DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

Record 1978/69

GEOLOGICAL AND GEOPHYSICAL INVESTIGATION OF THE PROPOSED MUGGA SOUTH LANDFILL SITE, ACT, 1977

by

R. EVANS & D.G. BENNETT

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CONTENTS

SUMMARY

An investigation of the Mugga South landfill site has been made to ascertain the excavation properties of the ground and to assess the potential for groundwater pollution by leachate. The site is generally suitable for landfill: readily excavated material to a depth of 5 m or more covers most of the area; groundwater-levels are generally below the base of the proposed landfill area; and leachate pollution of ground water can be controlled by clay-blanketing the trenches. The low water-table in the area, and the surface-water control measures, will ensure that waste is kept relatively dry and that the amount of leachate emanating from the trenches will be minimal.

INTRODUCTION

A new landfill site to serve South Canberra and Tuggeranong is required. The geology of five possible alternative sites was investigated by BMR in 1976 (Evans, Bennett, & Jacobson, 1978). Following a decision to establish Mugga South at the junction of Long Gully Road and Mugga Lane (Fig. 1), as the landfill site, the National Capital Development Commission requested a more detailed investigation of this site. Additional drilling and seismic traverses were undertaken in August 1977 and a leachate monitoring system was instituted. The landfill site is being designed by L.T. Frazer & Associates, Consulting Engineers.

The drilling was done by contractors, Steward Bros. Pty Ltd of Sydney, using a Pioneer 'Mole' drill for both hollow flight augering and tungsten-bit coring. The seismic survey was carried out by D.G. Bennett, Engineering Geophysics group, BMR. Chemical analyses of groundwater samples were made by M.J. Story, Conservation and Agriculture Branch, Department of the Capital Territory.

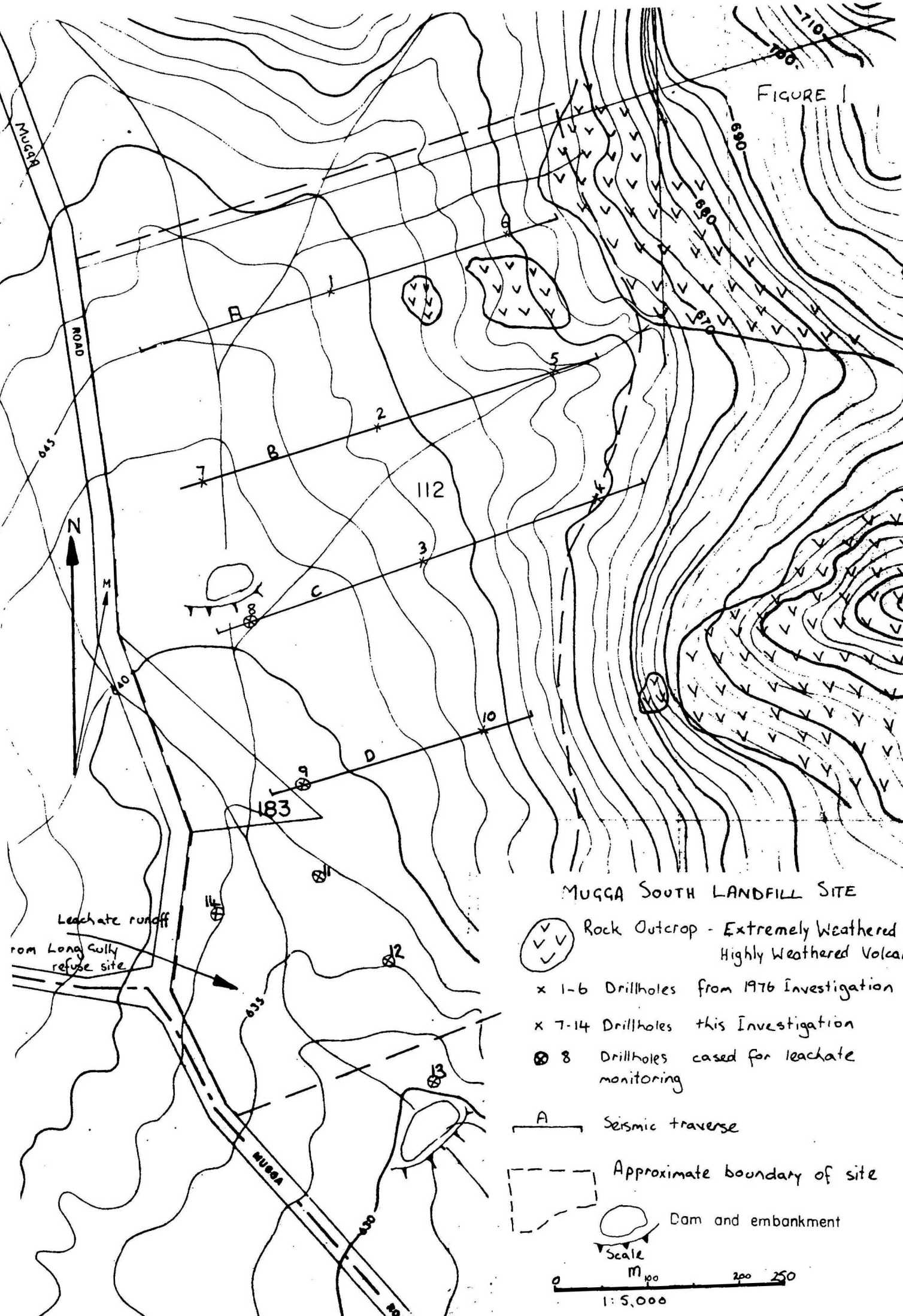
Development of the area as a landfill site entails the construction of about 20 parallel trenches, with only one or two trenches for use at any one time, running at right-angles to the slope (roughly east-west). Associated with the trenches will be surface water cut-off drains and a leachate collection system of drains and dams.

PHYSIOGRAPHY AND GEOLOGY

The landfill site occupies the lower slopes to the west of a north-south trending ridge (Fig. 1), and part of the valley floor at the foot of the slope. It consists of dissected colluvial outwash fans with substantial thicknesses of alluvium on the valley floor. The colluvial-alluvial deposits overlie highly to extremely weathered dacite. The site is drained by small headwater tributaries of Woden Creek.

The poorly developed colluvial-alluvial soils which cover the site range from skeletal soils on the higher slopes and ridge, to a minimal podzolic soil on the lower slopes and valley floor. The colluvium shows distinct layering and contains bands of dense clay that have been interpreted as buried soils; the clay bands extend over most of the site.

FIGURE 1



MUGGA SOUTH LANDFILL SITE

Rock Outcrop - Extremely Weathered to Highly Weathered Volcanic

× 1-6 Drillholes from 1976 Investigation

× 7-14 Drillholes this Investigation

⊗ 8 Drillholes cased for leachate monitoring

A Seismic traverse

Approximate boundary of site

Dam and embankment

Scale

0 100 200 250 m

1:5,000

The drillholes of the previous investigation, numbered 1-6 inclusively (Fig. 1), failed to encounter bedrock; the auger refused to penetrate an indurated colluvial layer that immediately overlies the dacite. The indurated colluvium blankets the site, although it is thin in some areas.

Blue-grey porphyritic dacite forms the ridge to the east and crops out on the higher slopes at the site. It was intersected in drillholes 7, 9, and 10.

SUBSURFACE INVESTIGATION

Eight drillholes, numbered 7 to 14 inclusively, were drilled between 9 and 18 August 1977, and four seismic traverses (A to D) were completed during August-September 1977. Of the eight drillholes, four (7, 8, 9, and 10) were primarily for the determination of subsurface excavation conditions and were drilled to a depth of 12 m. The other drillholes (11, 12, 13 and 14) were for monitoring groundwater-levels and were equipped with slotted casing; they will also be used to sample fluids for leachate testing. Holes 8 and 9 were subsequently cased for leachate monitoring. Logs of the drillholes are appended as Appendix 2.

Drillholes 7, 8, and 9 encountered thick alluvial sediments, consisting of gravels, sands and clays. Drillhole 8 was completed in alluvium at a depth of 12 m. Drillhole 10 encountered colluvium to 2 m, and extremely weathered volcanic bedrock? to 7m. The colluvium will be suitable for compacted low-permeability fill or blanket cover (R. Evans, D.G. Bennett, & G. Jacobson, 1978).

The seismic traverses (Plate 1) show that low-velocity material, less than 1200 m/s, is present throughout the area; generally easy excavation (rippable) is expected to about 5 m, with some areas on the lower slopes rippable to 9 m (see Appendix 1). Seismic velocities of 1000 to 1500 m/s are equated to indurated colluvium and extremely weathered bedrock. Material with velocities of 1200-2000 m/s may be partly rippable, but excavation is expected to require blasting. A seismic high-velocity zone near drillhole 3 may cause some excavation difficulties.

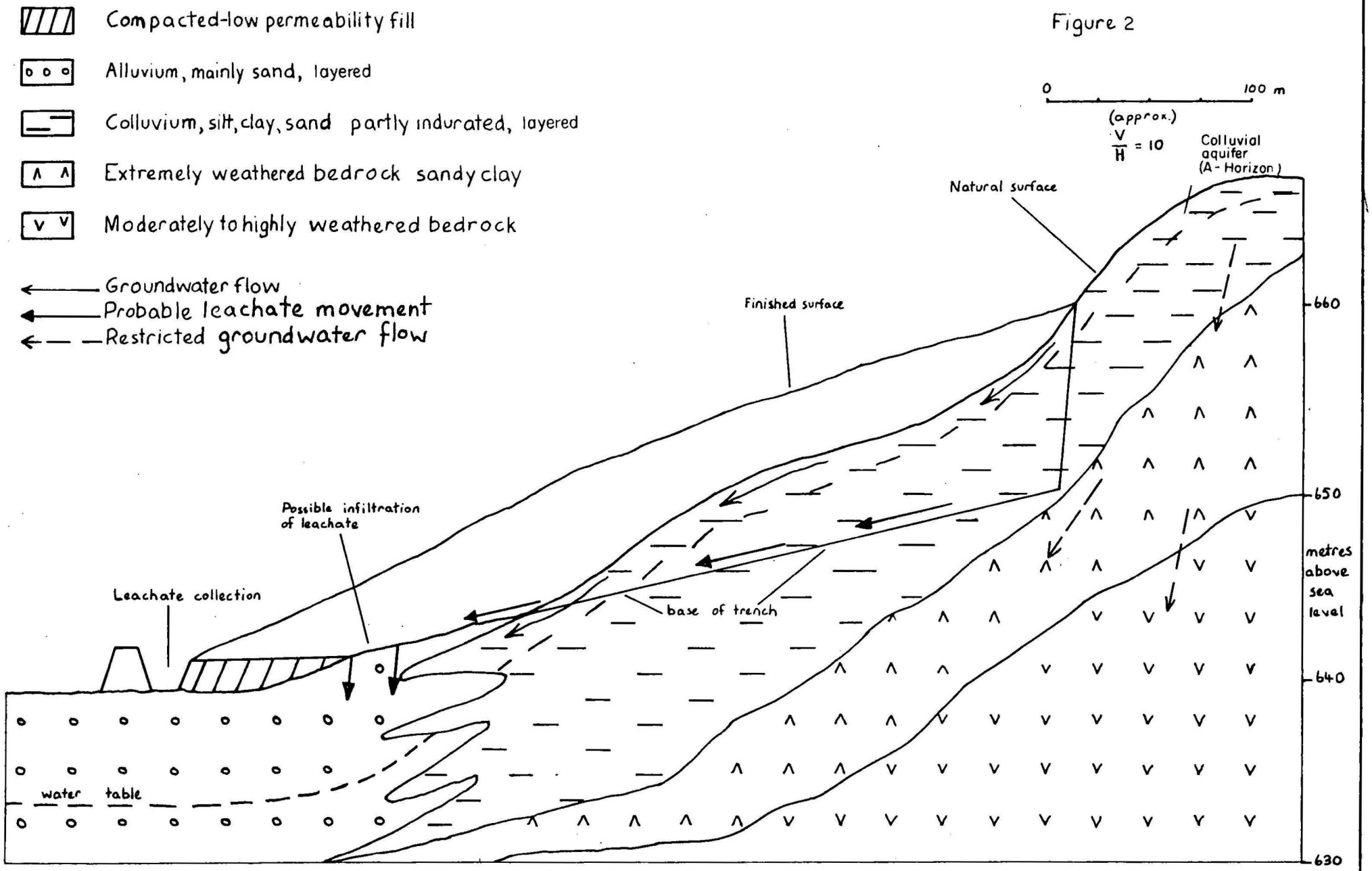
GROUNDWATER

Groundwater occurs in both perched colluvial/alluvial aquifers and in deeper, fractured-rock aquifers. The drillholes to a depth of 12 m have mainly encountered the colluvial and alluvial aquifers. Groundwater was encountered in drillholes 7, 8, and 9 within 5 m of the surface, and occurs in gravely sandy aquifers in the alluvium. During heavy rainfall the water-table may enter the landfill trenches through their bases on the lower slopes, allowing leachate direct access to the alluvial aquifer. However, as the trenches on the lower slopes will be clay-blanketed, the groundwater will be confined and the trenches should stay relatively dry. Any upwards leakage through the confining clay blanket would be intercepted by the surface runoff collection from the trench.

The groundwater regime in the colluvial and alluvial aquifers is shown schematically in Figure 2. On the upper slopes, groundwater movement is mainly lateral and within the A soil horizon; vertical infiltration is restricted by a relatively impermeable, indurated, colluvial layer. The downslope groundwater flow recharges the groundwater in the valley floor alluvium (Fig. 3). The A horizon becomes saturated after rain, exhibiting thixotropic properties. Some difficulty in moving equipment around the site is to be expected after rain and during the initial stages of development.

On the upper slopes of the site, most of the landfill trenches will be excavated in colluvium and extremely weathered bedrock (Appendix 1). This material is relatively impermeable and most of the leachate generated within the refuse is expected to drain downslope along the base of the trenches. On the lower slopes of the site, however, there is an area where the landfill would be in contact with relatively permeable alluvium. Clay-blanketing in the base of the trench is recommended in this area to seal the base of the landfill and restrict infiltration of leachate through the alluvium to the groundwater. The section of the lower slope that is to be built up will require compacted low-permeability material. Colluvium from the trenches upslope would be suitable for blanketing the base of the trench and for low-permeability compacted fill.

Figure 2



MUGGA SOUTH LANDFILL SITE
DIAGRAMMATIC CROSS-SECTION SHOWING GROUNDWATER MOVEMENT

The low water-table in the area, and the surface-water control measures proposed by the consulting engineers, will keep waste relatively dry, and the amount of leachate emanating from the trenches is expected to be small.

Hydraulic conductivity tests were made in holes 8 and 9 by a 'bailer' test, and in holes 12 and 13 by an analysis of residual drawdown. The results are set out below (Table 1).

TABLE 1. PERMEABILITY TESTING OF DRILLHOLES

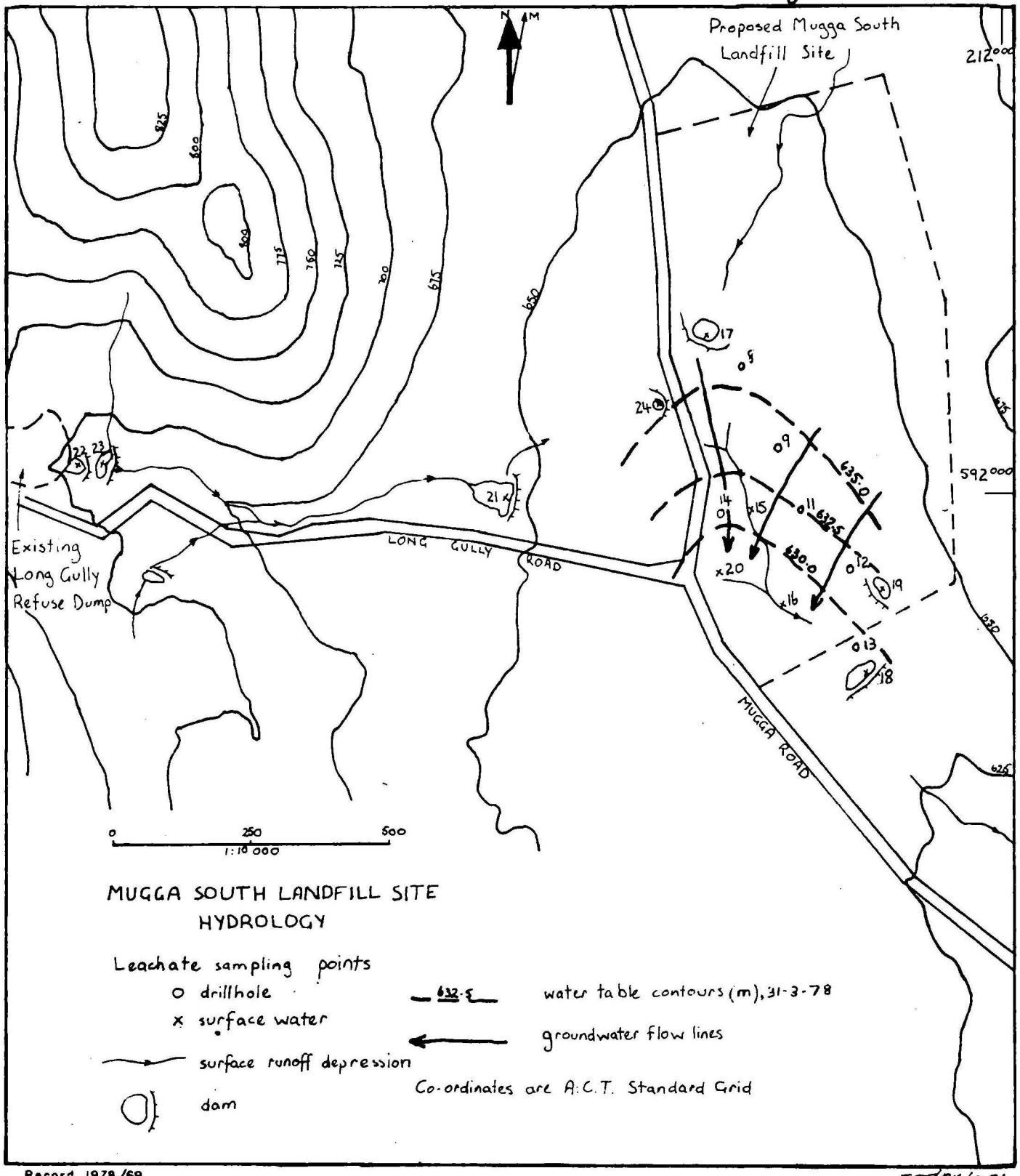
Hole No.	Hydraulic Conductivity (m/day)	Test Type
8	0.11	'Bailer'
9	0.09	'Bailer
12	0.03	Residual drawdown
13	0.04	Residual drawdown

LEACHATE MONITORING

Drillholes 8, 9, 11, 12, 13, and 14 were set up as piezometers to monitor possible leachate pollution of the groundwater. Drillholes 8 and 9 will be used temporarily until they are obliterated by trenches as the landfill site develops southward from the northern boundary. Additional information is required to assess the contribution that the Long Gully landfill site (Fig. 3) is making to groundwater pollution, as subsurface drainage from Long Gully enters the groundwater system just south of the Mugga South site (Fig. 1). Drillhole 14 already samples the Long Gully leachate, and three additional sampling holes are proposed.

Background water quality sampling started in November 1977 and some results are given in Table 2. The locations of sampling points are shown in Figure 3. It is proposed to monitor the possible development of leachate every 4-6 months in conjunction with the Department of the Capital Territory, and to use dissolved organic carbon as the main water quality parameter (Hughes, Eccles, & Malcolm, 1974). Background

Figure 3



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ISS/A16/2074

TABLE 2. CHEMICAL ANALYSES OF SURFACE WATER AND GROUNDWATER

by Conservation and Agriculture Branch, Dept. of the Capital Territory.

Sampling points (See Fig. 4)	Sample Date	Conductivity microsiemens/ cm	Hardness as $CaCO_3$ (mg/l)	Chloride (mg/l)	Dissolved Organic Carbon (mg/l)
8 (drillhole)	8.11.77	4000	940	860	1.0
9 (drillhole)	"	1300	620	138	0.7
11 (drillhole)	"	60	30	10	2.3
12 (drillhole)	"	3000	720	600	4.7*
13 (drillhole)	"	620	146	30	1.5
14 (drillhole)	"	640	150	158	3.7*
17 (dam)	"	70	28	8	14.9
18 (dam)	"	490	192	80	14.3
19 (dam)	"	120	40	18	12.9
20 (surface)	"	880	324	158	14
21 (dam)	"	1200	416	140	34
22 (dam)	"	1200	370	132	59
23 (dam)	"	1700	650	194	50
24 (dam)	"	670	262	86	27

*Results may be affected by sediment

values of dissolved organic carbon have been 1-5 mg/1 in groundwater and 14-50 mg/1 in dam water. The higher values in some dams reflect the proximity of leachate from the Long Gully refuse disposal site.

Detailed chemical analyses of some groundwater samples have been done by AMDEL (Table 3). The variations in salinity may reflect the different aquifer types. Bore 11 in alluvium had 70 mg/1 total dissolved solids, while the bores in fractured-rock aquifers had 400-1400 mg/1 total dissolved solids. However, the detailed analysis of cations and anions shows very little correlation.

CONCLUSIONS AND RECOMMENDATIONS

1. The thickness of readily excavated material is consistently greater than 5 m over most of the Mugga South landfill site, and is correlated with seismic velocities of less than 1200 m/sec.
2. Material with seismic velocities of 1200-2000 m/sec may be partly rippable but will require some blasting.
3. Groundwater-levels are generally below 4.0 m from the surface. With clay-blanketing the trenches should remain free from major groundwater leakage.
4. The colluvial cover will be suitable for compacted low-permeability blanketing.
5. Monitoring of the contribution of leachate from the Long Gully refuse disposal site is required to correctly evaluate the contribution of leachate from the Mugga South site.
6. After rain, saturated soils near the surface may restrict movement of equipment until drainage is provided.

TABLE 3. DETAILED BACKGROUND GROUNDWATER CHEMISTRY

(analyses by AMDEL, Feb. 1978 in mg/l)

	Bore 9	Bore 11	Bore 12	Bore 13
Calcium	147	3	98	35
Magnesium	62	3	67	15
Sodium	65	18	368	116
Potassium	2	1	7	1
Bicarbonate	678	38	697	420
Sulphate	11	11	40	28
Chloride	135	7	526	20
Nitrate	5	9	30	10
Total Dissolved Solids	760	70	1478	432
Total hardness as $CaCO_3$	622	20	520	149
Conductivity (microsiemens/cm)	1205	102	2303	656
pH	7.8	6.7	7.6	7.7
C.O.D.	23	25	25	11
Total nitrogen	0.2	0.3	0.8	0.4
Surfactants	0.15	1.05	0.13	0.075
Pet. spirit extract	6.0	1.0	2.5	1.0
Cadmium	<0.01	<0.01	<0.01	<0.01
Chromium	<0.05	<0.05	<0.05	<0.05
Copper	<0.04	<0.04	<0.04	<0.04
Iron	<0.05	0.04	<0.05	0.34
Manganese	0.06	0.04	<0.01	0.01
Nickel	<0.05	<0.05	<0.05	<0.05
Lead	0.18	<0.1	<0.1	<0.1
Zinc	0.10	0.07	0.01	0.01

REFERENCES

BUREAU OF MINERAL RESOURCES, 1975 - Internal File No. 1166

EVANS, R., BENNETT, D.G., & JACOBSON, G., 1978 - Geological and geophysical investigations of five alternative landfill sites, South Canberra and Tuggeranong, ACT, 1976. Bureau of Mineral Resources, Australia, Record 1978/68

HUGHES, J.L., ECCLES, L.A., & MALCOLM, R.L., 1974 - Dissolved Organic Carbon (DOC), an index of organic contamination in groundwater near Barston, California. Ground Water, 12, 283-90.

APPENDIX 1. CATEGORIES OF WEATHERED ROCK

Fr	Fresh	Rock intact, joints may be limonite-stained and clay-coated.
SW	Slightly weathered	Slightly discoloured, not noticeably lower in strength.
MW	Moderately weathered	Discoloured, noticeably weakened. N-size drill core can't be broken by hand.
HW	Highly weathered	Discoloured and weakened. N-size drill core generally broken by hand.
EW	Extremely weathered	Rock decomposed to soil and extremely discoloured, original rock fabric mostly preserved.

APPENDIX 2

LOGS OF DRILLHOLES 7-14, DECEMBER 1977

N.B. For logs of drillholes 1-6, December 1976, see BMR Record 1978/68: Geological and geophysical investigations of five alternative landfill sites, South Canberra and Tuggeranong, ACT, 1976.

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

GRAIN SIZE CHART

Classification	Range of grain size	
	U.S. Standard Sieve Size	Grain Size in Millimetres
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	305 to 76·2
GRAVEL		
coarse	3" to No. 4	76·2 to 4·76
	3" to 3/4"	76·2 to 19·1
fine	3/4" to No 4	19·1 to 4·76
SAND		
coarse	No. 4 to No. 200	4·76 to 0·074
	No. 4 to No 10	4·76 to 2·00
medium	No. 10 to No. 40	2·00 to 0·420
fine	No. 40 to No. 200	0·420 to 0·074
SILT & CLAY	Below No. 200	Below 0·074

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 7 Date: 9-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M, W, P, L, W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual, Alluvial Colluvial, Decomposed rock, Horizon A, B, C, Buried soil]
		Silt (organic)	SM	Dark Brown	M	Moderate k	Apedal			A1
		Sandy Silt	SM	Bleached	W	Moderate k	Apedal	Aq	35	Bleached A2
1		Sandy Clay	SC	Olive - Brown	D	Low k	W.P.			B1
		Gravelly Clay Sesqui-oxides	GC	Yellow-Brown, Red Mottled	D	Low k	Apedal Massive		45	
2		Clayey Sand	SC	Brown	M	High k	Apedal	Aq	40	Alluvial ▼ S.W.L. 9.8.77
3		Sandy Clay Sesqui-oxides (Large areas of MnO straining)	SC	Grey - Brown	D	Low k	? W.P.		75	
		Clayey Sand (Loose) (Well sorted)	SC	Brown	M to W	High K	Apedal Porous	Aq		
4		Sandy day, mod. indurated	SC	Grey - Brown	D	Low K	W.P.			
		Clayey well sorted Sand (Loose)	SC	Brown	M to W	High K	Apedal Porous	Aq	55	
5		Sandy Clay, mildly indurated	SC	Grey Brown	D	Low k	Apedal			
		Clayey well sorted Sand (Loose)	SC	Brown	W	High k	Apedal	Aq	40	
6									35	
7		Sandy Clay Shows large quartz grains within the clay	SC	Yellow-Brown	D	Low k			30	Extremely Weathered Bedrock
8		Competent Hard Volcanic bedrock to 12m. Medium to highly weathered. MnO stained on joints, clay skins Moderate to Highly fractured.							80	Bedrock
9									90	
10										

W.P. - Weakly pedal

Driller: STEWART BROS. Drill type: PIONEER Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 7 Date: 9-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M > PL, W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
11		As Above				Groundwater encountered within top 2-3m			100 / 90	As Above
12						Hole not cased.				

Driller: STEWART BROS. Drill type: PIONEER Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

RL 641·08m

Project: MUGGA SOUTH LANDFILL SITE Hole: 8 Date: 11-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D<M<PL<W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Organic Silt	ML	Dark brown	M	High k	Ap. P			A1
		Sandy Silt (clay)	SM	Black	W	High k	Apedal Porous	Aq	60	A2
		Sandy Clay	SC	Yellow-Brown	D	Moderate-Low	Apedal Massive			?B
1		Clay	CH	Yellow, Brown	D	Low k	Ap. M			Hard Pan
		Clayey Sand Pinhole structure (open)	SC	Light Brown	M	High k	Apedal Porous	Aq ?	40	Alluvium
2		Indurated Clayey Sand	SC	Yellow-Brown	D	Low k	Apedal Massive			
		Clayey Sand (well sorted)	SC	Brown	W	High k	Apedal Porous	Aq	60	
3		Some small indurated layers within (5cm)							35	
4									60	
		Sandy Clay	SC	Mottled Brown	M	Moderate k	Apedal			
5		Clay (some sand within the peds)	CH	Mottled-Grey, Brown, Red.	D	Low k	Weak Pedal		50	S.W.L. 11·8·77 Paleosol
6		Sandy Clay	SC	Mottled Brown		Moderate k	Apedal			
		Clay	CH	Mottled-Grey, Red, Brown.	D	Low k	Weakly Pedal		50	Alluvium
7		Clayey Silt	CL	Yellow & Brown	D	Moderate-Low k	Weakly Pedal		95	
8		Clayey Sand with some large gravel (2x4cm)	SC	Brown	M	Moderate-high k	Apedal Porous		65	
9									25	
10										

Driller: STEWART BROS. Drill type: PIONEER ■ Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 8 Date: 11-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D.M.<W<PL.W	Permeability (k) / Groundwater Observations	Massive Porous Structure Crumb etc.	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
11		Banded Silt (2-5mm) bands Some sand (not layered)	ML	Yellow & Brown	D	Moderate -Low k	Apedal Massive		45 25	alluvium
12						Hole cased for leachate monitoring Groundwater encountered within top 2-3m. Standing water level approx. 5m				

Driller: STEWART BROS. Drill type: PIONEER Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

R.L. 638·93 m

Project: MUGGA SOUTH LANDFILL SITE Hole: 9 Date: 16-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D<M<P L,W	Permeability (k) / Groundwater Observations	Massive Porous Cromb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		organic silt	ML	Dark brown	M	high K	Ap. P			A1
		silt	ML	black	M	high K	Ap, P			A2
		Silty Sand	SM	Yellow-Brown	M	High K	Apedal Porous		70	Sub-Solum?
		Clayey sand	SC	Yellow brown	D	Moderate K	Ap.			
1		Clay	CH	Mottled	D	Low K	Ap.			Hard Pan
		Clayey Sand (open) iron stained	SC	Brown Mottled	M	High K	Apedal Porous		50	
2									60	
3		(sandy) clay - dense	CH	Olive Brown	D	Low K	W.P.			Alluvium
		Sandy clay	SC	Brown	D	Low K.	Apedal Porous		40	
4		Clay & Silt (banded) Some minor sandy layers	CL	Olive Brown / Yellow-Brown	D	Low K	Apedal / Massive		50	▼ S.W.L. 16·8·77
5									70	
6		Clayey Sand, layered	SC	Light Brown	M	High K	Apedal Porous	Aq	100	
7									90	
8									40	
9		Well sorted Sand	SW	Brown	W	High K	Apedal Porous	Aq	65	
10		Weathered Volcanics		Purple						E.W. Bedrock

Driller: STEWART BROS. Drill type: PIONEER Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 9 Date: 16-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D.M.×P.L.W	Permeability (k) / Groundwater Observations	Massive Porous Structure Crumb etc.	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual, Alluvial Colluvial, Decomposed rock, Horizon A, B, C, Buried soil]
11		Extremely Weathered Volcanics Very incompetent		Purple	M	High k	Crumb		50 60	Extremely Weathered Bedrock
12						Hole cased for leachate monitoring Groundwater encountered in top 2-3m Standing water level approx 4.5m				

Driller: STEWART BROS. Drill type: PIONEER [redacted] Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 10 Date: 16-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M, W, Pl, W	Permeability (k) / Groundwater Observations	Massive Porous Structure Crumb etc.	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Silt (organic)	SM	Dark Brown	M	High k	Ap. P.			A1
		Clayey silt	ML	Light grey	M	High k	Ap. P.		60	A2 - bleached
1		Clayey Sand	SC	Red & grey Yellow mottled	D	Moderate - Low k	Apedal		70	B
2		Clayey Sand (indurated)	SC	Yellow - Brown	D	Low k	Apedal			Indurated colluvium
3		Clayey Sand (Slightly coarser than the above)	SC	Yellow - brown	D	Low k	Apedal		50	Extremely Weathered Bedrock ?
4									30	
5									55	
6									45	
7									25	
8		Volcanic rock coarse grained Moderately fractured							25	Highly Weathered Bedrock
9									25	
10									25	

Driller: STEWART BROS. Drill type: PIONEER Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

Project: MUGGA SOUTH LANDFILL SITE Hole: 10 Date: 16-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M > PL, W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
11		As Above							25	As Above
12									25	
						No Water Hole not cased				

Driller: STEWART BROS. Drill type: PIONEER Not sampled

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GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

R.L. 637.33m

Project: MUGGA SOUTH LANDFILL SITE **Hole:** 11 **Date:** 17-8-77 **Logged by:** R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text. plast)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M, W, Pl, W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure		Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Clayey Sand	SC	Brown	M	Moderate k	Apedal Porous	Aq	55	Alluvium - Colluvium.
		Sandy clay	SC	Yellow-Brown	D	Low k	Apedal Massive			
1										S.W.L. 17.8.77
2									30	
3							Apedal		20	
		Clayey Sand	SC	Brown	M	Moderate to Low k	Porous to Massive	Aq	40	
4		Varying percentages of clay and sand throughout.								
5					D to M				45	
6									30	
7		Clay	CL	Yellow-Brown	D	Low k	Massive		50	
									80	
8		Slightly clayey Sand	SC	Dark Brown	M	Moderate k	Porous	Aq	60	
9										
10									50	

Hole cased for leachate monitoring. Standing water level 1.15m

Driller: STEWART BROS. **Drill type:** PIONEER **Not sampled**

Record 1978/69

155/A16/2086

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Geological Log of Auger Hole

R.L. 635·53m

Project: MUGGA SOUTH LANDFILL SITE Hole: 12 Date: 17-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text. plast.)		Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D, M, W, PL	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure		Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Silty Sand	pin-hole structures	SM	Dark Brown	M	High k	Apedal Porous		60	A1
		Silty Sand	pin-hole structures	SM	Light Grey	W	Very-high k	Apedal Porous	Aq		A2 Bleached
1		Clayey Sand	Intense Sesqui oxide concentn.	SC	Mottled, Brown, Grey, yellow	D	Moderate-Low k	Apedal Porous		40	Sub-Soloum
2		Clayey Sand / Gravel Indurated		SC	Yellow-Brown	D	Low k	Apedal Massive		60	Indurated Colluvium
3											▽ S.W.L. 17·8·77
4										30	
5		Dense Sandy Clay		SC	Yellow-Brown Grey &	D	Low k	Apedal Massive		90	Paleosol
6		Possibly Alluvial. Shows minor individual beds (1 to 2 mm thick) Sand - Extremely Weathered			Red Brown Dark Brown Mottled					70	
7										50	
8					Dark Brown					75	
9										55	
10							Hole cased for leachate monitoring.			40	

Standing water level 3.10 m

Driller: STEWART BROS. Drill type: PIONEER Not sampled

Record 1978/69

155/A16/2087

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

RL. 630·51m

Project: MUGGA SOUTH LANDFILL SITE Hole: 13 Date: 17-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D.M.>PL.W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Silty Sand Corganic at top	SM	Dark Brown	M	High k	Apedal Porous		30	A1 ▼ S.W.L. 17.8.77
		Silty Sand	SM	Light grey	M	High k	Apedal Porous			A2 Bleached
1		Clayey well sorted Sand	SC	Yellow-Brown	M	High k	Apedal Porous	Aq	75	Alluvium-Colluvium
2									75	
3		Clay — Contains some Extremely weathered gravel (rock fragments). All grain size obliterated, shows. As colour change	CL	Grey, Yellow-Brown Mottled	D	Low k	Weak Pedal		70	
4		Clayey well sorted Sand	SC	Yellow-Brown	M	High-Moderate k	Apedal Porous	? Aq		
		Clayey Sand E.W. Bedrock (Volcanic)	SC						75	Extremely Weathered Bedrock.
5						Hole cased for leachate monitoring. Standing water level 0.49m				

Driller: STEWART BROS. Drill type: PIONEER. Not sampled

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS

Geological Log of Auger Hole

R.L. 637.74m

Project: MUGGA SOUTH LANDFILL SITE Hole: 14 Date: 18-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text, plast)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D.M > < PL.W	Permeability (k) / Groundwater Observations	Massive Porous Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
		Silty Sand Some Gravel layers	SM	Dark Brown	M	High k	Apedal Porous	Aq	25	A Horizon
1		Silty Sand Indurated	SM	Yellow -Brown	D	Low k	Apedal Massive		15	▼ S.W.L. 18.8.77 Colluvium
2		Silty Sand (some clay)	SM	Brown	W	High k	Apedal Porous	Aq	30	Colluvium
3		Silty Sand (Indurated Gravel base).	SM	Yellow -Brown	D	Low k	Apedal Massive		30	Indurated colluvium
4									35	
5		Silty Sand. Slightly Clayey, Indurated	SM	Yellow -Brown	D	Low k	Apedal Massive		15	Indurated colluvium
6									20	
7									40	
8		Extremely weathered Volcanics		Yellow -Brown					35	Extremely weathered Bedrock
9									40	
10										

Driller: STEWART BROS. Drill type: PIONEER Not sampled

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Geological Log of Auger Hole

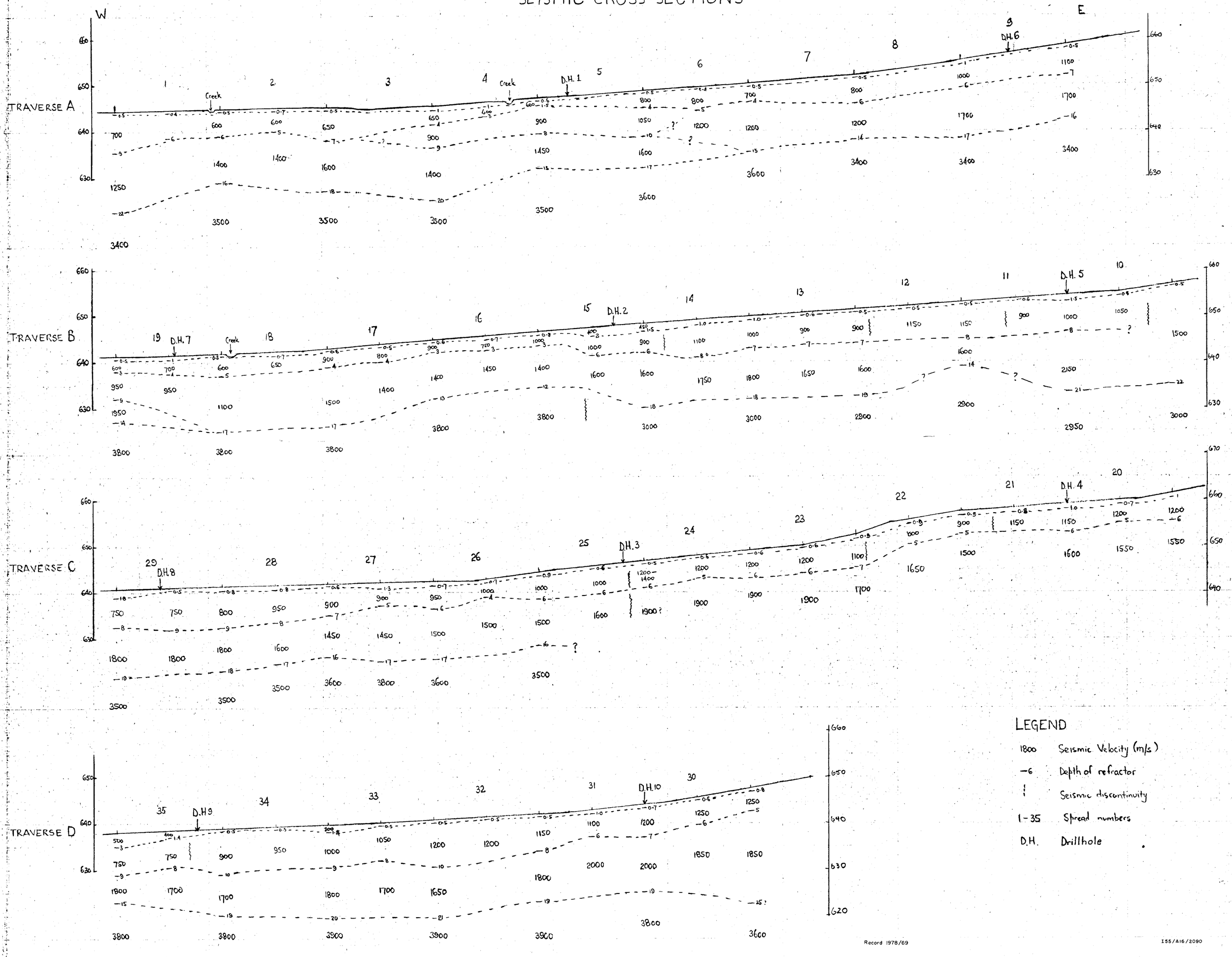
Project: MUGGA SOUTH LANDFILL SITE Hole: 14 Date: 18-8-77 Logged by: R.E.

DEPTH (metres)	LOG	ENGINEERING SOILS DESCRIPTION (Text. plast.)	Unified symbol	COLOUR Pale or dark Comb. col. R-B, Y-B	Moisture D.M > < PL.W	Permeability (k) / Groundwater Observations	Massive Pervas Crumb etc. Structure	Aquifers	Core Recovery (%)	GEOLOGICAL PEDOLOGICAL DESCRIPTION [Eolian Residual Alluvial Colluvial Decomposed rock Horizon A, B, C Buried soil]
11		Moderate to highly weathered Volcanics				Hole cased for leachate monitoring. Standing water level 1.32 m			30	M.W. to H.W. Bedrock
12									65	

Driller: STEWART BROS. Drill type: PIONEER. Not sampled

MUGGA SOUTH LANDFILL SITE

SEISMIC CROSS-SECTIONS



LEGEND

1800	Seismic Velocity (m/s)
−6	Depth of refractor
⁞	Seismic discontinuity
1-35	Spread numbers
D.H.	Drillhole

Record 1978/69

155/A16/2090