sands and terrace sand and gravels in the south. Plates 5 and 6 show the depth to the top of and the thicknesses of sand and gravel deposits respectively. In defining the particle sizes the following terms are used: fines are less than 75 microns in size; sand is 75 microns - 2mm; and gravel is coarser than 2mm (see Appendix 4).

The northeast

This area (Block H, Plate 6) is dominated by a deep subsurface channel running east-west containing coarse to medium-grained sand up to 8 m thick (Plate 6). This deposit is more extensive on the eastern edge adjacent to the Molonglo River. The sand deposit consists of an average 9% fines, 78% sand, and 13% gravel.

Sub-alluvium sand and gravels

Deposits in the central part of the area (Blocks B,C, F, I, J, Plate 7) are irregularly distributed owing to the change in location of flood channels with time both in the vertical and horizontal planes. The sand is generally overlain by between 2 and 4 m of topsoil and dark-brown clay, and is 5-8 m thick immediately north of the sewerage treatment works. On the western side (Blocks B, C) gravels are more dominant but occur in lenses at variable depths. In these areas the gravel consititutes up to 30% of the material (average 12%), whereas the sand is up to 90% on the eastern side (average 81%). Fines rarely exceed 10% (average 7%).

Dunes and terraces

This rather complex area extends across the whole of the southern flank of the Dairy Flat alluvial plain (Blocks D, G, K, L, Plate 7). Two main areas stand out in Plate 6 as having considerable quantities of sand and gravel. The area to the west contains very low relief (less than 2 m) dune sands, overlying a fluviatile sand and gravel terrace (See plate 1 and Block D, Plate 7). The dune sands are about 2 m thick, orange in colour, and consist of 80% medium to fine sand and 20% fines (see holes 4, 36, 39 in Appendix 3). The underlying terrace extends to the east, where the second main deposit lies and is a broad area, particularly around the sewerage treatment plant, but it narrows out to the east and west (Plate 5). A slight 'step-down' is notable on the northern edge of the terrace particularly on the north-trending tracks on the eastern side.

Distribution of sand and gravel within the terrace is fairly irregular, indicating that it is a number of successive terraces which have been eroded by flood channels, subsequently depositing more material. Sand layers range to more than 9 m thickness but are generally 2 - 4 m, while gravel layers are generally less than 2 m thick and are found below 4 m depth. The sections in Plates 3 and 4 show the nature of the terrace and how it drops away within the subsurface. The sands are coarser below a depth of about 5 m where gravels are more common. The shallow deposits average 12% fines, 74% sand, and 14% gravel, whereas the deeper deposits consist of only 6% fines, 63% sand, and 30% gravel.

NOTE ON RESOURCE AREAS

In view of the limited coverage by auger holes and geophysics and the complex nature of the deposits as channels, terraces, and dunes estimates of reserves are only preliminary and may have a significant margin of error. The figures quoted are a general indication only of reserves.

Sand and gravel

Plate 7 is an analysis of the resources of the Dairy Flat area as a whole, whether sand was found or not. Twelve subdivisions, or resource blocks, have been made with boundaries based on topography, geology, and man-made features while others were arbitrarily designated.

The results of the assessment of resources are summarised in Table 1. The total estimated economically recoverable reserves may be up to 5 million m^3 and include gravel, sand, and fines within each deposit. Using the mean grading of the reserves, the main fractions are:

gravel	500 000 m^3
sand	3 600 000 m^3
fines	800 000 m^3.

Topsoil

Material suitable for topsoil is found extensively in the area. Generally the material is black silt, and some clayey zones, with much organic matter. The friable loamy texture makes it suitable as garden topsoil. There are four main areas where reserves are considerable (see Plate 7).

1. The southeastern resource blocks J and F. Auger-holes 71 to 77, 65 to 68, and 70 intersected black organic loam to a depth of 2 m. The deposit probably follows the trend of the flood channels between these sample points, and totals about 500 000 m^3.

2. The northeast, adjacent to Dairy Flat Bridge; blocks H and I. Much of this area has already been stripped for topsoil but almost 1 m remains. The northernmost section was not stripped and 2 m of topsoil was found in hole 86. An estimate of the reserves is 80 000 m^3.

3. The central area, in resource block C. This is a small area and is possibly an extension of the thicker deposits to the southeast. Reserves are about 50 000 m^3.

4. Resource block A contains topsoil throughout its top 0.5 m and reserves are about 75 000 m^3.

The total recoverable reserves of topsoil from the Dairy Flat area is about 700 000 m^3. If the winning of topsoil can be coupled with winning of sand then the operation could be efficient.

TABLE 1. The sand and gravel resources of Dairy Flat.

RESOURCE BLOCK	AREA m^2	MEAN THICKNESS OVERBURDEN m	MEAN THICKNESS SAND & GRAVEL	TOTAL VOLUME OF SAND AND GRAVEL m^3	MEAN GRADING % FINES	MEAN GRADING % SAND	MEAN GRADING % GRAVEL	UNCONFORMITY	RANK	ESTIMATED ECONOMICALLY RECOVERABLE RESERVES m^3
A	150 000	5	3.5	525 000	10	50	40	uniform	D	-
B	287 500	4	3.4	975 800	10	70	20	Fair	C	240 000
C	345 000	4	3.2	1 104 000	10	80	10	Irregular	B	500 000
D	217 500	1.5	4.8	1 044 000	10	65	25	Mod uniform	A	1 000 000
E	222 500	5	1.1	250 000	15	70	15	Fair	D	-
F	197 500	4	5.9	1 120 000	10	80	10	Fair	A B	800 000
G	82 500	1	4.3	360 000	?	?	?	Mod uniform	A	350 000
H	115 000	3	2.1	380 000	10	75	15	Fair	C	90 000
I	332 500	4-8	2.5	832 000	20	70	10	Irregular	B	400 000
J	352 500	6	3.1	1 093 000	25	70	5	Irregular	B	500 000
K	207 500	1	5.2	1 079 000	25	70	5	Fair	A	1 000 000
L	112 500	1	1.9	200 000	?	?	?	Irregular	B	100 000
TOTAL	2 622 500			8 962 000						4 980 000

Notes on Table 1.

1. The areas of the resource blocks were calculated from the 1:10 000 map to the nearest 500 m^2 and range in size from 0.1 to 0.35 km^2.

2. The mean thickness of the overburden is taken from the auger logs and equals the depth at which the first sand or gravel layer more than 1 m thick is encountered.

3. The mean thickness of the sand and gravel deposits is also based on the auger logs. The total thickness of individual layers of sand and gravel is measured. Some layers are separated by clay or silt bands, others are continuous.

4. The total volume of sand and gravel was calculated from the mean thickness of the deposits within the given area of the resource block.

5. The mean grading is obtained from the laboratory grading results. Fines are that proportion of the material passing BS Sieve No. 200, sand is between BS Sieves No. 200 and No. 7 and gravel is coarser than BS Sieve No. 7.

6. The uniformity is interpreted from all aspects of the block and is labelled according to the size of a sand and gravel deposit and the extent of dissection by flood channels.

7. Rank indicates the degree to which the sand and gravel becomes economically recoverable. The classification is:-

   A. Most material is recoverable as the sand and gravel is fairly uniform and the top of the deposit is within 1.5 m of the surface.

   B. About half the material is recoverable owing to a significant area being irregular in composition and/or groundwater and lake influence making recovery difficult.

   C. About one-quarter of the material is recoverable, but most of these deposits underlie more than 3 m of silt.

   D. Sand and gravel are not likely to be economically recovered as the deposit is too deep and is overlain by more than 4 m of highly plastic clay.

GEOPHYSICAL INVESTIGATIONS

INTRODUCTION

Field parties from the BMR Engineering Geophysics group carried out field work as availability of staff and equipment for the investigation permitted. Several investigations were carried out in the period 1973-75. Plate 8 shows the location of geophysical traverses. Appendix 4 summarizes personnel involved in the field work and interpretation.

Initially a seismic and resistivity test traverse was carried out in December 1973 on the access road to the Canberra Sand and Gravel Company's existing workings. Following this work, a reconnaissance seismic survey covered the river flats in May 1974. Finally, Wenner traversing and a traverse of closely spaced resistivity soundings was carried out across the flats in October-November 1975 to assist the augering program. A test was also made of a novel resistivity technique using the drill stem of an auger as a large linear vertical electrode. The results of this test are not included in this report, but discussed in Pettifer (in prep.).

SEISMIC SURVEYS

Seismic methods, equipment and interpretation methods

The seismic refraction method used BMR's standard 24-channel refraction seismograph (Dresser SIE) and 8 Hz geophones (GSC-20D).

In 1973 a 414-m length of traverse of 6 spreads (3-m geophone spacings) was shot. Five shots were fired into each spread: one in the centre, two at 1 m off each end, and two at 34.5 m off each end of the spread.

In 1974 nine seismic traverses (R1 to R9) totalling 29 spreads (4-m geophone spacing) and 2668 m of traverse were shot. A similar pattern of shooting was adopted, except long shots were 46 m off each end.

The interpretation was carried out using the standard reciprocal time method (Hawkins, 1961). The half-difference method was applied to the two long shot records to obtain the deepest refractor velocity (Vale, 1960). Generally the deepest refractor detected was fresh bedrock; however, in places only weathered bedrock was detected.

Errors in interpretation arise from two main sources. Firstly, owing to the presence of a thick soil layer and low water-tables (3 to 4 m) in 1974, the refractions from the subsoil layer at the top of the water-table are often masked. This is the classic blind-zone (Merrick, Odins, & Greenhalgh, 1976) problem and leads to misinterpretation of soil thicknesses and depths to subwater-table alluvium and weathered bedrock.

Secondly, weathered bedrock in places may be of similar properties to the overlying alluvium and the seismic method will give erroneous results. Weathered bedrock may also form a blind-zone, being masked by the overlying alluvium.

Thirdly, errors arise in measurement of the small differences in velocity in alluvium. These differences reflect grainsize and clay proportion variations. Unambiguous interpretation of these differences is not possible because of the inherent scatter in the field data.

Interpretation of the Seismic results

Plate 9 shows the initial seismic test traverse interpretation and Plate 10 shows the interpretation of traverses R1 to R9.

Table 2 shows an interpreted velocity-lithology relationship for the Dairy Flat alluvium and bedrock compiled from correlations between seismic and auger drilling. The correlations are subject to errors in seismic interpretation as outlined above.

The seismic interpretation of the 1973 results illustrates the difficulties in interpreting small velocity differences within the alluvium. Discrepancies in depths between adjacent spreads and the presence of masked layers are the most common problems.

TABLE 2 : Seismic Velocities and Resistivities of Alluvium and Bedrock - Dairy Flat area

Lithology	Seismic Velocity (m/s)	Resistivity (ohm-m)
Soil, Silt		
- Dry to semi-saturated	250 - 1000	50 - 300 +
- Saturated	1100 - 1500	25 - 65
Sand		
- Dry to semi-saturated	100 - 400	150 - 320
- Saturated	1600 - 2000	50 - 180
Gravels (saturated)	1600 - 2200?	100 - 180
Clay-sand (saturated)	1500 - 1700?	50 - 80
Clay (saturated)	1100 - 1500	10 - 40
Mudstones		
- Weathered	2000?- 2500	30 - 100 + ?
- Slightly weathered to fresh	2600 - 3400	70 - 200
- Calcareous Mudstones	3800 - 4800	?
Ainslie Volcanics	3500 - 4800?	?
Groundwaters	-	13 - 29
Molonglo River Waters	-	71 - 100

The soil thickness and depth to water table are overestimated due to masking of velocities at the top of the water-table. Depth to water-table from seismic is 5 to 8 m. This disagrees with known water-table depths of 1 to 4 m. It is likely that saturated silts and clays (1100-1500 m/s) at the top of the water-table are masked. Consideration of blindzone errors in this case suggests that water-table depths from seismic should be 60 to 70 percent of those calculated ignoring the blindzone, giving values of 3 to 5 m which are closer to observed values. The error in water-table depth determination with the blindzone correction is less than 25%, which is acceptable.

Velocities increase from 1500 m/s to 1600-1800 m/s over the two anomalous zones defined by resistivity (chainages 220-280 m and 340-390 m) indicating that the seismic velocities are consistent with the resistivities; however the resistivity method is more definitive.

The weathered bedrock is often masked by the thick alluvium. The interpretation shows an attempt to define the limiting thickness of the blindzone in an alternative interpretation (boundaries shown dotted) by assuming velocities for the blindzone layer (Merrick, Odins, & Greenhalgh, 1976). The problem is not uniquely soluble because of variability of velocities and dip effects. The seismic does show however an increase in weathering thickness in the centre of this traverse. The Wenner tripotential sounding interpretation suggests weathering thickness may be as much as 110 m at chainage 185 m.

The 1974 seismic data is presented (Plate 10) in three sections across the river flats (R, R7, and R3; R2, R6 and R5; R9, R8 and R4). Similar problems were encountered in interpreting this data.

The subsoil layer is commonly masked particularly where soil thickness increases. This effect is illustrated in R8 where the 1500 m/s layer appears as a first arrival only where the soil is thinner. Weathered bedrock is commonly masked (R3) or may be indistinguishable in velocity from the overlying alluvium.

The seismic results show the increase in depth of alluvium in the centre of the flats, to greater than 25 m in places. Sediment thicknesses, from seismic, may be less than 7 m on the edge of the flats. Variations in bedrock or weathered bedrock velocity are evident on the northern and southern margins of the river flats (R3, R4, R5 and R1; R2, R9 respectively). Bedrock (3000 m/s) is detected only on R7 in the centre of the flats and is probably greater than 39 m deep on R6 and 32 m on R8.

Because of the uncertainties of definition of weathered bedrock from overlying alluvium, the seismic estimates of alluvium thickness should be accepted with reservation. In view of this and the blindzone problems the resistivity method is considered more effective for this type of environment than seismic refraction,

RESISTIVITY SURVEYS

Resistivity field procedure, equipment and interpretation methods

The resistivity work was carried out using a Geotronics FT-10 (S/N 1011) current transmitter. Received voltages were measured with a Data Precision Voltmeter Model 245 or in the case of very low voltages were first amplified by a Fluke high-impedance voltmeter/nulldetector Model 845AB and recorded on a Hewlett Packard HP680 recorder. Wenner traversing at 10-m spacing was carried out using low-power, direct-resistance-reading Megger instruments.

In the resistivity method, electric current is applied to the ground through two current electrodes and the potential differences set up by the current flow in the ground are measured between two additional points on the ground; the potential electrodes. In resistivity traversing the assembly of electrodes is moved along a traverse to measure lateral changes of resistivity. In resistivity sounding the assemblage of electrodes is successively expanded about a central position. This increases the depth of penetration of the current and allows investigation of changes in resistivity with depth. The dipole-dipole method is a combination of both these methods and enables a "pseudo-section" of variations of resistivity along a traverse.

In 1973, the dipole-dipole electrode configuration was used for correlation with the seismic and drilling. The dipole-dipole method has been used successfully to locate shallow, buried sand channels in the Goulburn Valley area (Polak & Ramsay, 1974).

In the dipole dipole configuration a collinear array of four electrodes is used. The current transmitting dipole of (length "a") is placed at an integral multiple of "a", say "na", distant from the receiving dipole (length "a"). By varying n (from 1 to 6) and moving the receiving position a distance "a" after each set of readings a combination resistivity-profiling sounding technique is established. The apparent resistivities are calculated and plotted at the intersection point of two straight lines at 45° from the dipole centres as shown in Plate 9. In this manner a "pseudo-section' showing variations of resistivity vertically and laterally is obtained. The vertical scale of the section depends on the contrast in resistivities. For the Dairy Flat work a = 10 m was used.

Following the resistivity work in 1973, Wenner traversing was carried out, in 1975, on 3 traverses in the river flats (Plate 8). In this method, equally spaced (10-m spacing) electrodes were used to obtain apparent resistivity values at 10-m intervals along the traverses. This provided a quick reconnaissance method of defining favourable areas of shallow sand and gravel accumulations. These areas are generally indicated by higher resistivity values. The results are plotted as profiles on Plate 8.

The resistivity work was completed in 1975 by a traverse of 36 electrical soundings across Dairy Flat. The soundings were spaced at 30 m, and in places at 10 m intervals. The half-Schlumberger electrode configuration was used for the sounding work. A remote stationary current electrode and mobile current electrode is used. The mobile electrode is progressively expanded from the centre of the spread (out to 50 m maximum in this survey) and the central potential dipole length is increased whenever the potentials become very small.

Resistivity sounding was also carried out, in 1975, on the 1973 test traverse using the Wenner tripotential method. Pettifer & Taylor (1976) describe field procedure, data reduction, and interpretation of this sounding method.

Preliminary interpretation of the sounding curves was carried out using standard 3-layer curves and the auxiliary point method (Orellana & Mooney, 1966). The interpretation was then adjusted to fit the field curves by matching the theoretical curve of the interpretation and the field curves. The theoretical curves were computed and plotted on the Wang 600-14 desk calculator and 612 Plotter using a program based on the Ghosh filter method (Ghosh, 1971) and written by F.J. Taylor.

The preliminary interpretation thus obtained was based on solutions which were consistent with field data. Due to the principle of equivalence (Bhattacharya & Patra, 1968, p. 32) other solutions are possible and with follow-up drilling, it was found that discrepancies in depth between the initial interpretation and drilling results could be resolved by invoking the equivalence law.

Resistivity interpretation

Plate 9 shows the dipole-dipole results for the initial tests in 1973. Plate 3 shows the results of the detailed traverse of resistivity sounding with auger drilling results and the Wenner traversing profiles are indicated on Plate 8.

Table 2 gives an interpreted resistivity-lithology relationship for the alluvium and bedrock in the Dairy Flat area. The values are subject to errors in interpretation as previously outlined and to variations in groundwater resistivity.

The "pseudo-section" of the dipole-dipole results, considered in relation to the seismic results of the same traverse (Plate 9) shows higher resistivity values at chainages 20 - 80 m, 220-280 m, and 340-390 m at dipole spacings of n = 1 to 6. These correspond to known older prior stream channels (see Plate 1) which cross the traverse. The Wenner tripotential sounding interpretation at chainage 185 shows 12.5 m to interpreted weathered bedrock and the dipole-dipole values at this chainage suggest that the dipole-dipole method with n = 6 did not reach true bedrock resistivity. This can be used as a guide to depth penetration of the method in this area.

The persistence of higher values of resistivity at larger dipole spacings (n = 3 to 5) at chainages 390 - 430 m suggests an increase in sand content with depth and towards the river away from the surface channel indicated at 340 - 390 m. This is expected, as this area is close to the existing sand leases.

The direction of this traverse is very close to the trend of the sand channels and this limits the value of the results. The test added little to the knowledge of the area and finer subdivision of the alluvium grainsizes and clay contents may have been possible with the use of the IP method. Further work should use the IP method in conjunction with resistivity.

The Wenner traversing profiles (Plate 8) show some highs which reflect shallower sand and gravel deposits (Plate 5); however in view of the complexity of the deposits and the generally high clay contents of the alluvium in the Dairy Flat area, the Wenner traversing data is not considered sufficiently definitive in this environment. Wenner traversing is more suitable to areas of thin (less than 2 m) overburden and clean sands, such as the Murray floodplains, Albury-Wodonga (Pettifer, Polak, & Taylor, 1975). Closely spaced soundings were then tried instead of Wenner traversing as a routine geophysical investigation technique.

The preliminary interpretation of resistivity soundings and auger drilling across the centre of the flats shows the value of detailed resistivity soundings (Plate 3).

From chainage 0 to 320 m (approx.) the interpretation does not define the sand lenses very well. This is probably due to the lower groundwater resistivities (higher conductivities - 760 mho cm^{-1}) in this area which lowers the sand resistivities to values indistinguishable from silts and sandy clays. Groundwater resistivities of as low as 13 ohm-m in this area are most probably attributable to contamination by leachates from the Fyshwick Sewerage Treatment Plant. The sand channel which passes beneath the sewerage plant has branches extending as far as auger hole 17 (chainage 650 m) and this might be thought to be the potential limit of influence of these contaminants. The resistivity interpretation suggests that the limit of influence at depth is only as far as 350 m chainage.

This interpretation is complicated firstly by the presence of a higher resistivity zone (100 ohm-m) at chainages 170 - 225 m (approx) coinciding to an area of less saline groundwaters (22 - 29 ohm-m; Plate 2) and secondly by the lack of water sample conductivities at boreholes 20, 21 and 23 (chainages 225-320 m approx.). The resistivity method shows promise then, as a means of monitoring the waste water from the treatment plant in the Dairy Flat area. Again the IP method should be considered.

From chainages 320 - 1000 m the resistivity method outlines very well the thickness of variations of the soil and silty clay overburden. Discrepancies in interpreted depths and auger drilling can be explained by invoking the law of equivalence of solutions in resistivity prospecting. The 100-180 ohm-m layer corresponds closely to the sand and gravel layer defined by auger drilling across the area. The base of this layer is not well defined, due possibly to lack of contrast with weathered bedrock or the fact that maximum electrode spacing of $AB/_2$ (50 m) in this area is inadequate to provide reliable deeper information. There is, however, evidence of a change in bedrock resistivity from resistive bedrock at approximately chainage 350 m to conductive bedrock further into the alluvial flats. This most probably represents a thickening of the lower resistivity, weathered mudstone layer beneath the alluvial flats proper.

CONCLUSIONS

Extraction

1. On the basis of this investigation a preliminary estimate of economically recoverable reserves is almost 5 million m^3 of which 0.8 million m^3 are fines, 3.6 million m^3 is sand, and 0.5 million m^3 is gravel.

2. Both the drilling and laboratory results proved useful in analysis of the deposits. Three major areas of sand were delineated:

   (a) The northeastern area (Block H, Plate 7) where a deep channel traverses the bend in the river and contains well-graded sands (90 000 m^3)

   (b) The sub-alluvial sands and gravels extend across the width of the plain (Blocks B C F I and J, Plate 7) and are found beneath 2-4 m of clay and topsoil. Some deposits are 5-8 m thick but are not easily accessible at depth (2 440 000 m^3)

   (c) Dunes and terraces extend across the southern flank of the plain (Blocks D,G, K and L Plate 7) but deposits are irregular. Sand layers are greater than 9 m thick in places and are near the surface. The deposits are gravelly sands at depth and well-graded sands nearer the surface (2 450 000 m^3).

3. Topsoil is extensive across the plain and consists of black silt, and some clayey zones with much organic matter. Total reserves from four main areas are estimated at about 0.7 million m^3.

4. The water-table in the summer months is generally at 556-559 m RL; 2-4 m on the eastern side and 1-2 m on the western side, but this level fluctuates with the seasons. In early 1974, a dry spell resulted in a water-table at 3-5 m. The groundwater contains contaminants derived from the Fyshwick sewerage treatment works and from dissolved pollutants from the Molonglo River.

5. The results of sample testing indicate that medium to fine sands with a greater proportion of fines tend to occur closer to the surface and coarse sands and gravels occur at greater depths.

Geophysical surveys

6. In 1973 a seismic and resistivity test traverse was carried out. The seismic interpretation of the results illustrates the difficulties in interpreting small velocity differences within the alluvium. The dipole-dipole resistivity interpretation located channels in agreement with surface features but was not detailed enough to make finer subdivisions of the alluvium grainsizes and clay contents. Further work should use the IP method in conjunction with the resistivity.

7. A reconnaissance seismic survey in 1974 illustrated the difficulties in interpreting small velocity differences within the alluvium and the uncertainties of definition of weathered bedrock from overlying alluvium. However, the thickness of the alluvium was interpreted as being from 7 m near the edge of the river flats to 25 m in the middle.

8. The Wenner resistivity traverse of 1975 provided a quick reconnaissance method of defining favourable areas of shallow sand and gravel accumulations; however because of the thick soil and silt overburden and high clayccontent, the method was discontinued.

9. Of greater value was the traverse of closely spaced resistivity soundings across the river flat from south to north. The southern part of the traverse did not define the sand lenses very well owing to nearby sewerage treatment works lowering the resistivity of the groundwater. However, the northern two-thirds of the traverse outlines the thickness of the soil and silty clay overburden, and agrees well with augering results.

RECOMMENDATIONS

1. Any area proposed for sand-mining operations should be investigated in greater detail. A number of boreholes should be drilled to define the deposits of sand and gravel more accurately.
2. Geophysical surveys in alluvium overlying weathered bedrock and particularly in alluvial plains with a complex geological history should include closely spaced resistivity soundings coupled with IP measurements.
3. Resistivity and IP measurements may be useful in delineating saline waste-water contamination from Fyshwick sewerage treatment plant. Further tests are recommended.

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APPENDIX 1

LOGS OF AUGER HOLES,
DAIRY FLAT SAND INVESTIGATION 1975-76

LOG OF AUGER HOLE
DAIRY FLAT SAND INVESTIGATION:

HOLE No: 4 Level: 560m Co-ordinates: 44140E 01245N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0–2.2		21.3	1.7	SM	Fine silty sand, little or no fines, light brown.
2.2–3.2				CL-CH	Mottled clay, micaceons, core is compact.
3.2–7		7.8		SW	Gravelly coarse sand with clay lenses 10-15 cm. thick, material has low plasticity and is generally loose.
7–9.6		5.5		GW	Gravel, with well rounded fragments up to 2cm. in size, core moderately compact, but minor fine material

17/10/76

HOLE No: 13 Level: 558m Co-ordinates: 43616E 01300N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0–0.6				OL	TOPSOIL, dark brown silt, organic material
0.6–1.3				CL	Red gritty clay, non plastic.
1.3–3.2		6.6	1.42 20/1/76	SW	Gravelly medium to coarse sand, lenses of organic clay within the sand.
3.2–6.2		4.8		GW	Fine gravel, well rounded fragments, minor sand and finer material.
6.2–7.4				CL	Clay and silt, no cohesion when wet, some sand and gravel fragments.
7.4–9.5				SW	Coarse, well graded sand with very minor finer material.
9.5–9.8				ML	Grey compact silt, minor silt.

* Percentage of material passing B. S. Sieve No 200

End of hole 9.8m.

Appendix 1

Sheet 1 of 5

M(Pf) 231 (Record No. 1977/54)

I55/A16/1783

LOG OF AUGER HOLE
DAIRY FLAT SAND INVESTIGATION:

HOLE No: 20 Level: 558m Co-ordinates: 45300E 01800N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0				OL	Topsoil, Black organic silt.
1–4			1.5	OH	Black clay, core is compact and has sticky texture
5					Fine sandy clay
6					Brown clay with some grey-red mottles.
7–9		9.3		SW	Medium grained sand, low clay content, some coarser lenses within this layer.

Drilled 18/2/76

HOLE No: 41 Level: 557m Co-ordinates: 44300E 02930N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0–1				OH	Topsoil, Black silty clay, some sand and grit, but core is compact. Much organic matter.
2–3				CH	Dark brown silty clay, high plasticity, compact core and even texture. Minor grey and red mottles
4				SC	Clayey sand, mid brown, very sticky consistency.
5–9		8.1		SW-GW	Sand gravel, colour ranges from mid grey-brown to yellow brown (probably mottling). Some clayey sand was found close to 9m. depth.

* Percentage of material passing B.S. Sieve No 200

March '76.

Appendix 1

Sheet 2 of 5

M(Pf) 231 (Record No. 1977/54)

I55/A16/1783

LOG OF AUGER HOLE

DAIRY FLAT SAND INVESTIGATION :

HOLE No: 45 Level: 557m Co-ordinates: 44200E 04238N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0 – 0.3				OL	Topsoil, Black clayey silt.
0.3 – 1.5			▽ 1·25	CH	Black clay
1.5 – 5				CH-SC	Brown clay with lenses of sandy clay Mottled grey and yellow.
5 – 5.7				GP	Gravel and sand, minor fines.
5.7 – 9.5				SW	Medium dark brown sand, well graded Minor gravel or fines

HOLE No: 18 Level: 558m Co-ordinates: 45075E 02737N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0 – 0.8				OH	Topsoil Black organic silty clay much humic matter, shiny surface
0.8 – 1.6			▽ 1·37 20/1/76	OL	Black silty clay, some sand. Slightly friable
1.6 – 2.2				CL	Very dark brown silty clay, massive
2.2 – 2.9				CL	Grey and orange mottled clay, some silt
2.9 – 7.2		7·3 / 12·1		SW	Well graded light orange sand, minor gravel fragments up to 3cm. Some clayey layers.
7.2 – 7.9				SC-GC	Sand and gravel with a green grey clay matrix.
7.9		End of hole 7·9m.			

* Percentage of material passing B. S. Sieve No 200

Appendix 1

Sheet 3 of 5

M(Pf) 231 (Record No. 1977/54)

155/A16/1783

LOG OF AUGER HOLE

DAIRY FLAT SAND INVESTIGATION :

HOLE No: 63 Level: 561 m Co-ordinates: 47575 E 00437 N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0				SM	TOPSOIL
0.2–2.6		55		SM	Orange fine sandy silt, even grained friable, minor clay.
2.6–7.9			2·6	SW (GW)	Medium grained sand with some coarse gravel in thin lenses. Mid brown colour, becomes darker with increasing depth Well graded. Gravel fragments, up to 3cm.
7.9–9.5				GC	Clayey gravel, yellow brown.

Drilled April '76

HOLE No: 71 Level: 560m Co-ordinates: 48950 E 00300N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0–2				OL	Topsoil Black friable silt, becomes sandy at 1-1·5m.
2–5.6		22		SC	Fine sand with layers of sandy clay up to 60 cm. thick. High percentage of recovery of clayey material so total percentage of clay is abnormally high. Mid-brown to orange colour
5.6–7				SW	Fine to medium sand, minor clay. Mid-brown colour
7–9.5				GC	Clay-sand-gravel mixture Clay is plastic and orange in colour.

* Percentage of material passing B. S. Sieve No 200

Appendix I

Drilled May 1976

Sheet 4 of 5

M(Pf) 231 (Record No. 1977/54)

155/A16/1783

LOG OF AUGER HOLE

DAIRY FLAT SAND INVESTIGATION :

HOLE No: 90 Level: 55.8 m Co-ordinates: 46775 E 01500 N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0 – 2.2				OL	Topsoil, very dark brown and black silt, friable organic matter
2.2 – 3.7				CH	Dark brown silty clay, compact, some mottled zones (red & brown)
3.7 – 9.5		5 (approx. 3.8 – 6.1)		SW	Medium to coarse grained sand, yellow orange colour, very few fines. Some gravel layers, otherwise this thickness is very well graded.

Drilled May 1976

HOLE No: 85 Level: 56.0 m Co-ordinates: 48737 E 04100 N

Depth (metres)	Graphic log	Sample Tested *	Water Depth	Classification	Description
0 – 1.4				OH	Topsoil, Black silty clay, highly plastic, organic matter. Some gravel up to 3cm in size
1.4 – 2.2				GP	Coarse gravel & sand, 1-3cm. in size.
2.2 – 9.5		11 (approx. 3.8 – 5.3)	2.5	SP	Coarse sand and gravel, sand is grey and medium grain size. Gravel is 2-3cm. in size.

* Percentage of material passing B.S. Sieve No 200

Drilled May 1976

Appendix 1

Sheet 5 of 5

M(Pf) 231 (Record No. 1977/54) I55/A16/1783

APPENDIX 2

PARTICLE SIZE ANALYSIS, GRAVEL AND SAND FRACTIONS

PARTICLE SIZE ANALYSIS
GRAVEL AND SAND FRACTIONS
DAIRY FLAT SAND INVESTIGATION

HOLE No	DEPTH TESTED	FIELD NAME	PERCENTAGE PASSING B.S. SIEVE: 1½"	3/4"	3/8"	3/16"	No 7	No 14	No 25	No 36	No 52	No 100	No 200	PLASTICITY INDEX
1	2.2 - 2.9	Silty sand					100	99.8	98.3	96.3	94.2	71.1	18.4	1
1	8.3 - 8.9	Fine sandy gravel	100	97.4	86.5	74.7	57.6	31.5	13.2	8.9	7.4	5.4	4.1	
4	0.85 - 2.1	Fine very silty sand				100	99.8	98.4	88.6	76.2	66.8	36.4	21.3	1
4	3.0 - 6.7	Gravelly sand	100	98.5	97.3	94.6	80.4	58.4	39.2	27.6	20.5	10.7	7.8	2
4	6.7 - 9.1	Gravel	100	86.0	73.3	62.9	49.6	30.7	15.7	11.5	9.7	6.9	5.5	
5	3.1 - 3.8	Medium sand		100	99.8	99.4	94.0	75.8	52.8	39.9	28.7	12.5	8.3	
5	6.9 - 7.6	Coarse sandy gravel	100	91.9	79.8	69.3	59.7	41.9	23.4	13.6	9.6	5.7	4.3	
6	1.5 - 2.2	Very silty sand		100	99.4	97.9	90.7	77.6	66.5	58.7	52.4	41.5	33.3	3
6	7.6 - 8.4	Coarse sand + gravel	100	77.9	60.1	48.2	34.5	20.0	8.6	5.3	4.2	2.9	2.4	
7	7.6 - 8.4	Silt, sand, gravel, mixt.	100	96.2	90.9	81.3	71.7	58.6	38.2	26.8	22.3	16.7	14.0	
7	3.8 - 4.6	Silty, sandy gravel	100	96.4	86.8	70.1	56.2	40.1	24.6	18.4	15.5	11.4	9.2	
36	0.75 - 1.5	Sand, silt mixt. some clay				100	99.9	97.8	82.2	66.9	54.2	33.3	23.4	
34	3.1 - 3.8	Medium sand			100	98.7	90.1	68.8	46.2	35.6	26.5	9.3	5.1	
37	2.2 - 3.1	Medium-coarse gravel.sand		100	99.7	96.4	82.4	60.3	40.3	28.1	19.4	9.6	7.2	
37	6.9 - 7.6	Sandy gravel	100	96.8	90.8	82.8	69.8	43.6	21.6	15.8	12.0	7.5	5.8	
38	2.2 - 3.1	Gravelly sand		100	99.7	92.4	67.1	38.9	21.8	15.4	11.0	4.9	3.4	
38	3.1 - 3.8	Sandy gravel			100	99.4	91.6	56.5	23.2	14.6	10.1	4.7	3.6	
39	0.75 - 1.5	Medium clayey sand				100	99.9	97.6	75.2	54.9	42.9	24.5	18.5	
39	3.8 - 4.6	Gravelly sand			100	98.4	83.3	54.5	32.4	24.8	19.3	11.0	8.0	
10	0.75 - 1.5	v. silty + clayey sand			100	99.7	99.5	96.7	88.0	73.6	60.8	37.8	28.3	1
10	3.1 - 3.8	silty med - coarse sand			100	99.6	96.9	80.8	57.7	45.5	36.4	17.2	12.3	NON-PLASTIC
11	3.1 - 3.8	Medium sand		100	99.9	99.1	93.4	76.1	55.1	37.7	26.2	12.3	8.6	
11	6.1 - 6.9	clayey med-coarse sand			100	98.5	90.4	68.5	44.9	34.4	29.0	19.9	14.9	

Appendix 2

Sheet 1 of 3

PARTICLE SIZE ANALYSIS
GRAVEL AND SAND FRACTIONS
DAIRY FLAT SAND INVESTIGATION

HOLE No	DEPTH TESTED	FIELD NAME	PERCENTAGE PASSING B.S. SIEVE:											PLASTICITY INDEX
			1 1/2"	3/4"	3/8"	3/16"	No 7	No 14	No 25	No 36	No 52	No 100	No 200	
12	2.2 - 3.1	Gravelly med. sand			100	97.6	84.1	61.4	42.5	32.5	25.1	13.4	9.1	NON-PLASTIC
13	1.5 - 2.2	V. gravelly med-coarse sand			100	95	77.6	56.1	37.8	26.4	18.4	9.3	6.5	
13	4.6 - 6.1	Fine gravell		100	98	68.1	26.3	13.3	9.3	7.7	6.6	5.2	4.8	
14	6.9 - 7.6	Coarse sandy grav.	100	93.5	86.1	78.2	69.3	43.8	19.8	14.3	12.0	8.3	6.3	
15	6.1 - 6.9	Coarse sand		100	98.9	98.3	96.0	76.1	29.0	12.0	7.2	3.5	2.6	
29	6.9 - 7.6	Coarse sandy gravel	100	93.5	89.3	84.1	71.2	43.9	12.9	6.8	5.1	3.7	3.1	
30	4.6 - 5.3	Clayey sandy gravel	100	89.9	73.8	65.1	57.2	45.3	29.9	23.9	20.4	15.7	13.3	
31	3.1 - 3.8	Coarse sandy gravel		100	98.8	93.4	75.4	49.4	27.7	18.1	13.3	7.3	5.3	
33	2.2 - 3.1	Medium sand		100	96.4	95.2	88.0	74.0	54.2	38.7	27.0	8.9	3.3	
33	3.1 - 3.8	Med-coarse sand				100	92	68.8	43.7	29.7	20.0	8.2	5.9	
28	3.8 - 4.6	very silty + clayey med-coarse sand			100	99.1	93.6	86.3	77.2	65.7	55.3	37.8	29.5	
28	8.4 - 9.1	gravel, some coarse sand.	100	85.8	76.5	62.6	41.9	21.3	11.1	8.4	7.0	5.2	4.1	
22	4.6 - 5.3	Medium sand		100	95.1	93.0	91.2	86.3	66.6	48.7	35.8	15.0	8.1	
22	6.9 - 7.6	Coarse sandy gravel		100	91.8	83.1	64.9	39.4	16.9	12.0	9.9	7.1	6.0	
23	6.9 - 7.6	Gravelly med. sand.	100	96.3	92.4	84.7	74.8	59.4	41.3	30.5	23.0	12.8	8.0	
21	6.9 - 7.6	Clayey gravelly sand		100	96.9	91.6	81.3	65.3	41.5	29.1	24.1	17.4	13.7	
20	6.9 - 7.6	Medium sand				100	99.2	93.1	62.7	34.6	21.5	12.9	9.3	
27	4.6 - 5.3	Med-fine sand				100	98.8	88.9	50.7	22.5	15.6	10.0	6.7	
18	3.1 - 3.8	Medium sand			100	99.6	95.3	80.1	50.5	33.1	25.8	13.6	7.3	
18	3.8 - 4.6	clayey gravelly sand		100	91.4	88.2	78.9	64.2	45.6	34.2	28.2	18.3	12.1	
17	6.9 - 7.6	Gravelly sand		100	89.5	85.6	79.0	65.6	42.5	25.6	12.0	10.1	7.1	
25	6.1 - 6.9	slightly clayey sandy gravel	100	89.8	80.4	69.3	55.7	40.4	25.5	20.2	18.2	14.1	11.5	
24	3.8 - 4.6	Clayey sand			100	98.8	97.4	92.1	71.9	50.0	35.9	23.2	16.7	

Appendix 2
Sheet 2 of 3

PARTICLE SIZE ANALYSIS
GRAVEL AND SAND FRACTIONS
DAIRY FLAT SAND INVESTIGATION

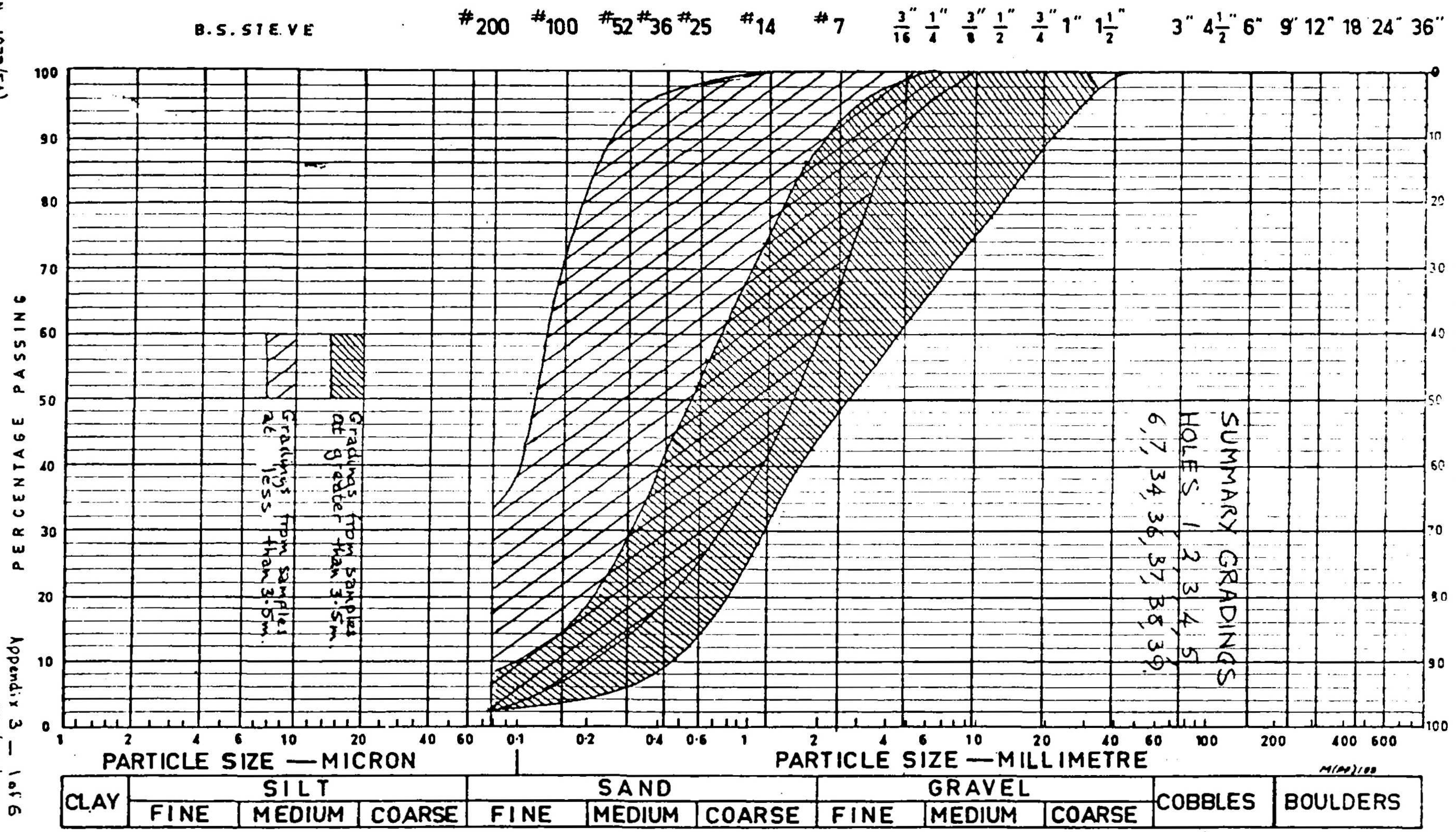
HOLE No	DEPTH TESTED	FIELD NAME	PERCENTAGE PASSING B.S. SIEVE: 1½"	3/4"	3/8"	3/16"	No 7	No 14	No 25	No 36	No 52	No 100	No 200	PLASTICITY INDEX
40	4·6-5·3	Gravelly sand			100	96·9	84·8	60·6	32·3	23·4	19·2	12·6	9·0	
41	5·3-6·1	Sandy gravel			100	91·7	71·2	55·8	31·5	19·5	15·7	10·8	8·1	
47	7·6-8·4	Gravel to sandy gravel		100	79·4	67·4	54·4	41·9	26·1	14·8	11·1	6·9	5·5	
48	3·8-4·6	Coarse gravelly sand				100	83·3	57·9	25·5	14·0	10·9	6·7	4·9	
55	3·8-5·3	Med-coarse sand		100	99	97	91	75	52	36	24	8	5	
63	0·75-2·2	Very silty fine sand.						100	98	95	92	78	55	
64	1·5-3·8	Med-coarse sand			100	98	86	63	42	30	23	11	7	
71	3·7-5·5	Clayey sand				100	97	93	82	65	53	34	22	
76	3·8-5·3	Clayey fine sand				100	98	90	76	64	55	37	26	
81	3·0-5·3	Medium sand, some gravel		100	97	93	85	66	32	16	11	7	5	
84	0·75-2·2	Silty-sandy gravel	100	86	71	63	60	54	48	44	40	30	22	
84	3·0-4·6	Fine sand, minor clay		100	99	99	97	90	70	50	37	20	13	
85	3·8-5·3	Med-coarse sand + gravel		100	98	95	80	55	38	29	24	16	11	
88	3·8-5·3	Fine sand					100	96	80	68	56	24	9	
89	4·6-6·1	Med-coarse sand			100	99	95	81	50	26	17	9	5	
90	3·8-6·1	Medium-coarse sand + gravel		100	98	95	81	56	30	17	12	8	5	

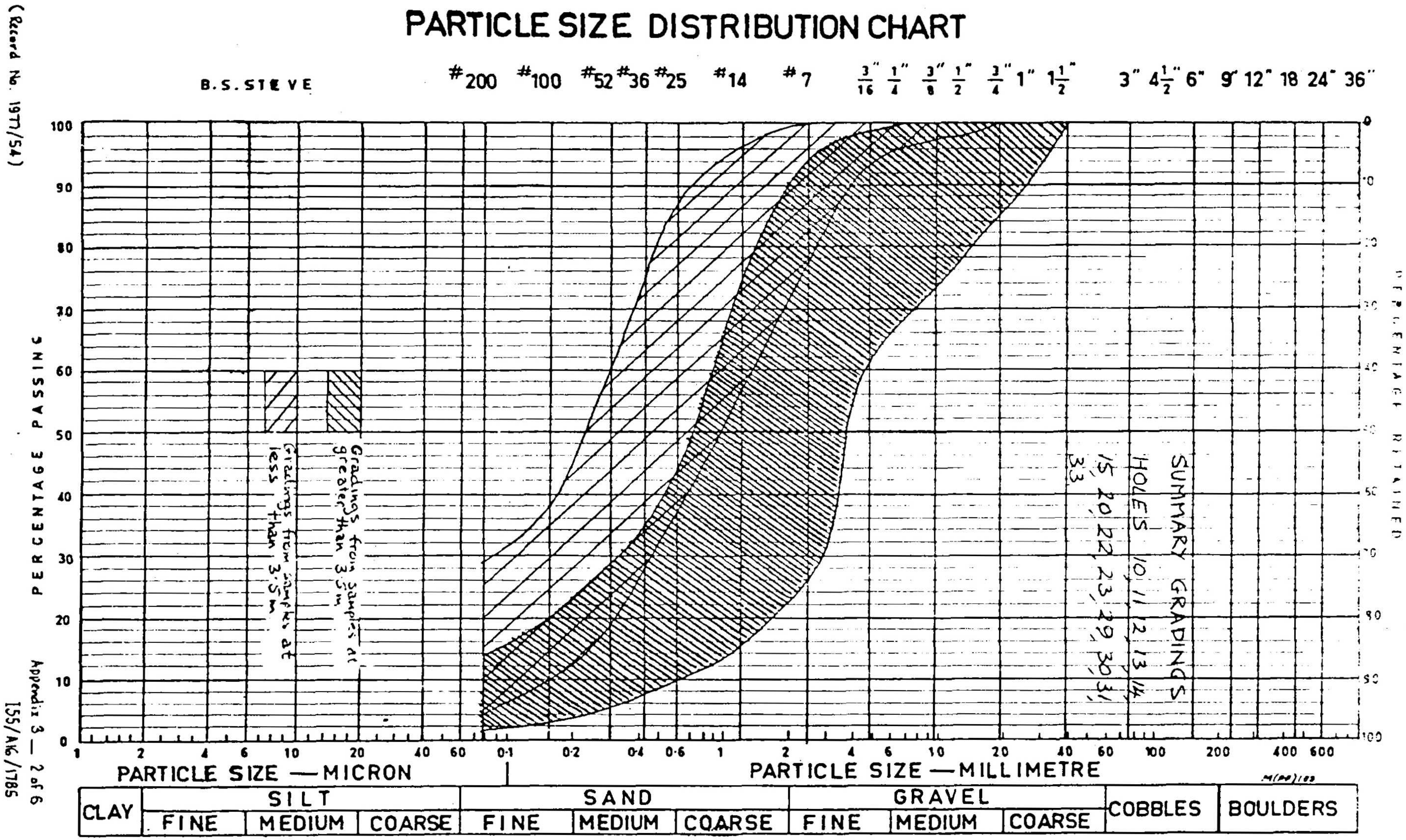
Appendix 2
Sheet 3 of 3

APPENDIX 3

PARTICLE SIZE DISTRIBUTION CHARTS.

PARTICLE SIZE DISTRIBUTION CHART





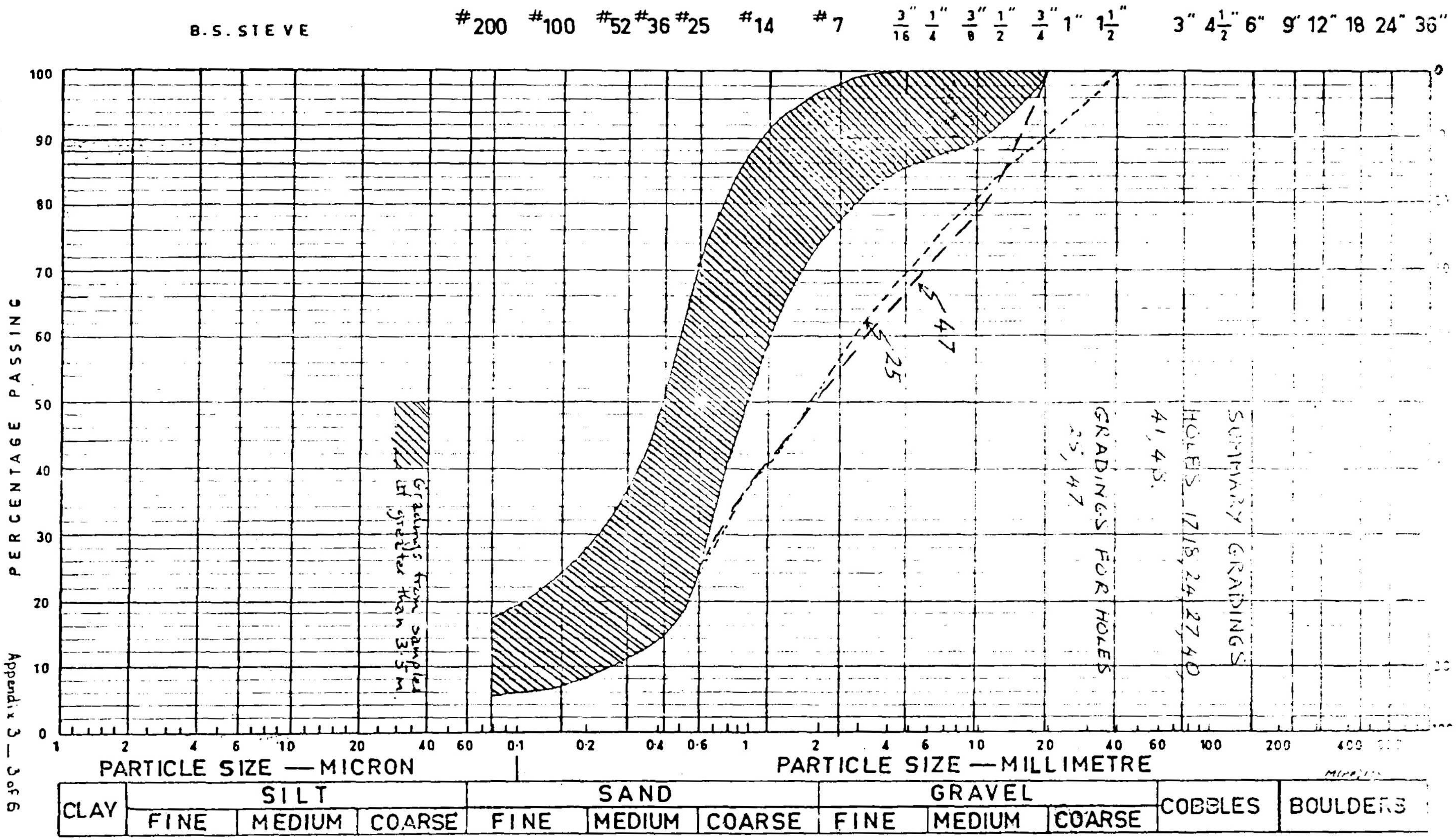
(Record No. 1977/54)

Appendix 3 — 2 of 6

I55/A16/1785

(Record No. 1977/54)

PARTICLE SIZE DISTRIBUTION CHART

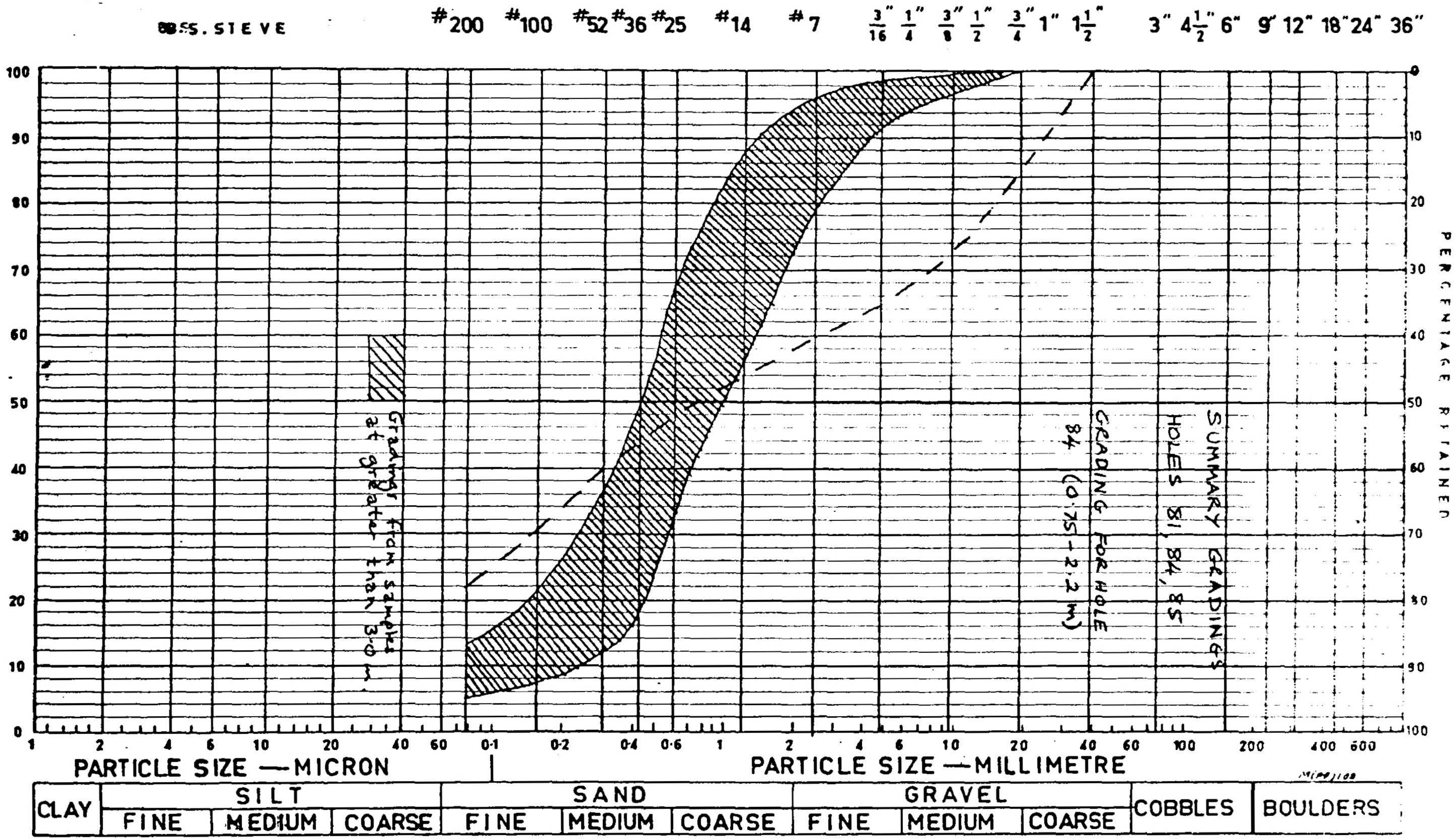


Appendix 3 — 3 of 6

155/A16/1785

(Record No. 1977/54)

PARTICLE SIZE DISTRIBUTION CHART

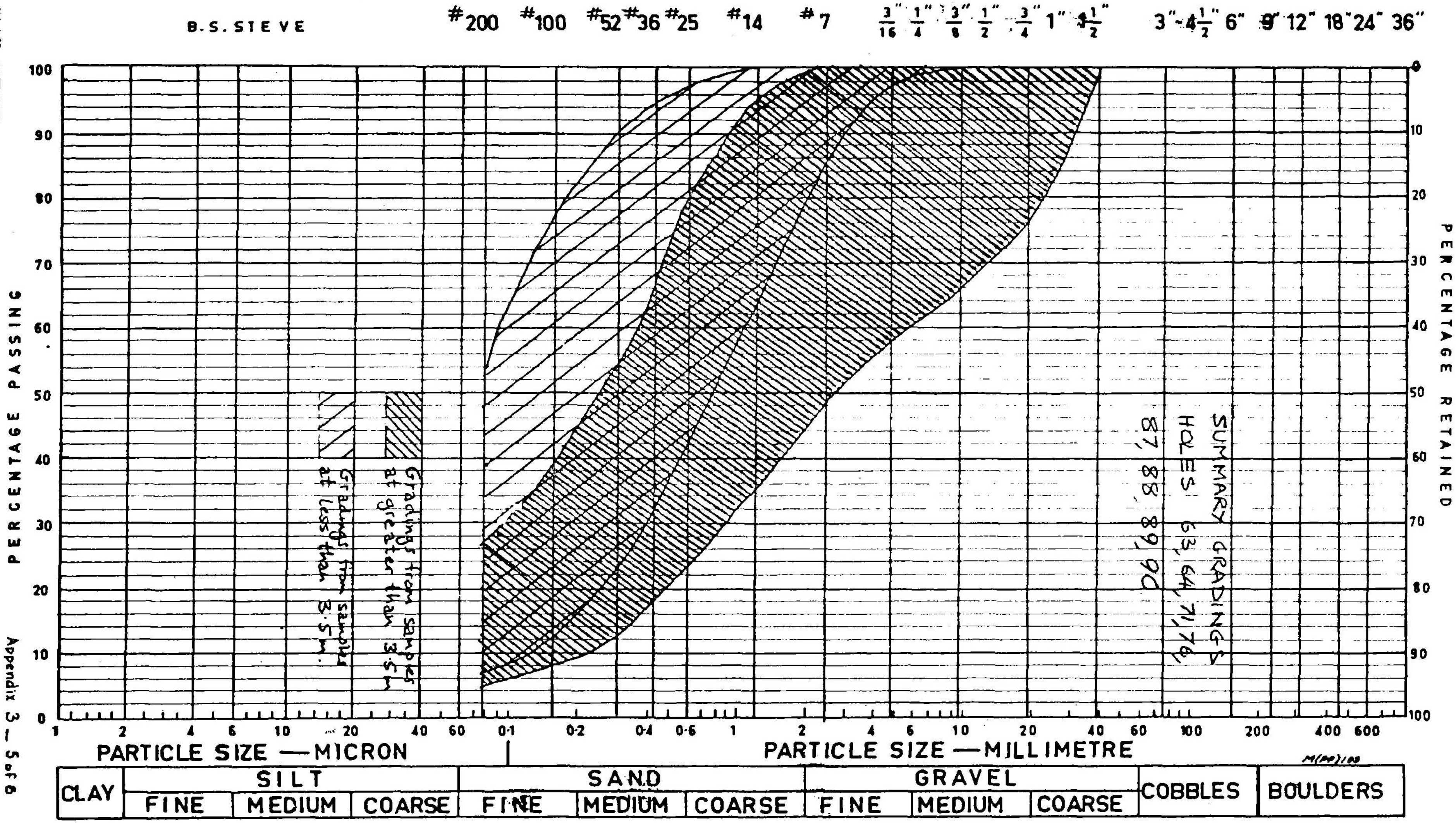


Appendix 3 – 4 of 6

155/A16/1785

(Record No. 1977/54)

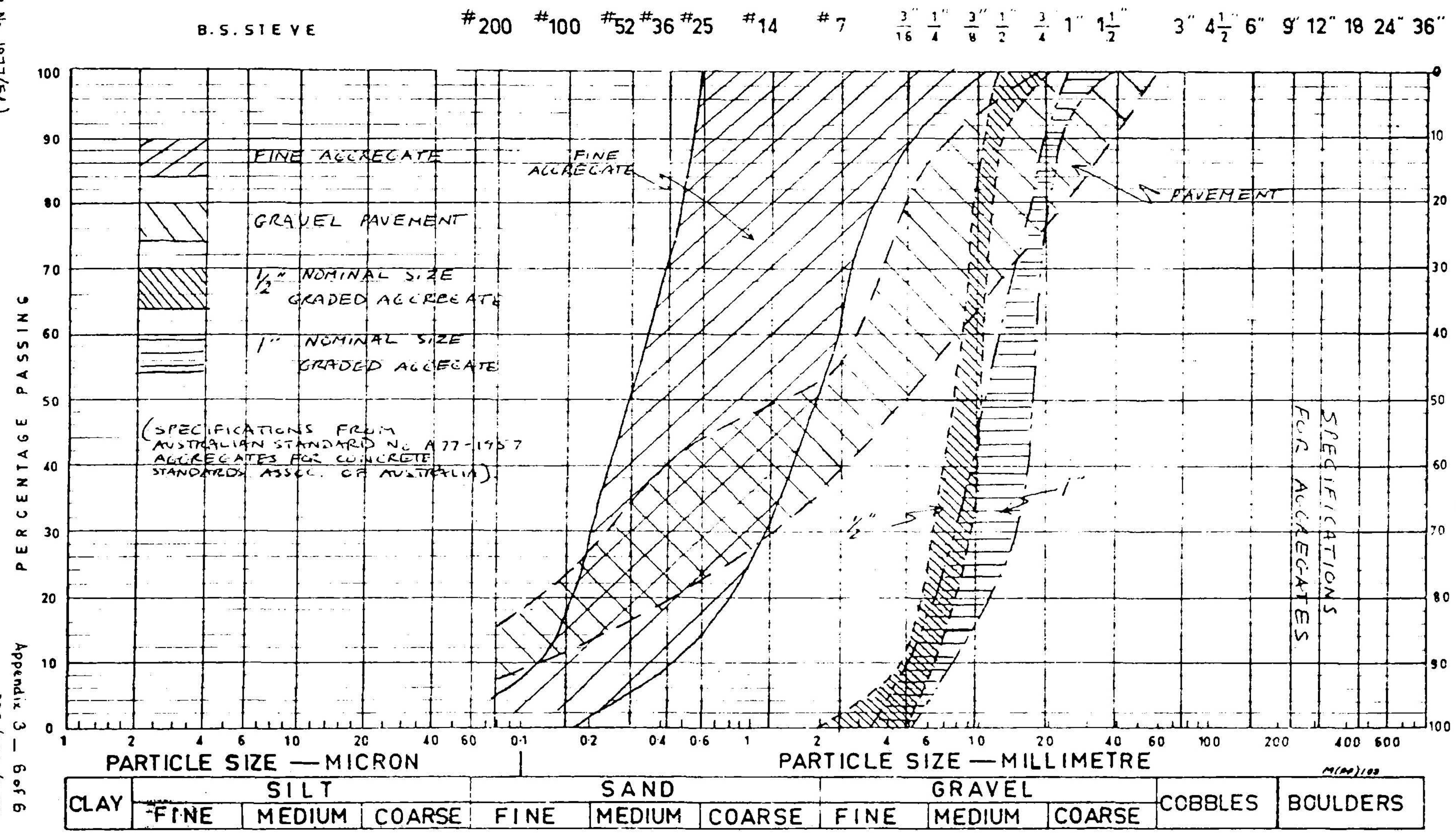
PARTICLE SIZE DISTRIBUTION CHART



Appendix 3 — 5 of 6

[55/A16/1785

PARTICLE SIZE DISTRIBUTION CHART



APPENDIX 4

GEOPHYSICAL SURVEY PERSONNEL

SEISMIC & RESISTIVITY SURVEY DEC. 1973

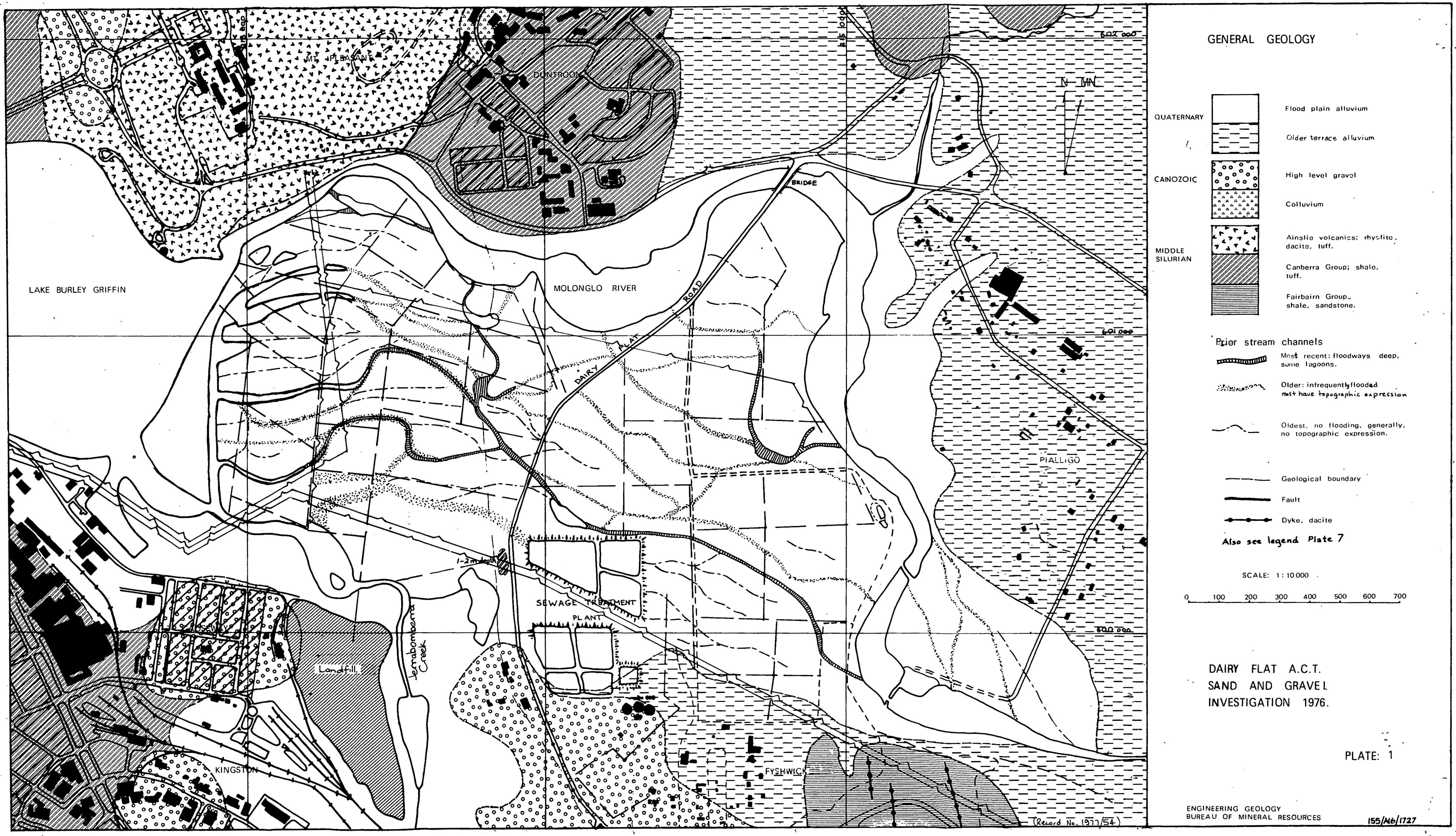
Field Personnel	D.C. Ramsay - geophysicist
	M.I. McDowell - geophysicist
	G.I. Jennings - seismic observer
Interpretation	Seismic-D.C. Ramsay, G.R. Pettifer
	Resistivity - M.I. McDowell, G.R. Pettifer
Geologist	D.C. Purcell

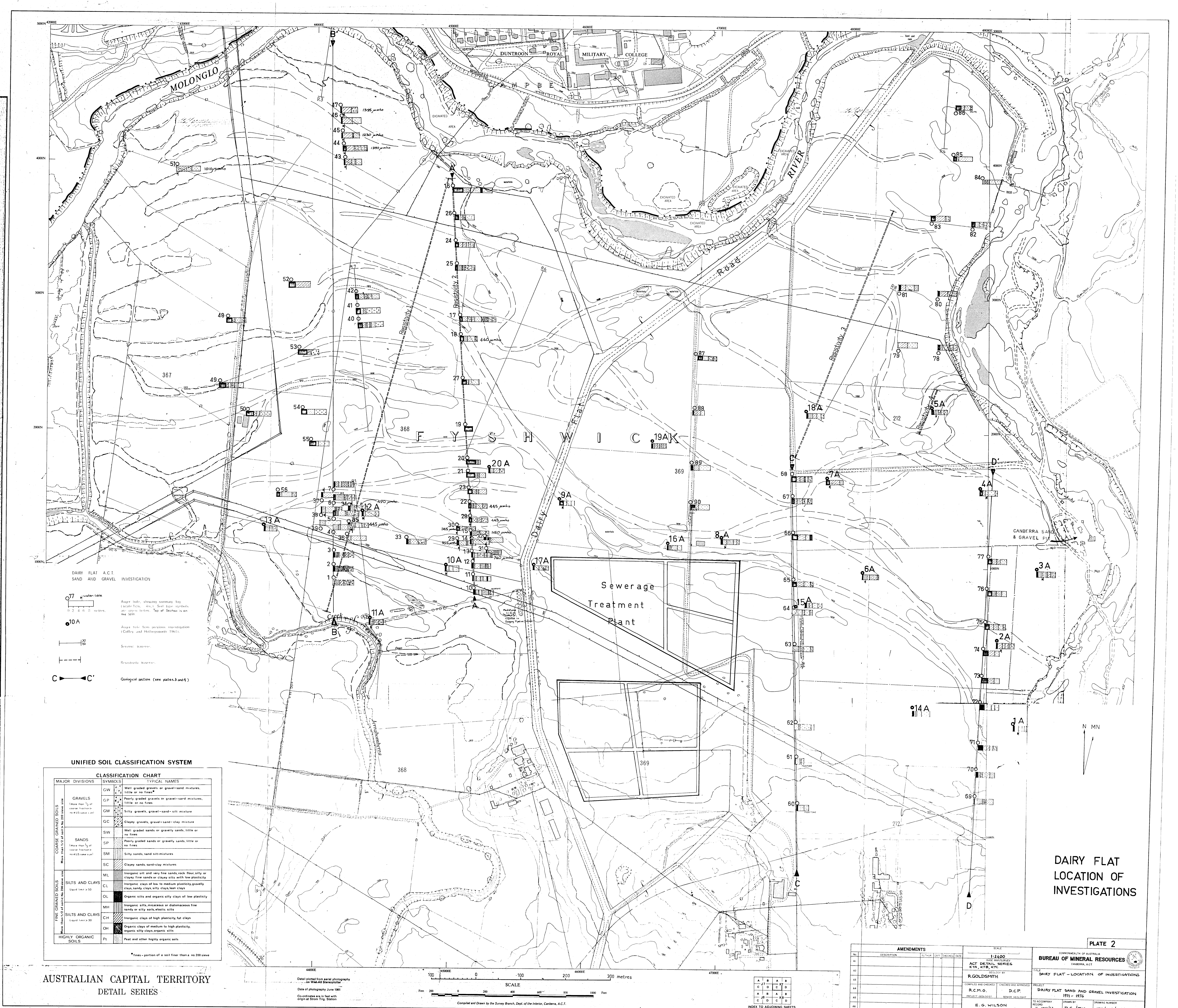
SEISMIC SURVEY MAY 1974

Field Personnel	M.I. McDowell - geophysicist
	C.L. Horsfall - geophysicist
	A. Baumgarten - Austrian Exchange Student
Interpretation	M.I. McDowell, F.N. Michail, G.R. Pettifer
Geologist	D.C. Purcell

RESISTIVITY AND AUGER SURVEY OCT-NOV 1975

Field Personnel	G.R. Pettifer - geophysicist
	D.G. Bennett - geophysicist
	D.C. Ramsay - geophysicist
	D.H. Francis - technical assistant
	M.N. Preston Stanley - field assistant
	M. Elliston - field assistant
Interpretation	G.R. Pettifer
Geologist	R.C.M. Goldsmith
Driller	G. Brandon


GENERAL GEOLOGY
QUATERNARY
CAINOZOIC
MIDDLE SILURIAN
Flood plain alluvium
Older terrace alluvium
High level gravel
Colluvium
Ainslie volcanics; rhyolite, dacite, tuff.
Canberra Group; shale, tuff.
Fairbairn Group, shale, sandstone.
Prior stream channels
Most recent: floodways deep, some lagoons.
Older: infrequently flooded most have topographic expression
Oldest, no flooding, generally, no topographic expression.
Geological boundary
Fault
Dyke, dacite
Also see legend Plate 7
SCALE: 1:10 000
0 100 200 300 400 500 600 700
N MN
DAIRY FLAT A.C.T.
SAND AND GRAVEL
INVESTIGATION 1976.
PLATE: 1
ENGINEERING GEOLOGY
BUREAU OF MINERAL RESOURCES
155/A16/1727
(Record No. 1977/54)
MT. PLEASANT
DUNTROON
BRIDGE
LAKE BURLEY GRIFFIN
MOLONGLO RIVER
DAIRY FLAT ROAD
PIALLIGO
SEWAGE TREATMENT PLANT
Landfill
Jerrabomberra Creek
KINGSTON
FYSHWICK
602 000
601 000
600 000



UNIFIED SOIL CLASSIFICATION SYSTEM

CLASSIFICATION CHART

MAJOR DIVISIONS		SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS (More than 1/2 of soil > No 200 sieve size)	GRAVELS (More than 1/2 of coarse fraction > no 4 U.S. sieve size)	GW	Well graded gravels or gravel-sand mixtures, little or no fines*
		GP	Poorly graded gravels or gravel-sand mixtures, little or no fines
		GM	Silty gravels, gravel-sand-silt mixture
		GC	Clayey gravels, gravel-sand-clay mixture
	SANDS (More than 1/2 of coarse fraction > no 4 U.S. sieve size)	SW	Well graded sands or gravelly sands, little or no fines
		SP	Poorly graded sands or gravelly sands, little or no fines
		SM	Silty sands, sand silt-mixtures
		SC	Clayey sands, sand-clay mixtures
FINE GRAINED SOILS (More than 1/2 of soil < No. 200 sieve size)	SILTS AND CLAYS Liquid limit > 50	ML	Inorganic silt and very fine sands, rock flour, silty or clayey fine sands or clayey silts with low plasticity
		CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
		OL	Organic silts and organic silty clays of low plasticty
	SILTS AND CLAYS Liquid limit > 50	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
		CH	Inorganic clays of high plasticity, fat clays
		OH	Organic clays of medium to high plasticity, organic silty clays, organic silts
HIGHLY ORGANIC SOILS		Pt	Peat and other highly organic soils

*fines - portion of a soil finer than a no. 200 sieve

AUSTRALIAN CAPITAL TERRITORY
DETAIL SERIES

DAIRY FLAT LOCATION OF INVESTIGATIONS

PLATE 2

AMENDMENTS				
No.	DESCRIPTION	AUTHOR	DATE	CHECKED	DATE
A1					
A2					
A3					
A4					
A5					
A6					

SCALE 1:2400

BASE MAP/SURVEY: ACT DETAIL SERIES K7A, K7B, K7C

GEOLOGY BY: R.GOLDSMITH

COMPILED AND CHECKED: R.C.M.G. PROJECT GEOLOGIST

CHECKED AND APPROVED: D.C.P. SENIOR GEOLOGIST

E.G. WILSON SUPERVISING GEOLOGIST

COMMONWEALTH OF AUSTRALIA
BUREAU OF MINERAL RESOURCES
CANBERRA, A.C.T.

TITLE: DAIRY FLAT - LOCATION OF INVESTIGATIONS

PROJECT: DAIRY FLAT SAND AND GRAVEL INVESTIGATION 1971 - 1976

TO ACCOMPANY RECORD No. 1977/54

DRAWN BY: R.G./T.K.

DRAWING NUMBER: 155/A16/1728

DAIRY FLAT SAND AND GRAVEL INVESTIGATION SECTION A-A'

PLATE 3

(Record No. 1977/54)

155/A16/1729

DAIRY FLAT SAND AND GRAVEL INVESTIGATIONS
GEOLOGICAL SECTIONS, B C&D.

(For locations of Sections see Plate 2.)

(Record No 1977/54)

PLATE 4

155/A16/1730

DEPTH TO TOP OF SAND OR GRAVEL DEPOSITS

Clay and silt may occur below the indicated depth

0 – 1
1 – 2
2 – 4
4 – 6
6 – 8
> 8

Depth in metres

0 100 200 300 400 500 600 700
metres
Scale 1:10 000

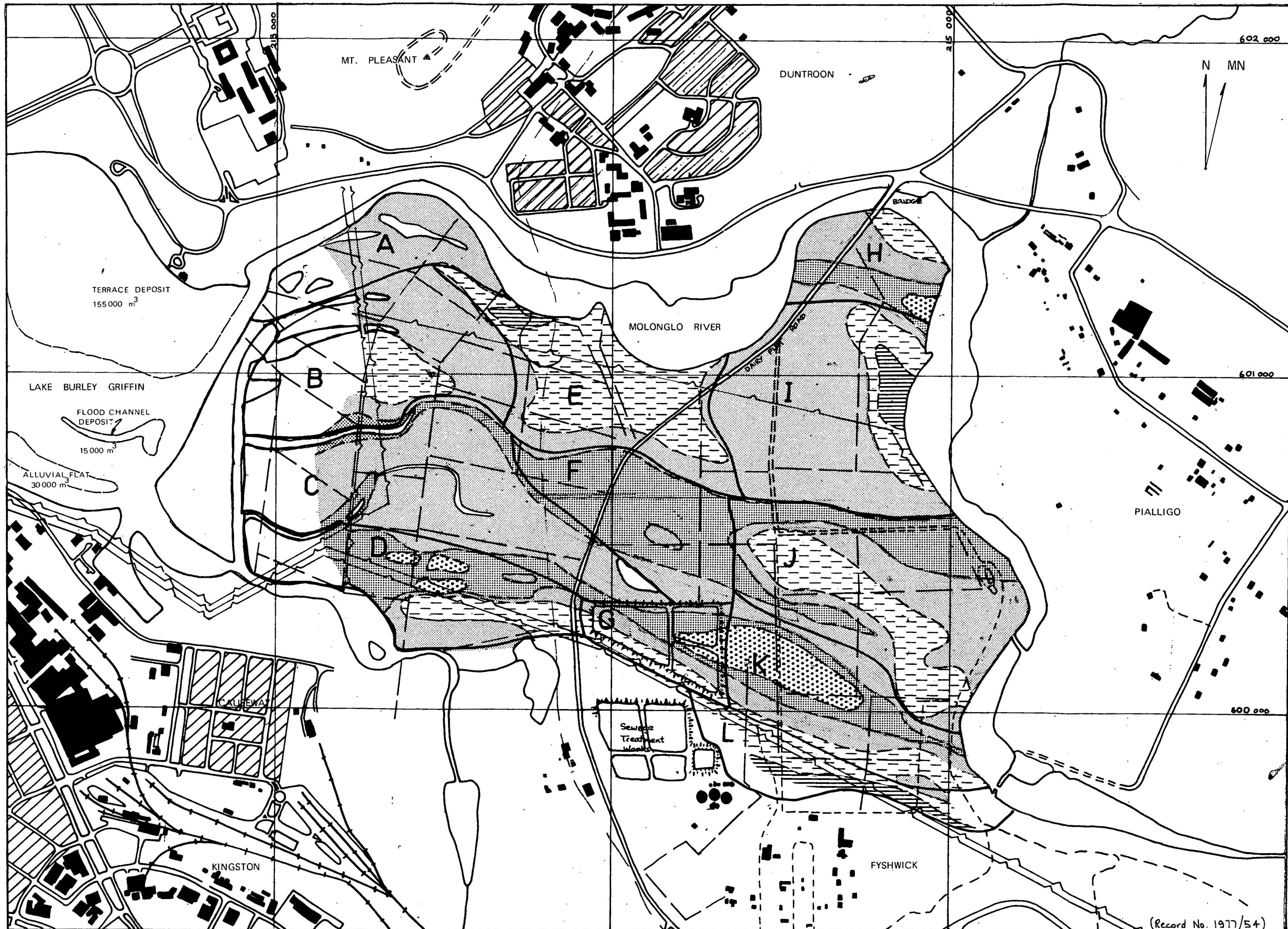
Built-up area
Fence
Powerline
Road
Track

DAIRY FLAT, A.C.T.
SAND AND GRAVEL
INVESTIGATION 1976

PLATE: 5

ENGINEERING GEOLOGY
BUREAU OF MINERAL RESOURCES

155/A16/1731



THICKNESS OF SAND AND GRAVEL DEPOSITS

Including total of all deposits includes discrete lenses, and does not take into account whether the deposits are economically recoverable or not.

- > 8
- 5 to 8
- 3 to 5
- 1 to 3
- 0 to 1

Thickness in metres

0 100 200 300 400 500 600 700

Metres

Scale 1:10 000

- Built-up area
- Fence
- Powerline
- Road
- Track

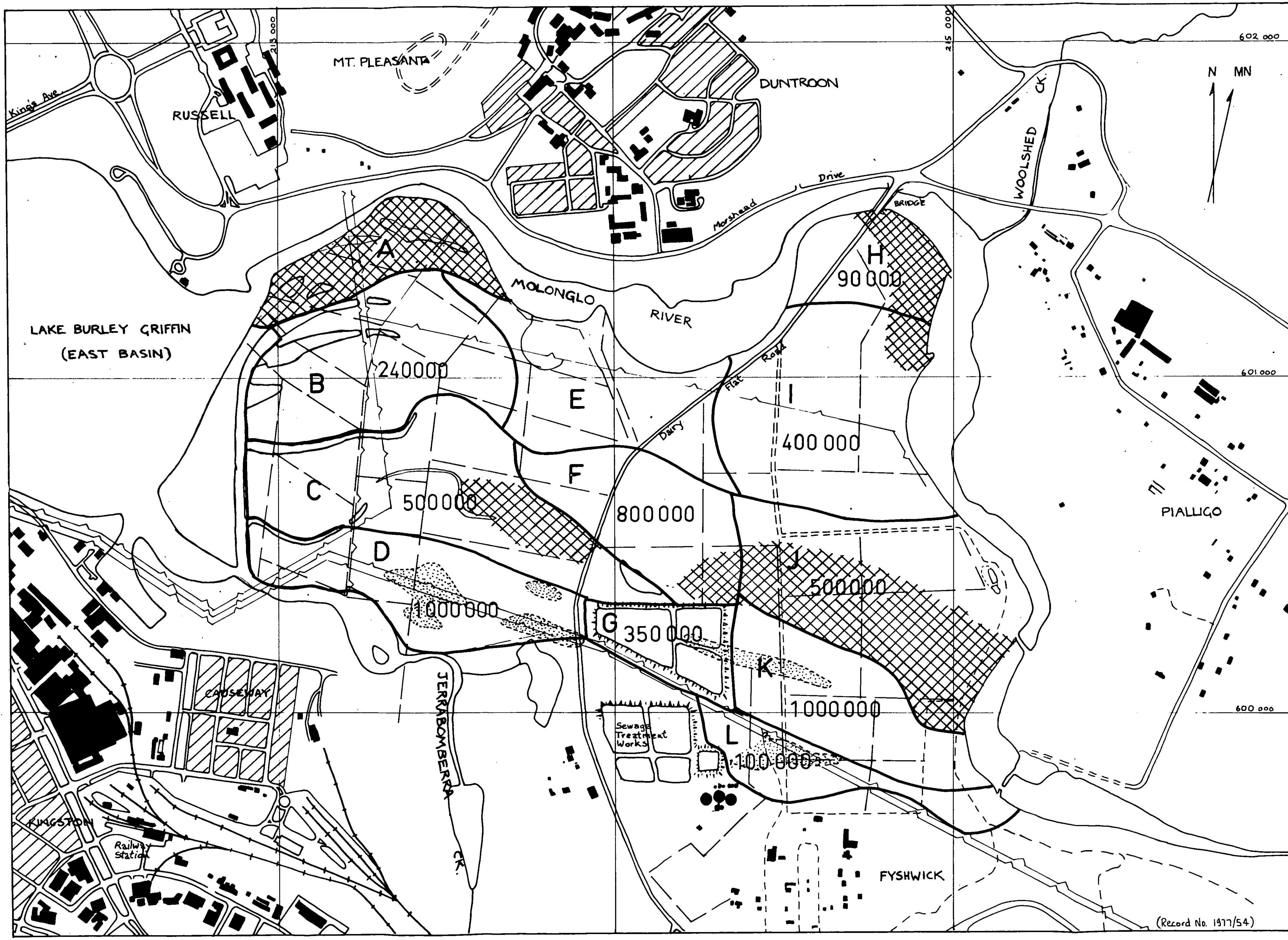
DAIRY FLAT A.C.T.
SAND AND GRAVEL
INVESTIGATION 1976

PLATE: 6

(Record No. 1977/54)

ENGINEERING GEOLOGY
BUREAU OF MINERAL RESOURCES

155/A16/1732



SUMMARY OF SAND AND GRAVEL RESOURCES

EOLIAN SANDS

TOPSOIL DEPOSITS

A RESOURCE BLOCK
Estimated economically recoverable reserves of sand and gravel in cubic metres.

Built-up area

Building

Fence

Powerline

Railway line

Road

Track

SCALE 1:10 000

100 0 100 200 300 400 500 600
Metres

DAIRY FLAT A.C.T.
SAND AND GRAVEL
INVESTIGATION 1976

ENGINEERING GEOLOGY
BUREAU OF MINERAL RESOURCES.

PLATE 7

155/A16/1733

LOCATION OF GEOPHYSICAL INVESTIGATIONS

DAIRY FLAT A.C.T.

PLATE 8

I55/B5-339

PLATE 9

DAIRY FLAT SEISMIC REFRACTION AND DIPOLE - DIPOLE TEST TRAVERSE 1973

Record No. 1977/54

I55/B5-369

PLATE 10

Record No. 1977/54

I55/B5-368