DEPARTMENT OF
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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1974/184

ENGINEERING GEOLOGY OF TUGGERANONG TOWN CENTRE, A.C.T.

by

P.H. VANDEN BROEK

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CONTENTS

SUMMARY

An engineering geological study was carried out for the proposed Tuggeranong town centre. The area is underlain by rhyodacite with minor areas of shale, rhyolite, and granite porphyry. Rock is exposed mostly as scattered outcrop, though areas of scattered boulders predominate in the north-western quarter. Weathering depths vary considerably; the central part of the area may be completely weathered to 6 m; below 6 m highly weathered rock commonly extends to about 11 m. Adjacent to Tuggeranong Creek and the Murrumbidgee River most of the weathered mantle has been removed. A number of faults and several prominent joint sets occur within the area.

The soils include skeletal soil, colluvium, slopewash, alluvium, and light and medium residual clay soils. Most soils are stable to moderately expansive; some local problems may occur where silty soils receive seepage water and lose most of their bearing strength.

In most places the potentiometric surface is well below ground surface; it is expected to rise in the central part of the area when the proposed lake on Tuggeranong Creek is filled after construction of the Tuggeranong Dam.

The soils thicknesses and the depths to which it should be possible to excavate without blasting have been estimated from auger logs, known rock and soil distribution, and geomorphic history.

Groundwater conditions at a particular site have been estimated from the level of the potentiometric surface and known rock conditions.

Good foundation conditions exist for all types of structures in most of the area and economic deposits of fine red sand may be located.

No major problems exist in the area for construction of a town centre.

INTRODUCTION

At the request of the National Capital Development Commission, the Bureau of Mineral Resources carried out an engineering geological study of an area set aside for the future town centre at Tuggeranong, A.C.T. (Fig. 1). This report outlines the investigations undertaken, and sets out the conclusions and recommendations of the study.

The site was mapped to determine the nature of the underlying rock, the types of soil present and their thicknesses, and to evaluate subsurface water conditions. This information was then used to assess foundation conditions and excavation characteristics, and to delineate engineering construction materials.

The investigation was carried out in two stages. The first stage covering the area initially designated to be the town centre (Fig. 2) was previously reported (Vanden Broek, 1973). An additional area known as Stage 2 was subsequently added. This Record presents the results of investigations in both areas, sometimes referred to as the Tuggeranong town spine, but referred to here as the Tuggeranong town centre.

BEDROCK

General

The distribution of the various rock types, the areas of rock outcrop, the nature of rock weathering, and rock defects was established by detailed outcrop mapping at 1:2400 scale; additional information was obtained by drilling ten observation bores for water-level measurement and by assessing the results of nine seismic spreads surveyed by the BMR Engineering Geophysics Group (see Plate 1).

The principal rock units within the area are purple-pink and blue-grey rhyodacite. Both are Siluro-Devonian acid volcanic rocks that comprise part of the Deakin Volcanics (Sud) in the Canberra 1:50 000 Sheet area.

Table 1 summarizes the composition, form of outcrop, and state of weathering of the rock types. An explanation of the various degrees of weathering is given in Appendix 1, and brief descriptions of the various rock types constitute Appendix 2.

Rock exposed at the surface has been mapped as continuous outcrop, scattered outcrop, or scattered boulders. Continuous outcrop indicates rock exposure over a significant area of about 25 m^2; scattered outcrop contains a number of rock outcrops, closely spaced, separated by small areas that lack outcrop. Areas of scattered boulders generally contain no prominent outcrops, but consist of blocky to rounded boulders in groups or scattered over the surface.

A volcanic complex, a concentric volcanic intrusion, occurs just outside the western margin of the town centre area in the bed of the Murrumbidgee River, downstream from the Pine Island Reserve. This area has been recommended for preservation as a geological monument.

Weathering

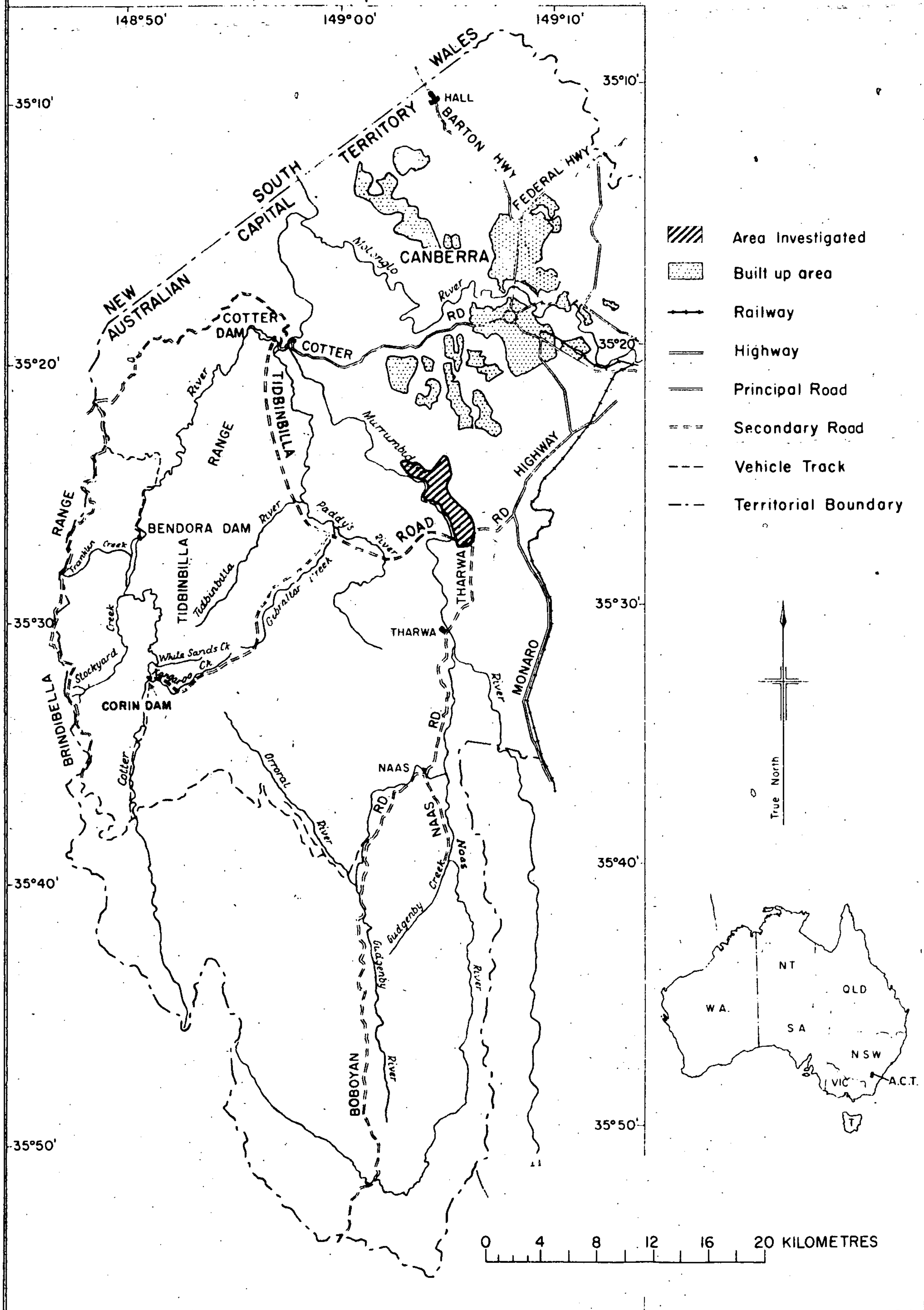
Weathering characteristics of the various rock types, except the rhyodacites, are given in table 1. Because the rhyodacites are so extensive and underlie most of the town centre a more detailed description of their weathering characteristics follows.

The central part of the town centre area is probably remnant of an old Tertiary weathering surface as weathering is relatively uniform and decreases with depth. A typical weathering profile beneath the upper soil

FIGURE 1

LOCALITY MAP

TUGGERANONG TOWN CENTRE



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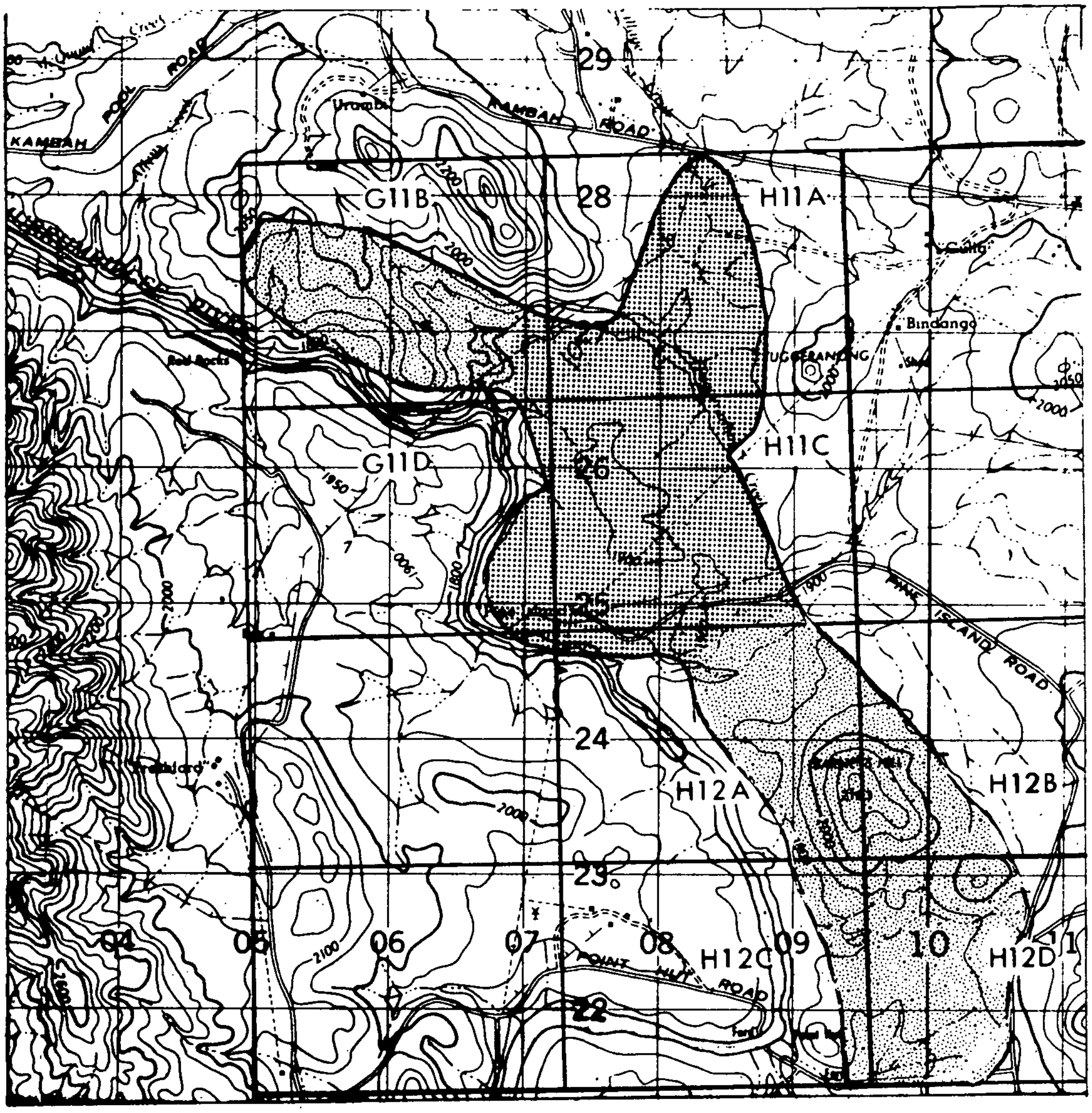
AREAS COVERED BY STAGE 1 AND STAGE 2

TUGGERANONG TOWN CENTRE



0 1 2 3 4 Kilometres

Area of Stage 1

Area of Stage 2

—2000— Contour in feet; interval: 50 feet

Creek, intermittent

Homestead

Road

H11A **1 : 2400 A.C.T. detail series sheet**

Conversion table

ft	m
1800	549
1850	564
1900	579
1950	594
2000	610
2050	625
2100	640
2150	655

TN MN

SCALE 1 : 50,000	COMMONWEALTH OF AUSTRALIA BUREAU OF MINERAL RESOURCES CANBERRA, A.C.T.	
Base map/survey Military Map	TITLE Areas covered by stage 1 and stage 2	
Geology by		
Compiled and checked P.V.B. Project geologist / Checked and approved A.T. Laws Senior geologist	PROJECT Tuggeranong Town Centre	
E.G. Wilson Supervising geologist	To accompany Record 1974/184 / Drawn by	Drawing No. 155/A16/1125

TABLE 1. SUMMARY OF ROCK TYPES

Rock type	Distribution and occurrence	Origin and form	Exposure	Form of outcrops	Weathering	Defect
Purple-Pink rhyodacite	Extensive, over S part of Plate 1	Thick sheet of welded tuff	On Tuggeranong hill, in S near right-angle bend in Tuggeranong Cr, and on Barneys Hill, poor and deeply weathered exposures elsewhere	Mostly scattered outcrop. Continuous outcrop in places along Tuggeranong Cr	See Section on weathering in text	Mostly jointing but fracturing and shearing where associated with faulting
Blue-grey rhyodacite	Widespread, over W part of Plate 1	Thick sheet of welded tuff	Adjacent to Murrumbidgee R, and in NW of area. Poor on gentler slopes	Mostly continuous outcrop in bed of Murrumbidgee R, elsewhere scattered outcrops except in NW which is mostly scattered boulders		
Grey-green rhyodacite	Forms a wedge between two faults in S	Thick sheet of welded tuff	On SW slopes of Barneys Hill but poor elsewhere	Scattered outcrops and scattered boulders		
Rhyolite porphyry	Two outcrops close to fracture zone	Small rounded intrusions	In a creek bed, as flat water-worn rock surfaces. S of Barneys Hill	Continuous	Highly to completely weathered	Highly fractured
Granite porphyry	Close to faults or within fracture zones	Small veins dykes and stringers	Well exposed in creek beds especially where silicified near major fault zones	Continuous	Mostly highly weathered; slightly weathered where silicified	Minor fracturing
Micro-granodiorite	To W of area in bed of Murrumbidgee R	Small intrusive volcanic complex	As rock bars	Continuous	Slightly weathered to fresh	Not apparent
Chert and hornfels	Adjacent to microgranodiorite margin	Contact metamorphism	Along the E bank of Murrumbidgee R	Scattered boulders	Highly weathered	Closely jointed
Shale	One small outcrop but can be expected beneath adjacent soil cover	Probably tuffaceous shale interbed	Only exposure in creek bed in far SE	Continuous within outcrop area	Slightly weathered	Finely laminated or cleaved
Rhyolite	Three small outcrops	Small intrusions	Three low-lying exposures on low rises	Continuous within outcrop areas	Highly to moderately weathered	Not apparent
Quartz-epidote	Close to faults or within fracture zones	Mostly small veins and stringers	In creek beds, indicated by boulder-strewn hills, and quartz-covered areas	Continuous and as scattered patches	Not very susceptible to weathering	Minor fracturing
Old river gravel	Widespread adjacent to Murrumbidgee R	Thin remnant beds, 1 m	As boulder-strewn areas mixed with younger soils	Scattered pebbles, cobbles, etc.	Some pebbles, moderately weathered slate	

layer, as indicated by drilling, comprises as much as 6 m of completely weathered rock (in places up to 8 m), 5 m of highly weathered rock, and 3 m of moderately weathered rock; below which is slightly weathered or fresh rock. To the margins of this surface where Tuggeranong Creek and the Murrumbidgee River have stripped much of the weathered zone, and beneath steeper-sloping or high ground, a completely weathered rock layer, if present, is rarely more than 2 m, more commonly 1 m thick. Beneath this layer highly weathered rock is not generally well developed and moderately or less weathered rock usually occurs within 2 to 3 m of the surface.

Where rhyodacite is exposed at the surface continuous rock outcrop is usually slightly to moderately weathered and generally becomes less weathered with depth, but if the rhyodacite is sheared or closely jointed it is likely to be highly to completely weathered to considerable depths. However, shear zones are not expected to constitute more than two percent of the rock in the town centre area. Areas of scattered rock outcrop include patches of slightly to highly weathered rock at the surface. Below the surface, completely weathered rock containing rock cores and patches of less weathered material usually occurs to depths of 4 to 5 m. Below this level moderately weathered rock is dominant. Areas of scattered boulders are largely confined to the northwest quarter of the area; they are underlain by moderately or less weathered rock within 1 to 2 m of the surface.

Strength

Samples of highly, moderately, and slightly weathered rhyodacite and some fresh rhyodacite were submitted to the Rock Mechanics Sub-section of the Geophysical Branch for uniaxial compressive strength and seismic velocity testing. Table 2 lists the rock types tested, their degrees of weathering, and the test results.

TABLE 2. LABORATORY RESULTS OF UNIAXIAL STRENGTH AND SEISMIC VELOCITY TESTS

Rock type	Degree of weathering	Uniaxial strength kg/cm^2	Seismic velocity m/s
Blue-grey rhyodacite	Highly weathered	-	2000 - 2500
" " "	Moderately weathered	190	5400 - 5800
" " "	Slightly weathered	280	5800 - 6000
" " "	Fresh	170*	5600 - 6000
Purple-pink rhyodacite	Highly weathered	-	4300 - 4700
" " "	Moderately weathered	90	4300 - 5300
" " "	Slightly weathered	210	5600 - 6000
" " "	Fresh	170*	5700 - 6100

*Premature failure along joint plane

The results of the uniaxial compression tests are much lower than expected; this is thought to be partly due to the fact that it was difficult to obtain core of the right dimensions (i.e. unbroken core of good quality) for the tests, and partly because some samples failed along joint surfaces before rock failure occurred.

Rock defects

The principal rock defects in the area are faults and joints (Pl. 1); faults are mostly associated with shear and fracture zones up to 100 m wide, and are mostly north-south trending. A prominant conjugate joint set is developed in the north-south and 112° directions (Fig. 3). A less frequently observed joint set is close to horizontal but these may be more common than surface mapping indicates; a more detailed description of the jointing is presented in Appendix 3.

Where shearing has accompanied faulting, the rocks are often completely weathered to considerable depths; where fracturing has occurred, faulting is often accompanied by small intrusions of granite porphyry and quartz-epidote veining.

Some opening of joints occurs within 400 m of the Murrumbidgee River, but the general absence of low-angle joints precludes any major stability problem in excavations.

SOIL

The distribution of soil types was derived from augering and by examining soil profiles in erosion gullies and roadcuts. The approximate distribution of soil types is shown in Plate 2, and Table 3 summarizes their general features.

Soil isopachs (depth contours) are shown in Plate 1. They are only approximate, and were derived from augering, drilling, and seismic results, from rock outcrop distribution and air-photo interpretation, and from comparison with adjacent areas of known soil depths.

The soils are described with reference to the unified soil classification system (Figure 4).

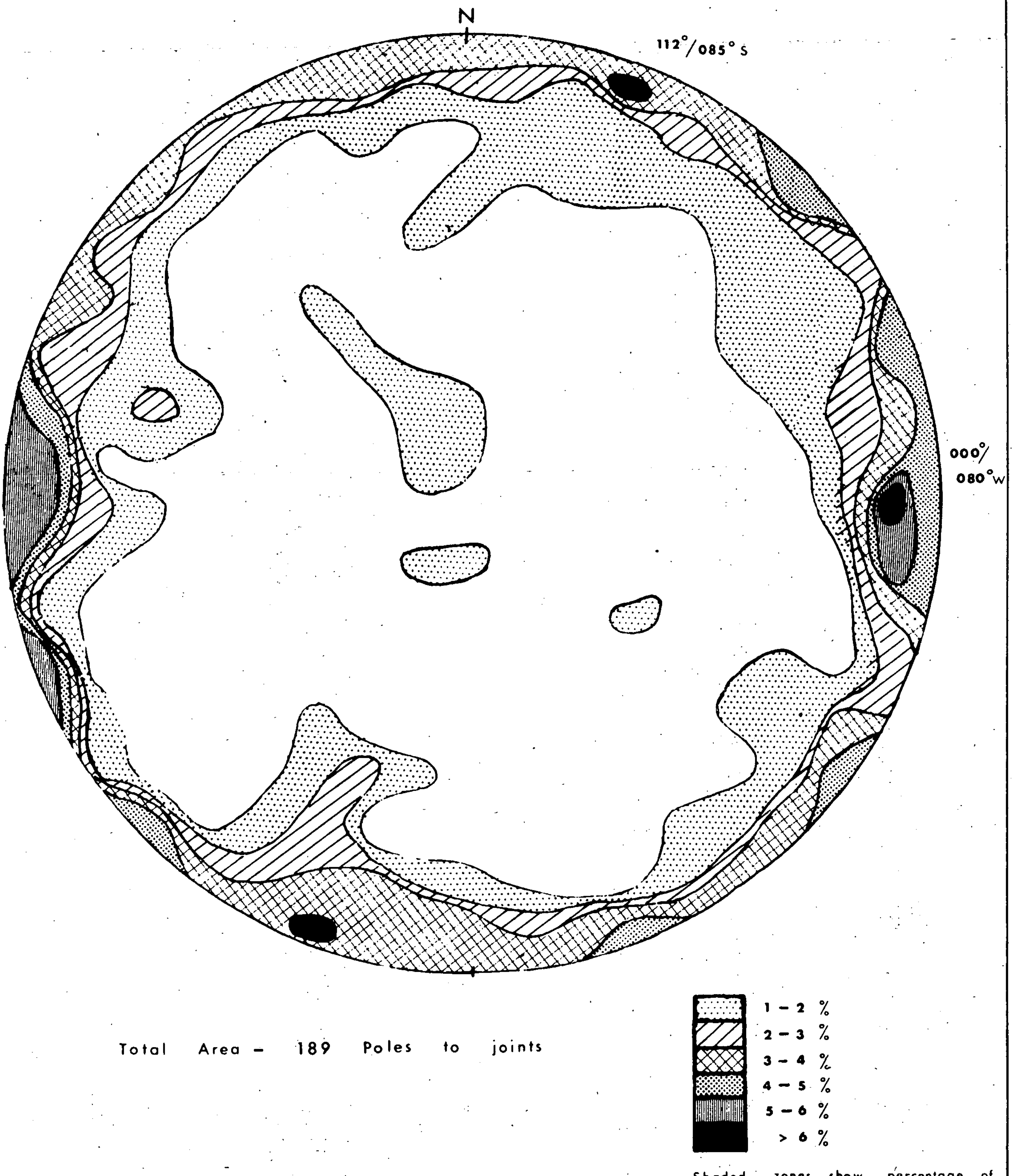
GROUNDWATER

Groundwater occurs in both the unsaturated and saturated zones; water in the unsaturated zone is referred to as vadose water, and is usually present during the wetter parts of the year, perched above the water-table.

FIGURE 3

TUGGERANONG TOWN CENTRE

Stereoplot of poles to joints



Total Area – 189 Poles to joints

Shaded zones show percentage of points per percentage of area

Drawn and compiled by J. Ceplecha

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Drawing No 155/A16/1126

UNIFIED SOIL CLASSIFICATION SYSTEM

FIGURE 4

CLASSIFICATION CHART

MAJOR DIVISIONS			SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS	More than 1/2 of soil > No 200 sieve size	GRAVELS (More than ½ 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-sard mixtures, little or no fines
			GM	Silty gravels, gravel-sand-silt mixture
			GC	Clayey gravels, gravel-sand-clay mixture
		SANDS (More than ½ 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

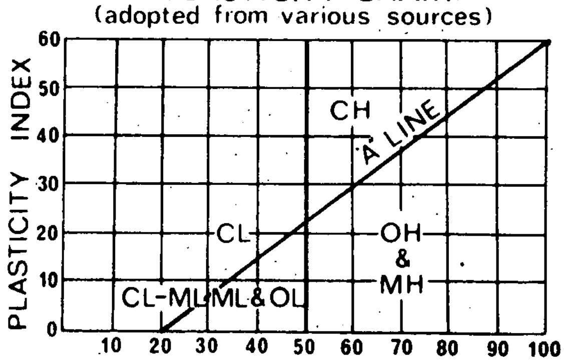
*fines – portion of a soil finer than a no. 200 sieve

GRAIN SIZE CHART

Classification	Range of grain size: U.S. Standard Sieve Size	Range of grain size: Grain Size in Millimetres
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	305 to 76·2
GRAVEL	3" to No. 4	76·2 to 4·76
coarse	3" to 3/4"	76·2 to 19·1
fine	3/4" to No 4	19·1 to 4·76
SAND	No. 4 to No. 200	4·76 to 0·074
coarse	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

PLASTICITY CHART

(adopted from various sources)



1973/165, fig. 3; 1974/184

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TABLE 3. SUMMARY OF SOIL TYPES

Soil type	Origin	Colour	Texture	Occurrence	Thickness (m)	Brief pedological description	Association	Soil water	Other features
Skeletal soil	Residual, developed from underlying parent material	Dark-grey or grey-brown	Gravelly, sandy silt (GM)	High ground and isolated hills, and where older soils stripped off, by sheet erosion	0.1-1	Very recent soil, no profile development	Usually underlain by moderately or highly weathered rock	Good infiltration, permeable and generally well above watertable	Clay-free, loose, non-cohesive. Good bearing strength.
Colluvium	Transported by gravity	Variable, usually same as parent weathered rock	Gravel-sand mixtures (GW or GP)	At the base of some hills, but above change of slope	1-3	Unstable cycle material	Usually overlies highly to moderately weathered rock	Good infiltration, may contain confined aquifers, good permeability, may store water and feed seepage areas downslope	Often loose and non-cohesive, but may be hard and cemented. Good bearing strength, often used as gravel pavement
Slopewash	Transported by mass wasting processes	Often light grey, white, or pinkish grey	Usually fine sand-silt mixtures (SM)	Longer, more gentle slopes	2-3	Unstable cycle material	Usually overlies highly or completely weathered rock	Only moderate infiltration and permeability	Often hard and cemented when dry, but weak and lacks cohesion when w Very low strength when charged wit water in poor-drainage areas. Usually has a honeycomb structure
Alluvium	Transported by water	Variable but often yellow-brown, grey-brown, or red-brown	Randomly interstratified; poorly sorted gravel, sand, silt and clay (GM-GC)	In the defined drainage depressions; the alluvium in the Murrumbidgee R is not included in this category	2-4	Usually includes older soil layers, may be quite complex	Usually overlies bedrock	Good infiltration into some layers. Often good horizontal permeability	Much of this material is at presen undergoing erosion, and gullying i common, bearing strength variable with layering
Light residual clay soils	Formed in situ on parent rock, older soil or transported soil	Upper layer grey-brown, lower layer orange-red or yellow-orange	Upper layer organic silt (OL) lower layer lean silty clay, sandy lean clay or sandy silt. (CL, CL-CH, or SM)	Developed over much of the area of moderate relief and which is undergoing only minor erosion	0.5-1	Red earths and red sandy soils, some minimal podzolics (gradational soil, A-B horizon)	Commonly overlies medium residual clay soils, alluvium, colluvium, or slopewash	Upper layer permeable but clayey B horizon retards infiltration	B horizon commonly contains iron oxide pisolites and usually has a good bearing capacity for small buildings
Medium residual clay soils	Formed in situ on parent rock or on heavy clay layers	Upper part of top layer dark grey, lower part of top layer grey-white. Upper part of bottom layer bright red or orange-yellow, lower part of bottom layer yellow-olive, or yellow-orange mottled	Upper part of top layer is organic silt (OL), lower part is inorganic silt. (ML) Upper part of bottom layer lean to medium plasticity clay (CL or CL-CH), lower part high plasticity or fat clay (CH)	In areas of low relief with well developed soil profile	1-2	Red and yellow podzolic soil	Usually overlies completely weathered rock or an older clay layer	Upper layers have good drainage but B horizon has low permeability	Lower layers are usually expansiv Top layers have very low strength but upper part of B horizon is qui firm and has good bearing strengt

Water in the saturated zone is referred to as phreatic water and in the Tuggeranong area mostly occurs in fractured rock aquifers. In the Tuggeranong town centre patches of boggy ground and seepage areas are widespread after heavy rain, and may be attributed to vadose water; their occurrence is shown in Plate 2. Three springs have been located; they are semi-permanent and are fed by phreatic water whilst the water-table is at a seasonal high level. The permeability of the various soil types is summarized in Table 3.

Groundwater in the saturated zone, phreatic water, flows from its recharge source to the east, the Isabella Plains area, and from the central part of the area down a pressure gradient that follows Tuggeranong Creek and falls westward to the Murrumbidgee River. Ten bores were sunk in the area between June and July 1973 for observation purposes and water-levels have been recorded since that time; logs of the bores are shown in Plate 1.

Phreatic water in fractured rock aquifers is generally of good quality, and usually contains less than 400 ppm total dissolved solids (T.D.S.), and a range of 200–400 ppm is common (Burton, 1967). Dissolved solids are usually calcium, magnesium, and bicarbonate ions. Eight of the ten observation bores drilled in the area had water flows of 0.2 - 0.7 m^3/h. Most water is present in the tension fractures of highly and moderately weathered rock zones though where the rock has been broken as the result of faulting, slightly weathered and fresh rock zones are the most permeable; this has occurred at bore holes 9 and 10 where flows in excess of 1 m^3/h were observed whilst drilling was in progress.

Drilling results indicate that a groundwater ridge extends north-south across the central part of the area in the vicinity of bore-holes 9, 1, and 10; the average or normal potentiometric surface here is 565 m above M.S.L. which is 13.5, 16, and 6.4 m below ground level at respective locations.

Hydraulic gradients away from this groundwater ridge vary, but are as steep as 1 in 30 westward to the Murrumbidgee River. Plate 3 shows cross-sections drawn through bore holes 2, 3, 4, and 9 at natural and exaggerated vertical scale (V: H = 4).

A plot of the water-levels in the 10 observation bores and a rainfall histogram for the last 15 months is shown in Figure 5. Figure 6 shows a plot of bore C13 which is located at Fyshwick and is the nearest bore for which records have been kept for the past eight years. It can be seen that water-levels in the town-centre bores have been steadily rising since drilling was completed early in 1973; they are now at a very high level, and the levels initially recorded can be taken as average water-levels that would probably be maintained during normal rainfall years. The water-levels in the bores should rise 1-2 m above this average in the spring and early summer months, and recede 1-2 m below the average during the autumn and early winter months. During drought years levels could be expected to subside by as much as 3-4 m below the average.

The water feature to be built on Tuggeranong Creek can be expected to change the groundwater regime of the central town centre area, and because the planned water-level for the dam, 568 m, is above the level of the groundwater ridge (Pl. 3), the water feature can be expected to raise the potentiometric surface of the ridge. The water-table is expected to rise adjacent to the water feature but groundwater should be confined beneath the highly weathered completely weathered rock interface i.e. about 4-5 m below ground surface. Subsurface conditions up to 200 m from the edge of the water feature may be significantly affected; the expected change in the potentiometric surface is shown in Plate 3, and foundations at depths within 1 m of the potentiometric surface can expect some water seepage.

In some places adjacent to the water feature the groundwater gradient may fall westward to the Murrumbidgee River if leakage paths exist and uniform steep hydraulic gradients prevail. The result could be a significant loss of storage, possible slope stability problems at the outlet of leakage, and springs occurring adjacent to the Murrumbidgee River that may have a nuisance value.

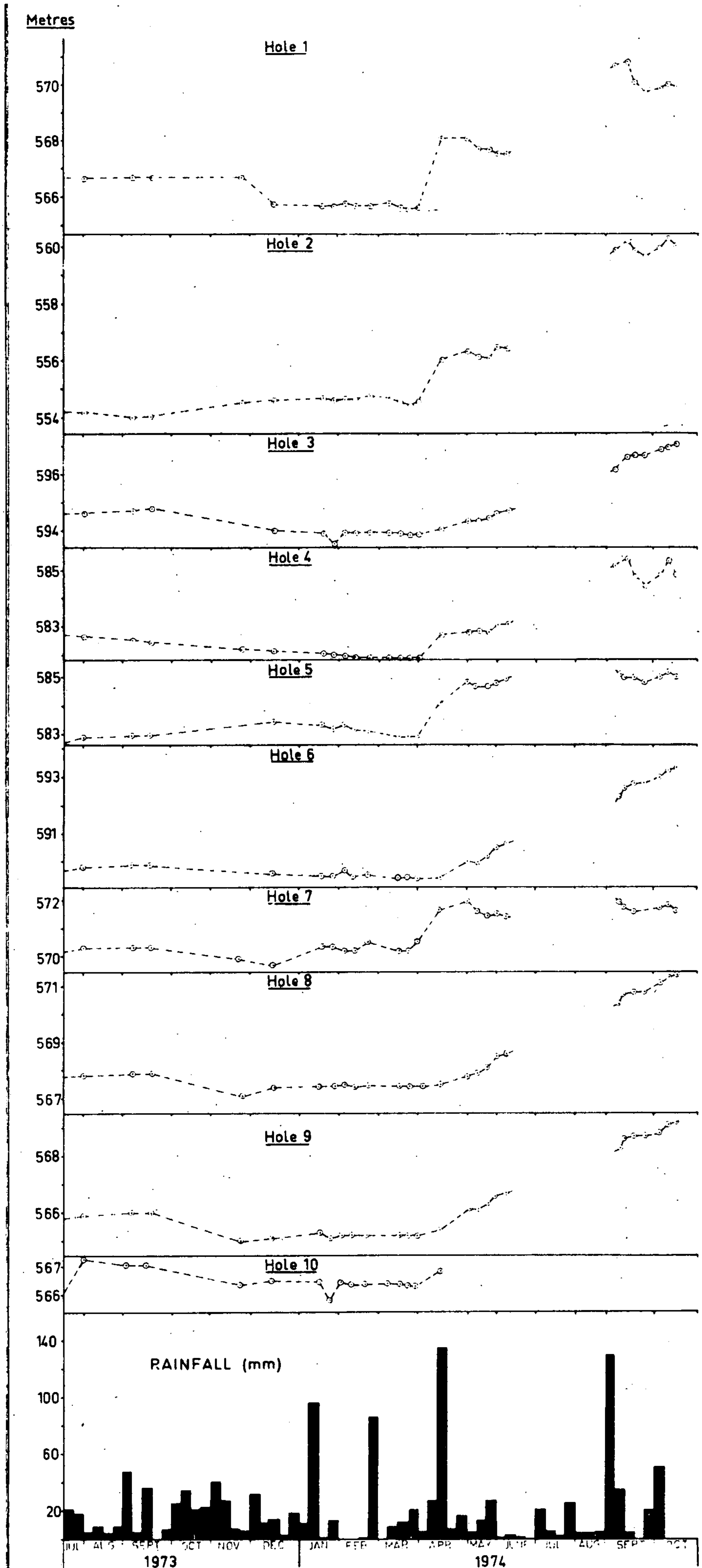
A study of the proposed Tuggeranong Dam water balance may indicate that low water losses underground from the dam during times of prolonged drought could reduce the aesthetic appearance of the water feature considerably.

EXCAVATION CHARACTERISTICS

The depth to which excavation can proceed will correspond approximately to the soil depth contours shown in Plate 1. Deeper excavation will generally be possible in completely weathered rock using heavy ripping equipment. Highly weathered rock can often be ripped or back-excavated where jointing is moderately to closely spaced and oriented in two or more directions; pre-blasting is generally required where the rock is widely jointed or where joints are unfavourably oriented relative to the excavation direction. Moderately weathered rock normally requires considerable pre-blasting, but where it is closely and loosely jointed into blocks it can be generally be removed with heavy machinery. Slightly weathered and fresh rock will require to be extensively pre-blasted before excavation.

An estimate of the groundwater inflow into an excavation, below the potentiometric surface, cannot be given for any particular site because of the variable nature of the ground. Generally where the rock is relatively unfractured, widely jointed, and hence relatively impermeable, the groundwater inflow from below the potentiometric surface is likely to be small. Where the rock is extensively fractured, water can be expected to rise readily to the potentiometric surface and inflows may be considerable.

FIG 5.



TUGGERANONG TOWN CENTRE

Water Levels In Observation Bores 1-10

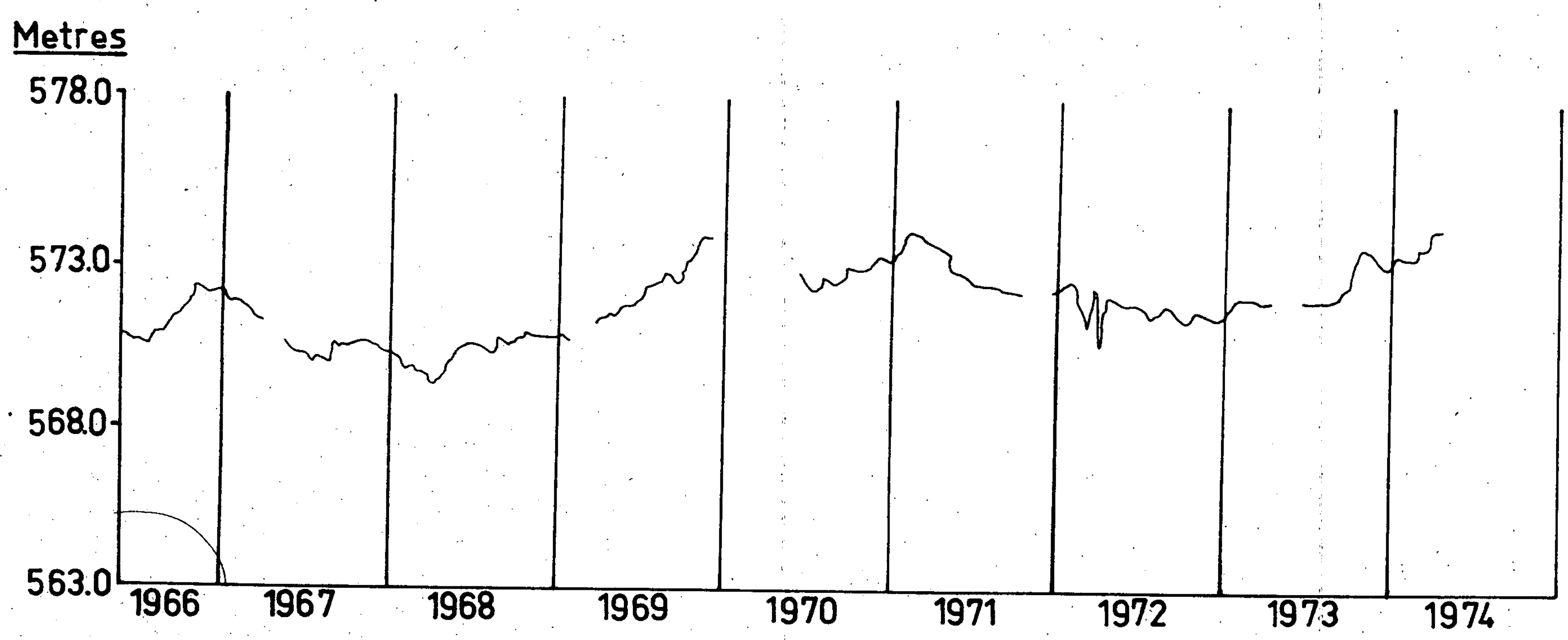


Fig:6 WATER LEVEL IN OBSERVATION BORE C13. (1966-1974)

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Some opening of joints is to be expected within high ground adjacent to the Murrumbidgee River, and may extend to 400 m from the river; however, regular unfavourably-oriented low-angle joints were not observed during the investigation. If such joints are present, movement along the joint planes may have already occurred with formation of the valley, and subsequent movement would be facilitated by excavation, but is not expected to constitute a major problem.

FOUNDATION CONDITIONS

It should be possible to site all large buildings within the town centre on highly or less weathered rhyodacite without digging excessively deep excavations. However, completely weathered rock to depths of up to 10 m may occur in parts of the area (Pl. 1).

Buildings up to three or four storeys could probably be founded on completely weathered rock; small amounts of uniform settlement could be expected, but foundation investigation is recommended. Two-storey and three-storey housing can be founded on most of the soils in the area as most are quite stable within 1 to 2 m of the surface. Some of the thicker heavy clay soils, those more than 2 m, are likely to be expansive, but should not present any major problems. Footings in soft, compressible soils such as fine silt should be avoided, especially where an underlying, relatively impermeable clay layer causes a high perched water-table after heavy rain. Where these soils are thick, and a more stable layer is not present for some depth, adequate foundation drainage may remedy the problem.

For more information on groundwater problems in deep foundations, refer to the section Excavation Characteristics.

ENGINEERING CONSTRUCTION MATERIALS

Two auger holes (numbers 34 and 35) were sunk to test the thickness of fine red sand that occurs in that area (Pl. 2); the results were not encouraging. A further search in the area outlined in Plate 2 could result in minor economic deposits of this material being located.

No large deposits of topsoil, non-plastic gravel, or river sand and gravel occur within the town centre area or in the adjacent section of the Murrumbidgee River.

CONCLUSIONS

1. Most of the area is underlain by volcanic rhyodacite.

2. Weathering depths vary considerably, and the central part of the area may be completely weathered to 6 m; below 6 m highly weathered rock commonly extends to about 11 m. Adjacent to Tuggeranong Creek and the Murrumbidgee River most of the weathered mantle has been removed.

3. Several major faults and associated fracture zones occur in the area, and two major joint orientations strike at 360° and 112° and dip 80° and vertically respectively.

4. Residual clay soils cover a large part of the area; they are generally 1 to 2 m thick.

5. Some change will occur in the average level of the potentiometric surface once the proposed Tuggeranong water feature is completed; a general rise of 2-3 m is expected for the potentiometric surface in the central part of the area, but a larger rise is expected within 200 m of the waters edge.

6. Significant leakage paths may exist for water from the storage area westward to the Murrumbidgee River where hydraulic gradients are steepest.

7. The soil depth contours may be taken as a guide to likely excavation depths, without blasting.

8. Groundwater inflows into excavations below the potentiometric surface will depend largely on rock condition at the site, but volumes in excess of pumping capacity are not expected.

RECOMMENDATIONS

1. That possible leakage paths from the proposed water feature be investigated further. This investigation would involve establishing at least four drill holes, for water-level monitoring and pump testing, in the area most likely to constitute a leakage path. The work could be done in conjunction with the present dam site investigation.

2. That water-levels be regularly monitored by BMR, especially during the filling of the proposed water feature.

3. That BMR be advised of the proposed locations, and foundation investigations for major buildings.

REFERENCES

BURTON, G.M., 1967 - Recharge conditions and siting of bores in fractured-rock aquifers of the A.C.T. Bur. Miner. Resour. Aust. Rec. 1967/93 (unpubl.).

GARDNER, D.E., 1968 - Preliminary notes on the geology of the Tuggeranong urban development area, A.C.T. Bur. Miner. Resour. Aust. Rec. 1968/75 (unpubl.).

PURCELL, D.C., 1971 - Tuggeranong-Weston Creek sewer tunnel, A.C.T., geological report on detailed investigations, 1971. Bur. Miner. Resour. Aust. Rec. 1974/11 (unpubl.).

ROSSITER, A.G., 1971 - Preliminary notes on the geology of the Village Creek area. Bur. Miner. Resour. Aust. Rec. 1971/11 (unpubl.).

VANDEN BROEK, P.H., 1973 - Engineering geology of Tuggeranong town centre, Stage 1, A.C.T. Bur. Miner. Resour. Aust. Rec. 1973/100 (unpubl.).

APPENDIX 1

DEGREES OF WEATHERING

FRESH:	Rock shows no discolouration or loss of strength.
SLIGHTLY WEATHERED:	Rock is slightly discoloured but not noticeably weakened; a two-inch diameter drill core cannot usually be broken by hand across the rock fabric.
MODERATELY WEATHERED:	Rock is discoloured and noticeably weakened, but a two-inch drill core cannot usually be broken by hand across the rock fabric.
HIGHLY WEATHERED:	Rock is usually discoloured and weakened to such an extent that a two-inch drill core can readily be broken by hand across the rock fabric. Wet strength generally lower than dry strength.
COMPLETELY WEATHERED:	Rock is discoloured and entirely broken down to an aggregate of particles that has the mechanical property of a soil; the original fabric of the rock is mostly preserved. The properties of the soil depend on the composition of the parent rock.

APPENDIX 2

BRIEF DESCRIPTION OF ROCK TYPES

Blue-grey rhyodacite: Phenocrysts of white to pale green plagioclase feldspar, and transparent quartz (2-4 mm across) are set in a blue-grey or blue-green aphanitic groundmass which constitutes about 60% of the rock.

Grey-green rhyodacite: Phenocrysts of white and pale green plagioclase feldspar, and transparent quartz are set in a grey-green groundmass.

Purple-pink rhyodacite: Phenocrysts of pink potash feldspar, white plagioclase feldspar, and transparent quartz up to 10 mm across are set in a dark mauve-purple, purple-pink, or dark grey aphanitic groundmass which constitutes about 60% of the rock.

Rhyolite porphyry: Large phenocrysts of potash feldspar and smaller phenocrysts of quartz and plagioclase feldspar are set in a pale pink or purple aphanitic groundmass.

Granite porphyry: Large phenocrysts of quartz and potash feldspar (5-10 mm across) are set in a pale pink microcrystalline groundmass.

Shale: A laminated sediment in which the constituent particles are predominantly clay.

Rhyolite: Fine-grained rock comprising grains of potash feldspar and quartz in a cryptocrystalline groundmass that is mostly made up of potash feldspar. Its yellow-brown colour is a weathering characteristic.

APPENDIX 3

DETAILED JOINT ANALYSES

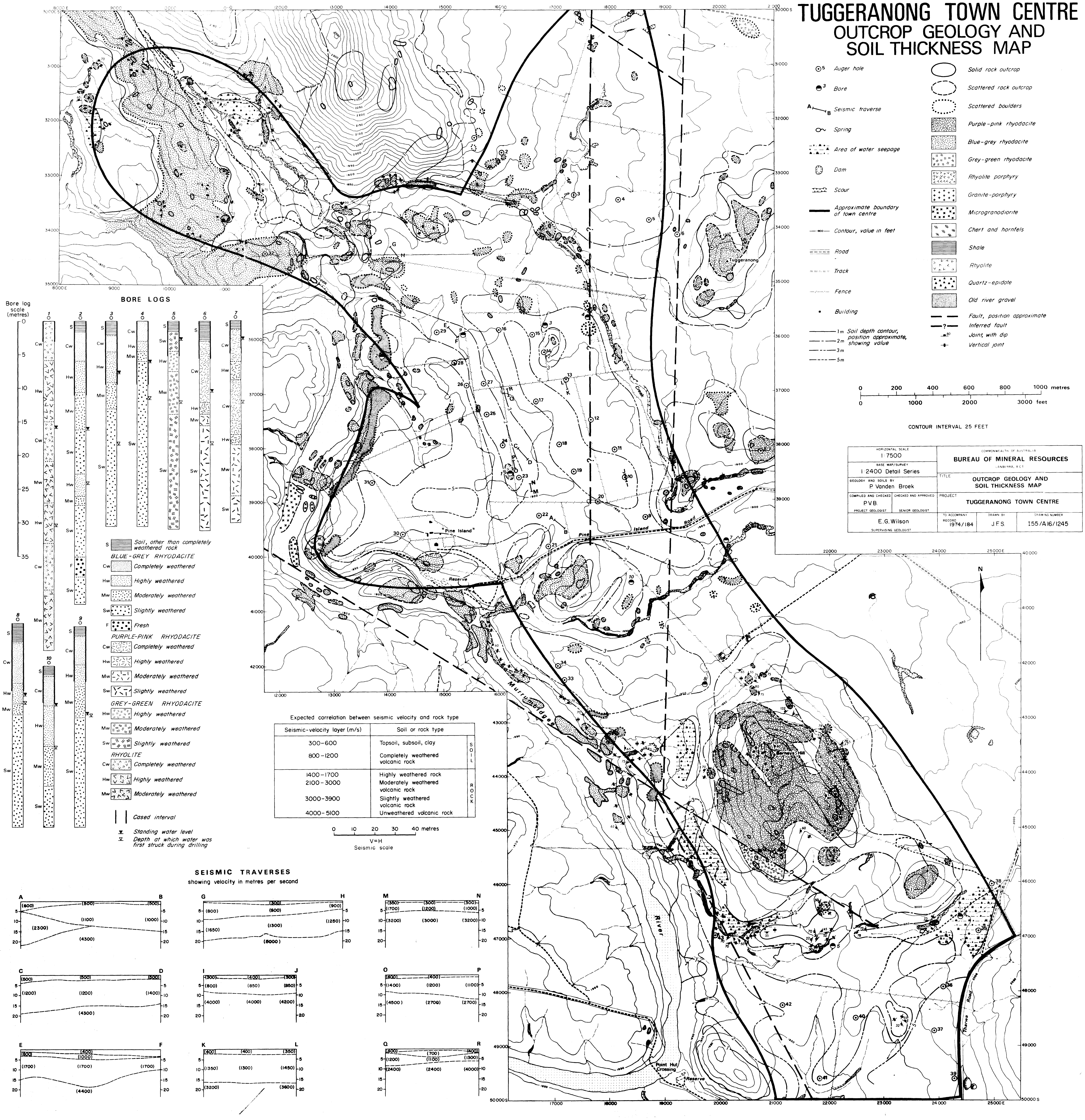
A plot of 189 poles to joint planes, measured at various outcrop localities, is shown on the stereograph presented in Figure 3. There are two major sets of joints striking at 360° and 112° that dip approximately 80°E and vertically, respectively. A less strongly developed joint set is close to the horizontal plane.

There is a broad spread at joint orientations around the circumference of the stereograph, that is, steeply dipping joints are most common but their strike is variable. At some localities as many as six orientations were measured.

Joint measurements for each of the rhyodacites were plotted independently, and showed that the horizontal jointing is confined to the blue-grey rhyodacite, but that there is a fairly even distribution of joint orientations over the remainder of the stereograph.

Joint spacing varies from widely to closely spaced. Areas of scattered boulders are usually underlain by rock which has moderate (15-100 cm apart) joint spacing. Near the major faults the rocks are often closely (less than 15 cm apart) to moderately jointed.

TUGGERANONG TOWN CENTRE
OUTCROP GEOLOGY AND SOIL THICKNESS MAP



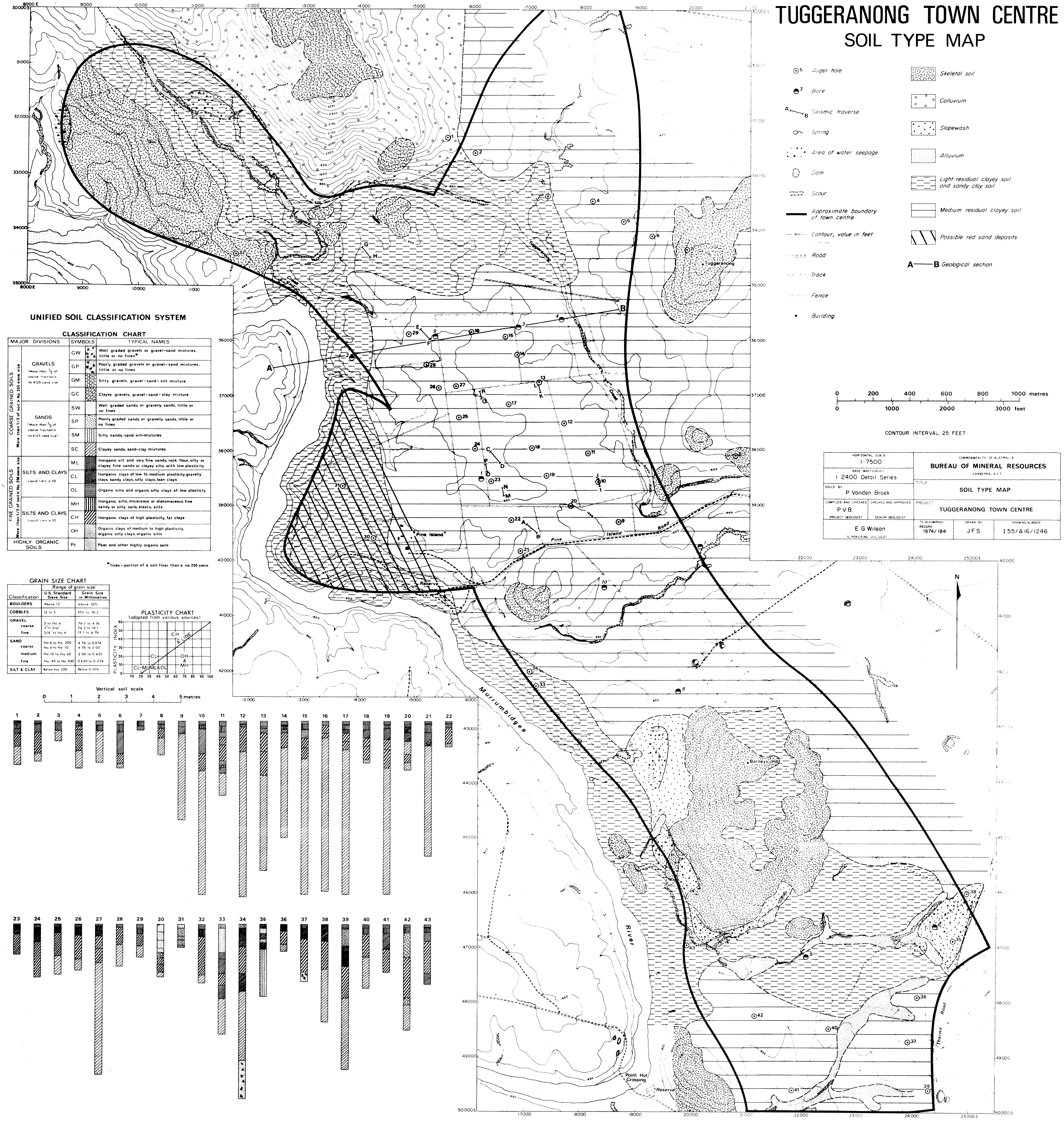
Seismic-velocity layer (m/s)	Soil or rock type	
300-600	Topsoil, subsoil, clay	SOIL
800-1200	Completely weathered volcanic rock	SOIL
1400-1700	Highly weathered rock	ROCK
2100-3000	Moderately weathered volcanic rock	ROCK
3000-3900	Slightly weathered volcanic rock	ROCK
4000-5100	Unweathered volcanic rock	ROCK

Expected correlation between seismic velocity and rock type

HORIZONTAL SCALE 1:7500	COMMONWEALTH OF AUSTRALIA **BUREAU OF MINERAL RESOURCES** CANBERRA, A.C.T.	
BASE MAP/SURVEY 1:2400 Detail Series	TITLE OUTCROP GEOLOGY AND SOIL THICKNESS MAP	
GEOLOGY AND SOILS BY P Vanden Broek	PROJECT TUGGERANONG TOWN CENTRE	
COMPILED AND CHECKED P.V.B. PROJECT GEOLOGIST; CHECKED AND APPROVED SENIOR GEOLOGIST		
E.G. Wilson SUPERVISING GEOLOGIST	TO ACCOMPANY RECORD 1974/184; DRAWN BY J.F.S.	DRAWING NUMBER I55/A16/1245

PLATE

TUGGERANONG TOWN CENTRE
SOIL TYPE MAP



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	Range of grain size: Grain Size in Millimetres
BOULDERS	Above 12"	Above 305
COBBLES	12" to 3"	305 to 76·2
GRAVEL	3" to No. 4	76·2 to 4·76
coarse	3" to 3/4"	76·2 to 19·1
fine	3/4" to No 4	19·1 to 4·76
SAND	No. 4 to No. 200	4·76 to 0·074
coarse	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

HORIZONTAL SCALE 1:7500	COMMONWEALTH OF AUSTRALIA **BUREAU OF MINERAL RESOURCES** CANBERRA, A.C.T.
BASE MAP/SURVEY 1:2400 Detail Series	TITLE: SOIL TYPE MAP
SOILS BY P Vanden Broek	
COMPILED AND CHECKED P.V.B. PROJECT GEOLOGIST; CHECKED AND APPROVED SENIOR GEOLOGIST	PROJECT: TUGGERANONG TOWN CENTRE
E.G. Wilson SUPERVISING GEOLOGIST	TO ACCOMPANY RECORD 1974/184; DRAWN BY J.F.S.; DRAWING NUMBER I55/A16/1246

PLATE 3

HORIZONTAL SCALE 0 50 100	COMMONWEALTH OF AUSTRALIA **BUREAU OF MINERAL RESOURCES** Canberra, A.C.T.
BASE MAP / SURVEY 1:2400 Detail series	TITLE Cross—sections A—B at natural and exaggerated vertical scale.
GEOLOGY BY P Vandenbroek	PROJECT Tuggeranong Town Centre
COMPILED AND CHECKED P.V.B. PROJECT GEOLOGIST / CHECKED AND APPROVED SENIOR GEOLOGIST	TO ACCOMPANY RECORD 1974/184 / DRAWN BY P. Dubbelaar / DRAWING NUMBER I55/A16/1275
E.G.Wilson SUPERVISING GEOLOGIST	