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GINNINDERRA SEWER TUNNEL, A.C.T.

ENGINEERING GEOLOGY COMPLETION REPORT, 1979

By

D.C. PURCELL & P.H. VANDEN BROEK

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1. Excavation of the Ginninderra sewer tunnel and appurtenant works began in October 1976 and was completed in September 1978. The tunnel was operational late in September 1979.

2. The rock was considered too hard for a tunnel boring machine, so the contractor used a standard drill-shoot-muck procedure, erecting tunnel support where necessary. Two headings and shaft excavations were worked simultaneously for part of the time, and one heading was worked continuously for three shifts per day.

3. Geological conditions were essentially as predicted by the geological and geophysical investigations. Poor tunnelling in the rhyolite section was accurately predicted.

4. Steel (RSJ) sets were erected for a total length of 1016 m, the average spacing of sets being about 1 m. Most of the poor ground was encountered in the upstream part of the tunnel in dacite and rhyolite and was due to a greater concentration of faults in the particular sections.

5. Survey overbreak during construction was 0.19 m outside the C-line (pay line), the average for the tunnel being 44.5 percent. The amount of overbreak was controlled by the incidence of faults, sheared zones, and seams and the presence of incompetent rhyolite.

6. The most significant groundwater flows into the tunnel were restricted to the upstream heading, especially the section of tunnel between chainages (Ch) 1800 and 2300 and also in the region between shaft 1 and Ch 1300. Maximum outflow from the upstream heading before concrete lining and grouting was 36 m^3 per hour.

7. The correlation between seismic velocities and tunnel conditions in this tunnel is consistent with that found in the Tuggeranong, Ryan, and Pine Ridge tunnels.

8. Concrete placement was in sections of several hundred metres of tunnel every 3-4 days. Backfill and pressure grouting were thought to be reasonably successful; the greatest groundwater flow into the completed lined and grouted tunnel occurred in the upstream heading at Willow Bend, and was limited to about 13.5 m^3 per hour.

FIGURE 1

LOCATION MAP
GINNINDERA SEWER TUNNEL
MOLONGLO VALLEY INTERCEPTOR SEWER
LOWER MOLONGLO WATER QUALITY CONTROL CENTRE
CANBERRA A.C.T.

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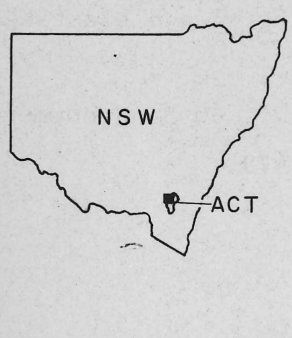
0 1 2 3 4 km



N

BWPCC Belconnen Water Pollution Control Centre

Lower Molonglo Water Quality Control Centre

Tunnel

Buried pipeline

Shaft

1. INTRODUCTION

The project comprised all works necessary for the construction of a sewer tunnel from the Belconnen Water Pollution Control Centre (BWPCC) to the Lower Molonglo Water Quality Control Centre (LMWQCC); the main works are two 2.1 m diameter tunnels 893 m and 4298 m long, joined at Willow Bend by 120 m of pipe buried in an embankment of tunnel spoil, and four shafts along the longer tunnel.

At its northern end, the Ginninderra sewer tunnel intercepts the existing Belconnen Trunk sewer, and sewage from the Belconnen area is now treated at the LMWQCC and discharged into the Murrumbidgee River (Fig.1).

The Department of Housing and Construction (DHC) designed and supervised construction of the works for the National Capital Development Commission. The contract for construction was awarded to Barclay Bros. Pty Ltd for almost $7m. Excavation of the works commenced in October 1976 and was completed in September 1978; lining and grouting continued for nearly twelve months. The contract was completed in early September 1979 and the tunnel was operational in late September 1979.

A pre-construction geological report was prepared by the Bureau of Mineral Resources, Geology & Geophysics (BMR) (Lang & Purcell, 1976), and selected parts were subsequently incorporated into an "Information for Tenderers" document. On request from DHC, a BMR geologist was assigned to the DHC engineering team to provide a complete geological service during construction. A general view of the work area and upstream portal is shown in Figure 3.

The tunnel was excavated by the conventional drill and blast method. The downstream heading was excavated from Willow Bend, commencing 21 October 1976 and breaking out at the LMWQCC on 30 April 1977; the concrete lining was poured after a short delay.

The four shafts in the upstream section of the tunnel were excavated from the surface to tunnel level by drilling and blasting.

Excavation of the upstream tunnel from Willow Bend commenced on 18 April 1977 and was completed on 21 September 1978.

The general layout of the tunnel is shown in Figure 2. Access to the upstream and downstream sections of the tunnel was gained from Willow Bend where the site works were established, and the tunnel spoil was dumped in the gully to form a enlarged working area.

2. GENERAL GEOLOGY

The regional geology of the area is described in the Canberra 1:250 000 Geological Series map and Explanatory notes (Strusz, 1971), and the area was more recently mapped for the Brindabella Sheet of the 1:100 000 Geological Series (Owen & Wyborn, 1976).

An interpretative solid geology of the area is shown in Plate 1. The tunnel was driven through a sequence of acid volcanics and tuffaceous sediments, intruded by granite; all rocks are regarded as Upper Silurian in age.

The rocks are faulted, gently folded, and along the tunnel line are tilted about 20-30^{o} southwest.

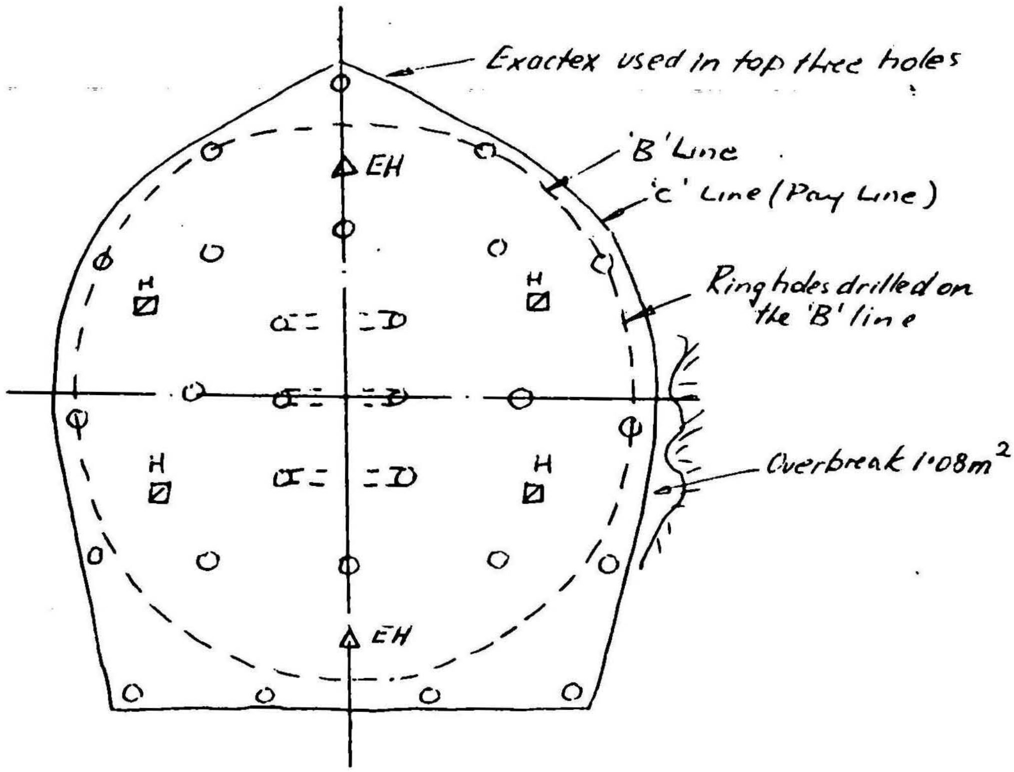
The geology exposed during excavation of the tunnel did not differ greatly from that outlined in the geological investigation report (Lang & Purcell, 1976). The rock types intersected had been predicted with reasonable accuracy from the surface mapping and investigation drilling, and the rock conditions underground did not differ significantly from the predictions of the report.

2.1 Rock Types

Five main rock types were intersected by the tunnel (Plates 1-4):

Dacite. Dacite flows and tuffs are continuous along the tunnel to the north of fault no. 2; dacite is also present to the south of fault no. 3 and is continuous except for a wedge of rhyodacite and rhyolite between faults nos. 4 and 5. The dacite is commonly porphyritic in texture and comprises white or pink phenocrysts of quartz and potash feldspar set in a dark grey, blue-grey, green, pink, or purplish groundmass of crypto-crystalline alkali feldspar and quartz. It occurs as bedded tuff, welded ash, extrusive flow, and sill-like intrusions. Where intrusive, the rock is slightly coarser-grained, and generally more massive.

Example No. 2 Drill/load pattern
Chainage 3061; Date 31.10.77
Rock Type Granite Porphyry; Drill 1803 mm; Pull 1.57 m av.
Explosive 28 mm AN60 plus Exactex; Detonators safety fuse type.



1. Pattern - normal rock conditions

Hole	No.	Loading/hole	Primer	Sticks
Cut holes (wedge)	8	1 Primer + 4 sticks	8	32
Inner holes	6	1 Primer + 6 sticks	6	36
Ring holes	6	1 Primer + 6 sticks	6	36
Crown/shoulder	3	1 Primer + 1 stick + 3' exactex	3	9 (equiv)
Lifter holes	4	1 Primer + 8 sticks	4	32
Total holes	27 No.		27	145
		Total Explosive		172 sticks

Explosive : 172 sticks x 0.385 lb/stick = 66 lb = 30 kg
Face area : Pay 'C' line 6.6025m^2 O/B 1.08m^2, total 7.68m^2

Explosive consumption $\frac{30 \text{ kg}}{7.68 \times 1.57 \text{ m}}$ = 2.48 kg/m^3 solid excavated

2. Hard rock conditions: drill 4 extra holes to "1" marked 'H'.

3. Very hard rock conditions; drill 2 holes extra to "1" & "2" marked 'EH'.

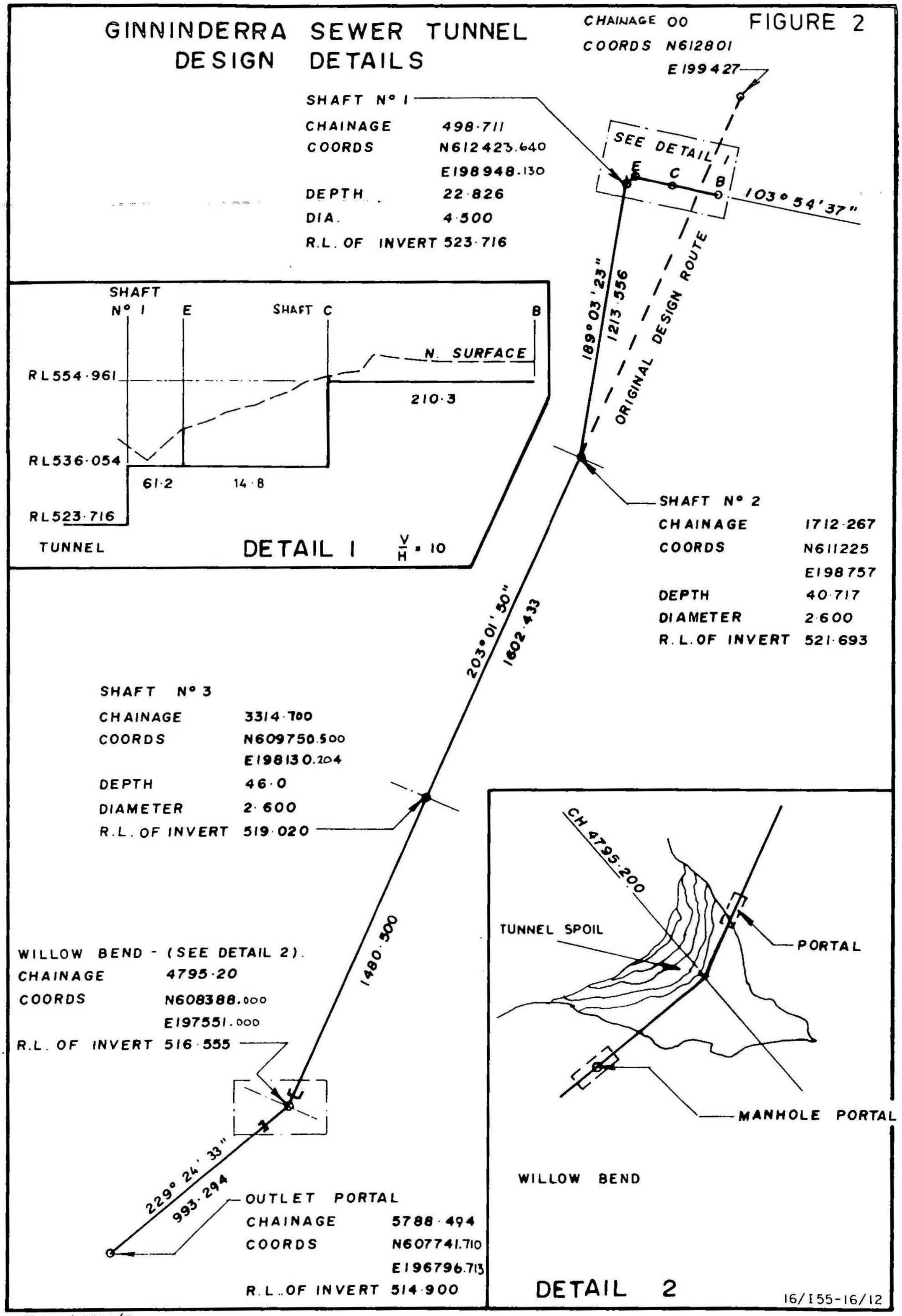


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Fig. 3: General view of work area and upstream portal, Willow Bend. Slumping of the slope above the portal took place after benching of the work area at the portal.

Bedding is visible only where the rock is tuffaceous and interbedded with other sediments or ash. Elsewhere bedding is not apparent, although some joints are folded and may have formed parallel to the bedding planes. The tuffaceous and extrusive units have been tilted about 20° to the southwest.

<u>Rhyodacite and rhyolite</u> (Ch 4380-4670). Green rhyolite and purple rhyodacite are found within the wedge between faults nos. 4 and 5. The rhyodacite is generally porphyritic and comprises glassy clear quartz and pink potassium feldspar phenocrysts set in a purplish-pink, pale yellow, or yellow-green groundmass of cryptocrystalline alkali feldspar. The purple rhyodacite occurs mostly as extrusive flows which in places grade into fine-grained, siliceous, pale green rhyolitic tuffs or ash. The rock is moderately to closely jointed and moderately to extremely weathered, and the purple, yellow, and green varieties of this rock appear to be weathering manifestations of minor variations in chemical composition. Fractured, sheared, and extremely weathered rhyolite porphyry (Ch 1105-1125) intrudes dacite and rhyodacite in the northern section of tunnel, and is associated with quartz and epidote veining. Bedding is not visible except where interbeds of siliceous or fine-grained tuffs occur. All contacts of rhyodacite and rhyolite with the dacite are faulted.

<u>Granite porphyry</u> (Ch 3720-2720 and Ch 1493-1306). The granite porphyry is centrally located along the tunnel to the north of fault no. 3. The rock is porphyritic and comprises phenocrysts of glassy quartz, white to pale green plagioclase feldspar, dark pink garnet, and altered dark green biotite and pyroxene set in a pale grey to pinkish grey microcrystalline groundmass of quartz. The rock is a high-level intrusion; its northern intersection of the tunnel (Ch 1306-1493) shows intrusive contacts with hornfels against dacite and shale, whereas the more extensive section farther south has been faulted against dacite in the south (Ch 3720) and has an irregular and possibly faulted contact against black shale in

the north (Ch 2720); the relation between the granite porphyry and black shale appears to be more consistent, with a sill-like form for the granite porphyry. Flow banding was absent from the granite porphyry and the rock was fairly uniform in appearance throughout; the only variation in rock type within the granite occurs at Ch 3652, where a small pink coarse-grained granite dyke intersects the tunnel line. A small, extremely weathered plug of granite porphyry intrudes tuffaceous sediments in the tunnel at Ch 2300-2360, but the granite porphyry does not extend to the surface.

Siliceous siltstone (Ch 3883-3940). This rock is a black silicified siltstone that has a dull resinous lustre caused by slickensiding of the phyllosilicate minerals exposed during excavation. It is interbedded with extrusive dacite and partially absorbed by intrusive dacite at Ch 3883-3940. This rock has been extensively fractured, disrupted, intruded, and silicified by dacite.

The relation between the siliceous siltstone and sediments to the north is not known; it does not appear to be tuffaceous as are the sediments to the north, and it is not thinly bedded or laminated.

Tuffaceous sediments and crystal tuff (Ch 2719-1493). Dark grey laminated shale and pale grey bedded crystal tuffs were intersected in the northern section of the tunnel, south of fault no. 2. Interbeds of off-white tuffaceous sandstone and dark grey siltstone are associated with these volcanic sediments. Grey dacite flows containing black shale xenoliths separate successive sedimentary layers, and granite porphyry intrudes at Ch 2300-2360. The contact between this sequence and overlying massive welded tuff at Ch 1745 is faulted and sheared. Bedding dips to the west or southwest at 5-15^{o} for nearly the entire length of sequence intersected.

2.2 Structure

The structures associated with the five main rock types intersected by the tunnel are:

Dacite. Most dacite intersected by the tunnel is moderately to closely jointed, with sections of fragmented rock common in or adjacent to fracture zones associated with clay seams and faults; some is widely jointed, but more massive rock does occur in which the joints are commonly filled with white calcite. Joints are generally tight, and about 50% of the excavated rock broke out across the rock substance rather than along joint surfaces. Most joints are continuous across the tunnel, and where they are shallow dipping, they extend over tensof metres. In some instances shallow joints are folded gently, and are not necessarily derived from or aligned with bedding or flow layering. Joint surfaces were found to be generally devoid of clay except in or adjacent to major defect zones.

Seams are fairly common within the dacite, with usually 1 or 2 every 50 metres; where seams are abundant they are associated with closely jointed or fragmented sections of rock, or with faults.

Rhyodacite and rhyolite (Ch 4380-4670). Most rhyodacite and rhyolite intersected by the tunnel is closely jointed, fragmented sections being common. Moderately jointed sections do occur in a few places, and these sections show the strong development of the horizontal joint set; two or three steeply dipping joint sets are also common. Joints are generally open a few millimetres and joint surfaces are commonly clay coated. Cementation is absent from joint surfaces, and more than 60% of rock excavated broke out along joint surfaces (up to 100% in places). Most joints are continuous across the tunnel and the horizontal set extends over tens of metres.

Seams are numerous and where shallow dipping they are persistent, being traceable for tens of metres, commonly 4-10 cm wide, and filled with clay and crushed rock.

Granite porphyry (Ch 3720-2720 and 1493-1306). Much of the granite porphyry intersected by the tunnel is moderately to widely jointed, sections of closely jointed rock being about 40-60 m apart. Joints are tight and so well cemented with calcite that 60% of the rock breaks across the rock substance. Two joint sets are commonly present: a shallow SW dipping to horizontal set that extends over tens of metres, and a steeply dipping set that is less well developed and often not continuous.

Seams are mostly thin (0.5-2 cm across), not very numerous (about 1 seam every 50 m along much of its section), and clay coated.

Siliceous siltstone (Ch 3883-3940). This rock is closely fractured to fragmented along its entire section, with fractures oriented in many directions. Most fractures are not tight and fracture surfaces are slickensided. Seams are numerous and clay coated.

Tuffaceous sediments and crystal tuff (Ch 2717-1493). Most of this section comprised shale or dacite tuff that showed strong, well developed, moderately to closely-spaced or laminated bedding planes which are horizontal or dipping at 5-10° to the southwest. One dominant, moderately to closely spaced, steeply dipping (60-80° NE and SW) non-continuous joint set was apparent for most of the section.

Clay seams are fairly common and are generally associated with bedding planes particularly in the shaly sections. The clay seams were the cause of large pockets of overbreak in many places.

Defects generally were not tight, although some tuff sections were calcite cemented, and joint surfaces were commonly clay coated, particularly adjacent to seamy sections. About 50% of the rock broke out along defect planes in most of the section, but where overbreak was encountered, the rock parted completely along defect planes.

2.3 Weathering

Most of the tunnel rock was fresh to a slightly weathered, except the rhyodacite and rhyolite which was generally moderately to highly weathered (Table 1).

Dacite. Most of the dacite intersected by the tunnel excavation was slightly weathered and quite hard. Alternating with slightly weathered rock were short sections, generally of either moderately weathered or fresh rock or much less commonly, highly weathered rock. A longer section mainly of highly to extremely weathered dacite was present between Ch 4280 and 4416, and constitutes about 6% of the total dacite excavated. The fine-grained dark grey dacite between Ch 1308 and 1127 was mostly fresh rock and proved hard to drill.

Rhyodacite and rhyolite. Most of the rhyodacite and rhyolite intersected during excavation of the tunnel was highly to extremely weathered; moderately weathered rock was encountered in only a few places. These rocks were more susceptible to weathering at depth than the other rock types intersected; this may be attributed to the moderately to closely fractured nature of the rock and the high percentage of very fine-grained potassium feldspar in the groundmass which is more readily weathered.

Granite porphyry. The granite porphyry is commonly extremely weathered at depths of 10-20 m and up to 30 m below the ground surface; however, at tunnel level (50-60 m below ground surface) it was generally slightly weathered to fresh-stained.

Only a small section of extremely to highly weathered granite porphyry occurs at tunnel levels from Ch 1390-1400; this rock is closely fractured and the fractures could have formed during movement associated with the formation of fault 2. A section of moderately to highly weathered rock (Ch 1340-1308) adjacent to the faulted contact with dark grey dacite is thought to be a fracture zone associated with post-intrusion movement along fault 2.

Siliceous siltstone. The siltstone is essentially unweathered at tunnel level but does not crop out at the surface. Lack of weathering of this rock at tunnel level is probably attributable to the siliceous nature of the rock and the fact that defects have all been sealed with calcium carbonate.

Tuffaceous sediments and crystal tuff. At the surface these rocks are susceptible to weathering. Crystal tuff beds are extremely weathered and are not exposed at the surface, and highly to extremely weathered pale brown to yellow-green shale crops out as low rubbly rises. At tunnel level the rocks may be fresh, fresh-stained, or in places slightly weathered, and generally are very dark grey and black.

3. ENGINEERING GEOLOGY

3.1 Rock types and tunnelling conditions

'Rock condition' mentioned in this report is based on Terzaghi's Rock Condition Number (RCN), in which numbers ascending in sequence correspond to an increase in tunnelling difficulty, hazard, and cost. However, Terzaghi's Numbers have been partly modified to suit local conditions; a full description of each of the eight categories appears in the definitions in Appendix 1.

Table 1 summarises the rock condition of the various rock types intersected by the tunnel excavation; it also shows the degree of weathering for each rock type. Most of the rock was fresh to slightly weathered and has Rock Condition No. 1,2, or 3.

3.2 Overbreak

Overbreak in this report refers to the volume of rock excavated outside the C-line (pay line) expressed as a percentage of the volume occupied by the tunnel lining (see Fig. 4). Overbreak has been calculated by two methods:

(i) survey-estimated overbreak

(ii) concrete placement (volume) overbreak.

Overbreak roughly estimated as the distance beyond the C-line to the excavated tunnel wall has been shown on the detailed geological tunnel logs, and was estimated by the project geologist while logging the tunnel.

The contractor partly based his tender price on an average factor for overbreak of 38.2%.

Survey-estimated overbreak. Tunnel cross-section were taken by the contractor at stations generally spaced every few metres. Seven measurements were made

TABLE 1. ROCK CONDITION (RNC) AND DEGREE OF WEATHERING FOR EACH ROCK TYPE

Length encountered shown in metres

	Dacite	Rhyodacite and rhyolite	Granite porphyry	Siliceous siltstone	Tuffaceous sediments and crystal tuff
RCN 1, 2, 3 (%)	1850 (80)	64 (16)	1063 (90)	47 (82)	963 (79)
RCN 4 (%)	297 (13)	195 (48)	112 (9)	10 (18)	204 (17)
RCN 5 or worse (%)	169 (7)	147 (36)	13 (1)		57 (4)
TOTAL	2316	406	1188	57	1224
Fresh and/or slightly weathered (%)	1931 (84)	40 (10)	1073 (90)	57 (100)	1189 (97)
Moderately weathered (%)	213 (9)	307 (77)	70 (6)		20 (2)
Highly and/or extremely weathered (%)	172 (7)	59 (13)	45 (4)		15 (1)

2 at invert, 2 at centre-line, 2 at spacing line, and 1 at tunnel crown. An average overbreak figure for each profile was then calculated. (The calculations are included as Appendix 2).

Table 2 summarises survey-estimated overbreak calculation for both headings.

Calculation of concrete volume from overbreak survey. Using the figures derived from the overbreak survey, it is possible to convert percentage overbreak to the volume of concrete to be placed. The calculations are set out in Appendix 2. The volumes are set out in Table 3.

Concrete volumes place . The percentage overbreak based on volumes of concrete placed were set out on page 57 of the construction report (Noack, 1979), and have been included in Table 3.

The concrete volumes calculated from survey overbreak exceeded the volumes of concrete placed. Part of the difference would be accounted for by the volumes of backfill grout, steel sets, and timber lagging, and the remainder is probably attributable to the method of carrying out the overbreak survey. The survey method whereby seven or more measurements are taken radially from the centre of the tunnel and averaged for overbreak at that chainage, has an inbuilt bias that depends on the locations of the seven individual points selected for measurement; in most cases the points selected have tended to give higher than average overbreak values.

It is clear from the percentage figures in Table 3, that the over-estimation of overbreak volume from survey measurements ranges from 25 to 47 percent. The over-estimation of concrete volumes calculated from surveyed overbreak ranged from 16 to 28 percent.

TABLE 2. SUMMARY OF SURVEY-ESTIMATED OVERBREAK

	UPSTREAM HEADING		DOWNSTREAM HEADING	
	Unsupported	Supported	Unsupported	Supported
Tunnel length surveyed (m)	2433	800	732	108
Total overbreak(1)	377.7	292.5	78.66	33.5
Average overbreak(2) in m outside C-line	0.156	0.365	0.107	0.310
	Overall average for tunnel 0.19 m			
Average overbreak(3) expressed as the increase in tunnel cross-section (m^2)	1.09	2.57	0.756	2.19
Percent overbreak(4)	36%	85%	24.8%	72%
Average overbreak per heading as percent	48.5%		30.6%	
Average overbreak for whole project	44.5%			

(1) This figure represents the sum of the products of the average overbreak, expressed as a distance measured beyond the C-line, and the length of section to which each average overbreak applies.

(2) Obtained by dividing total overbreak (1) by the length of tunnel surveyed.

(3) Obtained from (2) by multiplying by 7.06 m (length of C-line).

(4) Obtained by dividing (3) by 3.04 (cross-section area to the C-line) expressed as a percentage.

The difference in average overbreak between the upstream and downstream headings is probably attributable to the higher percentage of support (9% more) that was required on the upstream heading.

TABLE 3. CONCRETE VOLUMES AND PERCENTAGE OVERBREAK

	UPSTREAM		DOWNSTREAM		TOTAL LENGTH		STEEL SUPPORT SECTIONS	
	Survey method estimate	Concrete placed	Survey method estimate	Concrete placed	Survey method estimate	Concrete placed	Survey method estimate	Concrete placed
Tunnel length (m)	4298	4320	893	1210	5191	5430	1016	43.2
Volume of concrete	19121	16197	3540	3455	22661	19633	5671	1957
Concrete volume over-estimated by (%)	16%	-	28%	-	17%	-	19%	-
Concrete volume to C-line	13065	12992	2710	2798	15775	15790	3089	131.3
OVERBREAK								
Concrete volume	6056	3205	883	637	6939	3834	2582	64.4
%	46.3	24.5	30.6	22.8	44	24.3	83.5	49
Over-estimated by	47%	-	25.5%	-	45%	-	41%	-

The measurement of overbreak by survey methods for the estimation of concrete volumes has rarely proved to be satisfactory. Where an accurate estimate of concrete volumes is required, the Waite Plate Method (Fellowes, 1976) of photographic profiling should be considered.

3.3 Tunnel support

A typical tunnel section showing details of supports used is shown as Figure 4. Invert struts were not used. Most steel sets were spaced at between 1.1 and 1.2 except at the upstream heading outlet portal where the average spacing over 50 m was 0.9 m. Steel supports were 102 mm X 762 mm x 15 kg RSJs (two segments) braced with 19 mm mild steel tie rods. Timber lagging was used in varying quantities as required for the rock condition. Rock bolts were used only at tunnel shaft junctions where the rock mass had two degrees of freedom to move. The support predicted and the support actually used were as follows:

	Predicted support (Lang & Purcell, 1976)	Actual support
Upstream	23%	21%
Downstream	12%	12%
Overall average	15%	14%

Seismic velocity and support. Comparison of tunnel support with other data such as overbreak, rock type, and advance rate have been stated elsewhere in this report.

A comparison of seismic velocities versus support may not be very meaningful owing to the depth of the tunnel below ground surface. However, a correlation of seismic velocity, rock condition number (RCN), and steel support is given in Table 4. The correlations are similar in the higher velocities to those obtained in the Tuggeranong, Ryan, and Pine Ridge Tunnels (Purcell, 1977 and 1979); however, there is some divergence from the

FIGURE 4

GINNINDERRA SEWER TUNNEL
TUNNEL CROSS — SECTIONS

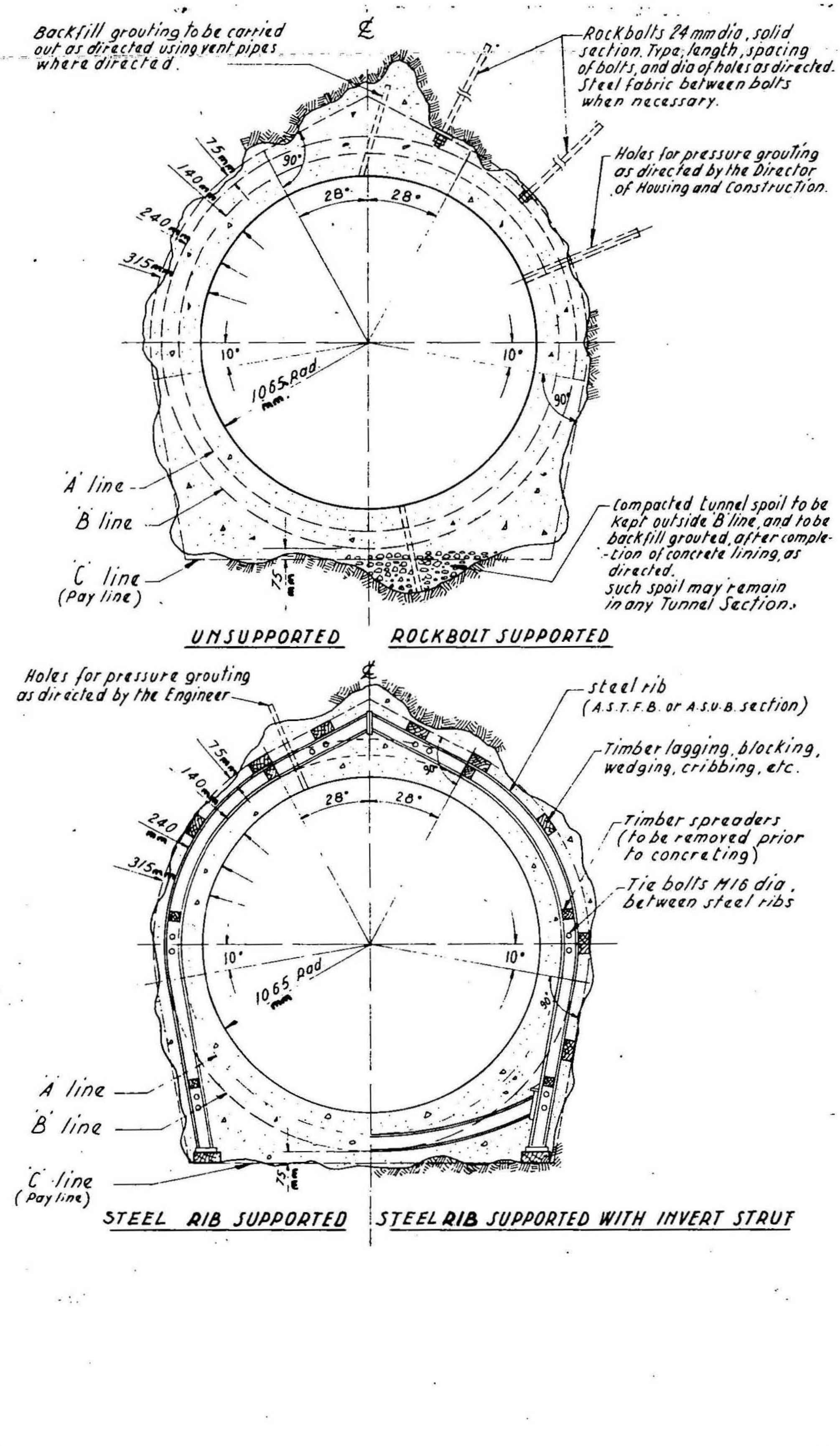

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TABLE 4. SEISMIC VELOCITIES, SUPPORT, AND RCN

	*SEISMIC VELOCITIES (m/s)					
	1000-2000	2100-3000	3100-4000	4100-5000	>5000	TOTAL
No. of metres	105	256	993	1997	585	3936
(% of route)	(3%)	(7%)	(25%)	(50%)	(15%)	
Length steel supported	75	139	344	387	57	1002
(% of velocity)	(71.5%)	(54%)	(35%)	(19%)	(10%)	
Most common RCN	4-5	4	3-4	3	3 and 2-3	

NOTE * Highest recorded velocity in region of tunnel if tunnel below highest recorded refractor. Otherwise velocities are those through which the tunnel was driven.

graph of the Tuggeranong tunnel where a high percentage of support was required in low-velocity rock at shallow depths (Fig. 4).

3.4 Excavation rates

The various excavation rates and correlations are summarised in the tables below. Daily progress has been plotted on the detailed tunnel logs. Three 8-hour shifts were generally worked on the upstream heading but often only 2 shifts per day were worked on the downstream heading. The figures given in the tables below are based on three 8-hour shifts per day; whenever only 2 shifts were worked per day, this is counted as 2/3 of 1 day. Sections of tunnel where long lead-up times occurred (generally at the tunnel portals) have not been included in the data presented below.

Table 5. General excavation rates

	No. of metres excavated	No. of days taken	Average advance rate
Downstream heading	893	75	11.9 m/day
Upstream heading	4298	379	11.4 m/day
Total	5191	454	11.4 m/day

Table 5 shows very little difference in the advance rates between the two headings (about 4%). Higher excavation rates were obtained in the upstream heading (Table 5) than in the downstream heading but ground conditions were not as good in sections of the upstream heading, and twice as much support was installed (21% compared to 11%).

Advance rate is tabulated against rock condition in Table 6. The rate per day for rock with RCN 2-4 ranged between 10 and 12 m per day, but for rock with RCN 4-5 was less than 9 m per day.

TABLE 6. ADVANCE RATE AND ROCK CONDITION NUMBER (RCN)

	DOWNSTREAM HEADING			UPSTREAM HEADING			TOTALS		
RCN	Metres	Days	m/d	Metres	Days	m/d	Metres	Days	m/d
2	-	-	-	23	2	11.5	23	2	11.5
2-3	209	18	11.6	651	53	12.3	860	71	12.1
3	284	24	11.8	1568	134.5	11.6	1852	158.5	11.6
3-4	194	17	11.4	1148	96	12.0	1342	113	11.8
4	167	16	10.4	496	50.5	9.8	663	66.5	10.0
4-5	-	-	-	232	26.5	8.7	232	26.5	8.7
5	-	-	-	142	16.5	8.6	142	16.5	8.6

The advance rate has also been tabulated against the main rock types for which the various lengths of support are listed (Table 7). The advance rate was fairly constant, ranging from 10.9 to 12.4 m per day, except in the purple rhyodacite at the outlet portal of the north heading where the rate was reduced to 9.9 m per day, and in the grey dacite porphyry where the advance rate was only 10.1 m per day.

Table 8 shows the advance rates tabulated against supported and unsupported sections, and reduction in the advance rate of 1.9 m per day was recorded for the supported sections. A comparison of predicted and actual amounts of support for the tunnel shows that 1016 m of tunnel was supported, whereas the prediction for support was 1106 m, an overestimate of about 9 percent.

3.5 Ground vibration and tunnel blasting

As the tunnel was located sufficiently far away from houses and any engineering structures (excepting the Electricity Substation) ground vibration tests were not carried out. No complaints were received during tunnel construction.

The explosives used were as follows (Noack, 1979):

(i) Gelignite An60, 28 mm diam., and

(ii) Exactex

The typical loading patterns shown in Appendix 2 for the granite porphyry and Walker Member dacite gave an explosive consumption in the order of 2.5 kg per m^3 of solid rock excavated.

Exactex was used in the three crown holes in an endeavour to reduce crown fragmentation and overbreak.

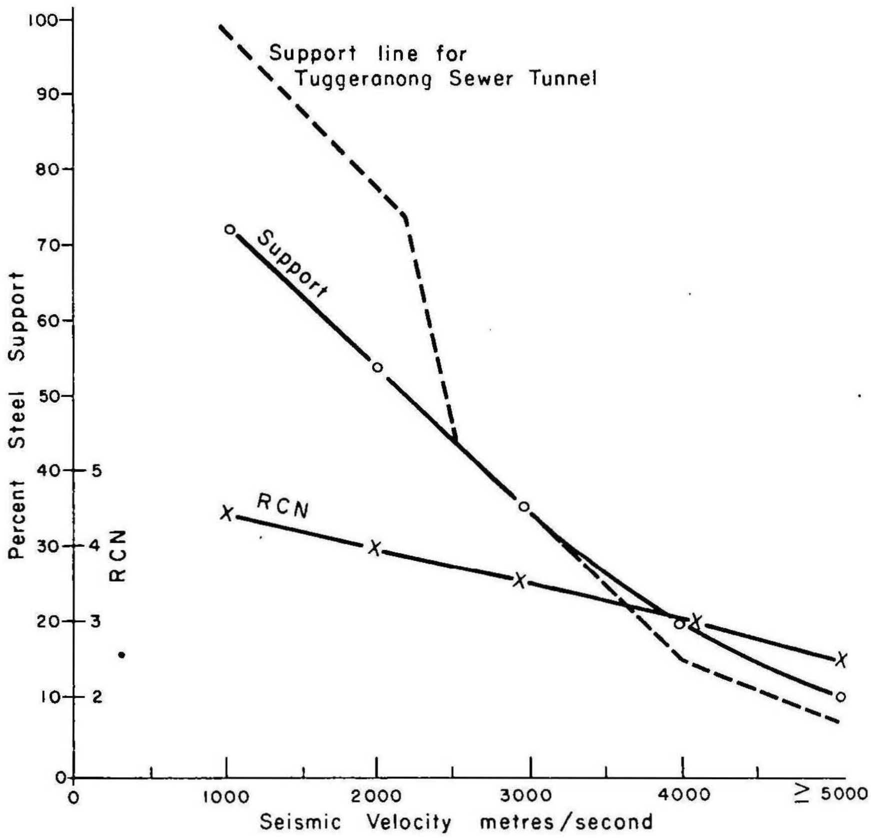


Fig. 5 Relationship between Rock support, Rock condition and Seismic Velocity 16/I55-16/14

RECORD 1981/5

TABLE 7. ADVANCE RATE, ROCK TYPE, AND SUPPORT

	TUNNEL STATION from	to	Distance m	Steel support m	(%)	Days	m/day
Dacite grey-green	(Portal) 5763	- (Portal) 4870	893	108	(12%)	75	11.9
Rhyodacite purple	(Portal) 4756	- 4410	346	30	(8.6)	34	9.9
Dacite and siliceous siltstone	4410	- 3720	690	218	(31.5)	62	11.1
Granite - adamellite	3720	- 2718	1002	51	(5.0)	85	11.8
Shale	2718	- 2580	138	64	(46)	12	11.5
Shale, tuff, sandstone Interbedded	2580	- 1494	1086	47	(4)	88	12.4
Granite porphyry	1494	- 1308	186	31	(17)	15	12.4
Dacite dark grey, fine	1308	- 1127	181	56	(31)	16	11.3
Rhyolite porphyry - rhyodacite	1127	- 1067	60	19	(32)	5.5	10.9
Dacite porphyry grey	1067	- (Portal) 458	609	100	(16)	60.5	10.1
Totals			5191	724	(14)*	454	11.4

* 14% is tunnel average

TABLE 8. ADVANCE RATE AND SUPPORT SUMMARY

	UPSTREAM HEADING			DOWNSTREAM HEADING		
	Unsupported	Steel supported	Total	Unsupported	Steel supported	Total
Length (m)	3390	908	4298	785	108	893
Days taken to excavate	287	92	379	64.5	10.5	75
Advance rate m/day	11.8	9.9	11.4	12.2	10.3	11.9

NOTES:

Upstream heading: 21% of tunnel steel supported

Downstream heading: 12% of tunnel steel supported

PREDICTIONS OF SUPPORT PRIOR TO EXCAVATION

Upstream heading: Up to 990 m (23.2%)

Downstream heading: Up to 110 m (12.3%)

Prediction error: 1106 m predicted, actual 1016 m - i.e. support over-estimated by about 9%.

Electric detonators with ½ second delay were used, except within 1 km of the 330 kV substations at Ch 1800-2600, where non-electric detonators were used.

3.6 Tunnelling and groundwater

Water infiltration into the tunnel on the downstream heading (Ch 4870-5763) was negligible, and during excavation any water inflow together with the waste drilling water was pumped upstream to the portal through a 10 cm discharge line. After concrete lining only minor quantities of water inflitrated through shrinkage cracks (P. Noack, pers. comm.). Accordingly no pressure grouting was undertaken on this heading.

Water infiltration into the tunnel on the upstream heading (Ch 0458-4756) increased progressively during excavation to a maximum constant flow of 37 000 litres per hour. Infiltration water flowed from the tunnel along an invert side drain and discharged through a V-notch weir. Measurements of water outflow were made daily, and a summary graph of these data is shown in Figure 6.

It is estimated that short-duration peak flows from pockets of groundwater intersected by the tunnel in the course of excavation were of the order of 75 000 litres per hour (Ch 1910, Ch 1865 and Ch 1210); however, no delays in tunnelling resulted from these flows.

Most of the groundwater infiltration took place along three sections:

(i) the tunnel section between shaft 1 and Ch 1300

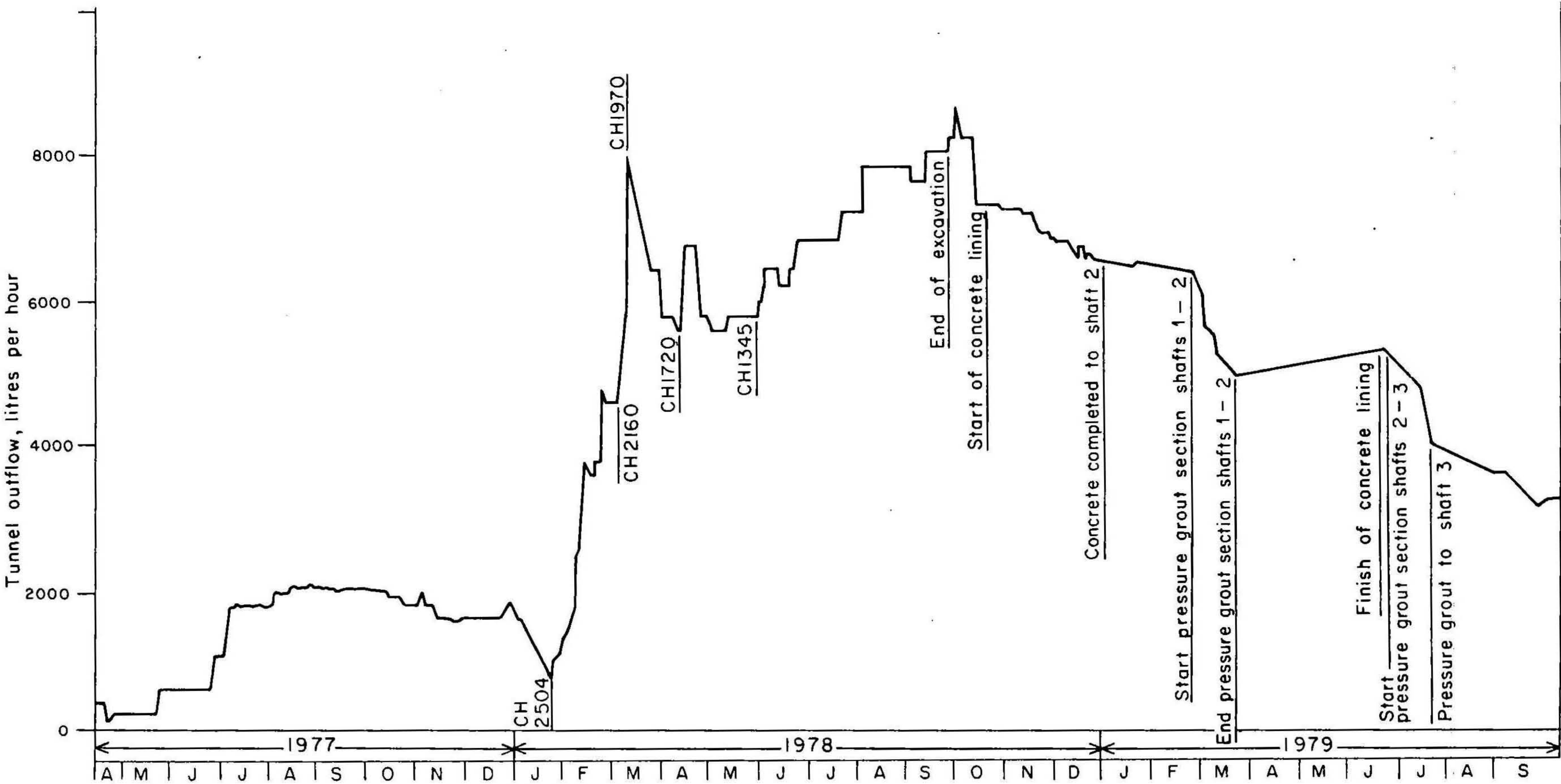
(ii) chainage 1800-2300, and

(iii) chainage 3600-4100

It is not possible to record separately the effect that concrete lining, backfill grouting, and pressure grouting had on reducing the water infiltration as these three operations were carried out concurrently most of the time. Pressure grouting of the tunnel section between shafts 1 and 2 reduced the short-term inflow through the concrete lining from 12 200 litres per hour to 3900 litres per hour.

At the completion of all concrete works the infiltration rate had been reduced to 13 200 litres per hour. It is expected that the long-term infiltration rate could be of the order of 22 000 litres per hour after the water-table stabilises.

Most groundwater inflows were associated with major and minor faults. Either the groundwater inflows issued from the fault itself, particularly where the rock was only fractured and not filled with clay or gouge, or more commonly the groundwater inflows came from fractured rock adjacent to the fault. Many faults contained clay and crushed rock; this reduced their permeability and caused them to act as barriers to the flow of groundwater from the adjacent rock which in some cases had bben fragmented by the fault and had a high porosity and permeability. Such a condition brought about the high inflows at chainages 750, 4040, and 1310 when the adjacent faults 4, 3, and 2 were penetrated and the water held back by the faults were released.



RECORD 1981/5

16/I55-16/13

Fig. 6 Water outflows from upstream heading during construction

4. REVIEW OF THE PRE-CONSTRUCTION GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS

Fourteen diamond-drill holes and nine groundwater observation bores, with a total length of 1045 m, were drilled to investigate the 5 km tunnel. The seismic refraction survey was directed towards (1) the identification of low-velocity rock at tunnel depths, which was usually associated with faulting, and (2) changes in lithology, which were identified generally by variations in the thickness and the velocities of the weathered profiles. Seven kilometres of seismic traversing was undertaken and the interpretations were developed with reference to the geological mapping. The geological conditions encountered were essentially as predicted by the investigation reports (Lang & Purcell, 1976; Taylor, 1975); in particular the locations of faults and changes of lithology were accurately identified.

Support predictions for the tunnel were over-estimated by about 10 percent; the predicted overbreak was generally less than 50 cm beyond the C-line; surveyed overbreak, expressed as the percentage increase of concrete volume over and above the concrete placed within the C-line, was calculated from tunnel survey measurements as 45 percent.

Drainage of groundwater from the zone to the north of Willow Bend by drillhole GST 17 before construction greatly reduced the amount of water held behind fault 4 in that section. The largest inflows during excavation were associated with interbedded dacitic tuffs and sandstones beneath the electricity substation, and further north in welded pyroclastic flows near Ginninderra Creek.

The close liaison between geologists and geophysicists during the investigation phase of the project was a major influence in the preparation of a comprehensive engineering geology report that proved to be accurate in the prediction of rock condition and tunnel support.

5. REFERENCES

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APPENDIX 1:

Definition of Terms

including

Rock condition numbers and degrees of weathering

APPENDIX 1: DEFINITION OF TERMS

ROCK CONDITION NUMBERS

1. Descriptions of the Rock Condition Numbers (RCN) have been modified after Terzaghi (1964) and Deere, Merritt, & Coon (1969) on suit geological conditions encountered in tunnelling operations in the ACT since 1971. To date these tunnels have passed mainly through acid volcanics and sedimentary rocks derived from them.

2. Predicted support requirements for each RCN should be used only as a guide, as very narrow but poorly oriented defects in an otherwise long section of competent rock (e.g. RCN 2) may require 2 or 3 steel sets or a few rock bolts for stablisation. The predictions of support assume an excavated tunnel diameter of up to 4m.

3. It should also be noted that RCN 7 and 8 have not been recorded to date in the ACT.

ROCK CONDITION

Number

Description of the Rock Mass

1. HARD INTACT ROCK: Rock massive, very hard and very strong, with no significant joints or other defects. Breaks across sound rock when blasted. No support necessary.

2. HARD WIDELY JOINTED ROCK: As above, but may be foliated or bedded with a fairly high resistance to separation of surfaces. Prominent continuous joints spaced 1-3 m are tight; joints usually not continuous for more than a few metres. No support required.

3. MASSIVE, MODERATELY JOINTED: Rock mostly hard and strong. Continuous joints generally spaced 0.5-1 m are usually fairly tight, but some water seepage along joints may occur. Rock may be partly blocky in places, and generally breaks along joint surfaces when blasted. Steel or rock-bolt supports generally not required in 3 m diameter tunnel; in a 4 m tunnel, some rock-bolts may be required where blocky or poorly oriented defects cross the tunnel.

4. MASSIVE, MODERATELY JOINTED, SEAMY: As above but defect surfaces generally clay-coated and loose. Clay seams and sheared or fractured rock with clay common. Rock may be moderately weathered or altered and soft in parts. Steel-set support (1-1.3 m spacing) sometimes required in tunnels up to 3 m diameter; more often in 4 m tunnel. Rock-bolts may be preferable in places.

5. CLOSELY JOINTED AND SEAMY: Closely jointed, seamy, and fractured rock; joints and fractures are loose and open (where not clay-filled), and may result in large water inflows into the excavation; includes highly and extremely weathered (or altered) rock. May exert considerable weight on steel-set supports; steel supports spaced at 1 m (or less) with heavy timber lagging. Rock-bolts not usually effective.

6. SEAMY AND CRUSHED ROCK: Includes unconsolidated sand, slopewash, etc. Refers to fault zone material (gouge) or shattered rock where clay and gravel make up the greater percentage of the material mass. If water content is high, these materials may run or flow and exert significant side pressures. Stand-up time near zero. Rock-bolting not effective. Steel sets 0.5 m centres, invert struts, and possibly linear plates. Shotcrete or gunite often effective in containing running ground.

7. SQUEEZING GROUND: Slow movement of rock into the tunnel without perceptible volume increase (rock with clay minerals with low swelling characteristics).

8. SWELLING GROUND: Material expands in volume upon exposure to water (e.g. montmorillonite clay, serpentinite, anhydrite, etc.).

DEGREES OF ROCK WEATHERING

FRESH	: No discolouration or loss in strength.
FRESH STAINED	: limonitic staining along fractures; rock otherwis fresh and shows no loss of strength.
SLIGHTLY WEATHERED	: Rock is slightly discoloured, but not noticeably lower in strength than the fresh rock.

MODERATELY WEATHERED : Rock is discoloured and noticeably weakened; N-size (54 mm) drill core generally cannot be broken by hand across the rock fabric.

HIGHLY WEATHERED : Rock is discoloured and weakened; N-size (54 mm) drill can generally be broken by hand across the rock fabric.

EXTREMELY WEATHERED : Rock is decomposed to soil, but the original rock fabric is mostly preserved.

ROCK SUBSTANCE

This is defined as intact, effectively (for engineering purposes) homogenous rock. Repeated mechanical tests on the material would give acceptable coefficients of variations (e.g., uniform results).

ROCK MASS

Rock mass is a body of material which is not effectively homogenous, that is, the rock substance is crossed by natural defects such as joints, faults, seams etc.

SHEARED ROCK

Consists of rock intersected by close (<1 cm), slightly curving intersecting fracture planes; the fracture surface may be smooth, polished, slickensided, or coated with clay.

CRUSHED ROCK

Consists of rock which is mechanically disintegrated but not obviously chemically decomposed.

FRACTURED ROCK

Consists of rock which is intensively jointed in several directions. Fracture surfaces are often clay-coated.

FAULTED ROCK

Faults can be sheared, crushed, or fractured rock, and where relative displacement of rock can be seen. Unless evidence for faulting is quite definite the term should not be used.

JOINT SPACING

Very close - joints spaced <5 cm

Close - joints spaced 5 to 30 cm

Moderately close - joints spaced 30 cm to 1 m

Wide - joints spaced 1 to 3 m

Very wide - joints spaced >3 m

JOINT APERTURE

This describes the amount of separation of the joint surfaces. Joints may be open or tight. If two joint faces fit perfectly it is probable that the joint in the rock mass was tight (or closed). However, if they do not fit it probably means that the joint was open; or possibly filled with clay that has been washed away during drilling.

BEDDING

Laminated	-	<10 mm thick
Thinly bedded	-	10 mm to 100 mm thick
Thickly bedded	-	>100 mm thick

GRAINSIZE

Coarse-grained	-	1 mm to 4 mm in diameter
Medium-grained	-	$\frac{1}{4}$ mm to 1 mm in diameter
Fine-grained	-	$<\frac{1}{4}$ mm in diameter

ROCK QUALITY DESIGNATION (RQD)

RQD is the ratio (expressed as a percentage) of length of core recovered to the total length of core run, counting only those pieces of hard and sound rock 10 cm in length or longer.

APPENDIX 2:

SURVEY OVERBREAK CALCULATIONS

AND

EXPLOSIVE LOADING PATTERNS

ESTIMATION OF CONCRETE QUANTITIES FROM SURVEY OVERBREAK DATA

Upstream heading (4298 m)

Pay concrete: 3.04 m^3 per m of tunnel

3.04 x 4298 — 13065 m^3

Overbreak concrete, unsupported section (3390 m)

Average overbreak as a percentage of pay concrete in this section: 36%

Overbreak concrete: 3.04 x 3390 x 0.36 — 3710 m^3

Overbreak concrete, steel supported section (908 m)

Average overbreak as a percentage of pay concrete in this section: 85%

Overbreak conrete: 3.04 x 908 x 0.85 — 2346 m^3

Total overbreak concrete, upstream heading: — 6056 m^3

TOTAL ESTIMATED CONCRETE — 19121 m^3

Overbreak concrete as a percentage of pay concrete for this heading — $\frac{6056}{13065} \times 100$ — 46.3%

Downstream heading (893 m)

Pay concrete: 3.04 m^3 per m of tunnel

3.04 x 893 — 2710 m^3

Overbreak concrete, unsupported section (785 m)

Average overbreak as a percentage of pay concrete in this section: 24.8%

Overbreak concrete: 3.04 x 893 x 0.248 — 597 m^3

Overbreak concrete, steel-supported section (108 m)

Average overbreak as a percentage of pay concrete in this section: 72%

Overbreak concrete: 3.04 x 108 x 0.72 — 236 m^3

Total overbreak concrete, downstream section: — 833 m^3

TOTAL ESTIMATED CONCRETE: — 3543 m^3

Overbreak concrete as a percentage of pay concrete for this heading: — $\frac{833}{2710} \times 100$ — 30.6%

Calculations

Cross-section area of pay concrete

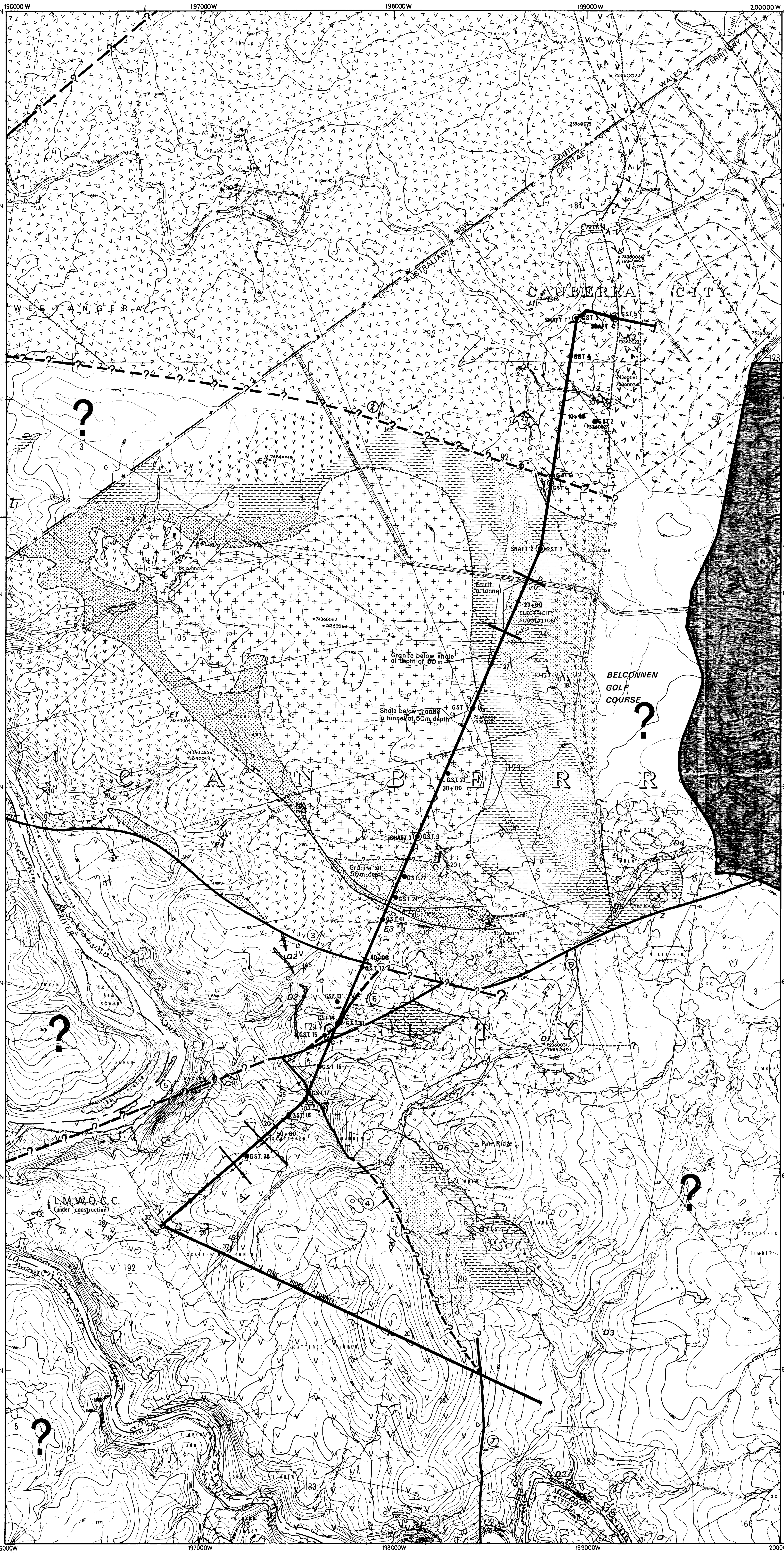
Radius to internal surface of concrete	=	1.065 m
Cross-section area to internal surface	=	3.56 m^2
Radius to C-line (circular)	=	1.380 m
Cross-section area to internal surface	=	5.98 m^2
Area pay concrete (circular)	=	5.98 - 3.56 = 2.42 m^2
Additional area for horse-shoe shaped irregularities	=	0.62m^2

Therefore area pay concrete (horse-shoe section) = 3.04 m^2

Length of C-Line

Length of circular C-line	= 8.69 m
Length of circular C-line 200^o arc	= 4.82 m
Sealed horse-shoe section of lower part of tunnel	= 2.24 m

Total C-line length = 4.82 + 2.24 = 7.06 m



GINNINDERRA SEWER TUNNEL
Interpretive Solid Geology

STRATIGRAPHIC SEQUENCE

ROCK NAME	UNIT NAME	AGE
— Granite porphyry	Ginninderra porphyry[1]	Ludlovian
— Light grey dacitic densely welded pyroclastic flows. — Dark grey member at base.	Willow Bridge tuff[2]	
unconformity		
— Dacitic densely welded tuffs & pyroclastic flows. Bedding in places.	Walker member Uriarra Volcanics[3]	Wenlockian
— Dacitic welded tuffs, agglomerates, pyroclastic flows, sills & dykes. — Quartz sandstone marker bed. — Shale. Thin beds interbedded with pyroclastics. — Sandstone. Thin beds interbedded with shales & pyroclastics. Graded bedding from pyroclastics to sandstones	Painter porphyry[1]	
— Green Rhyolite — Purple Rhyodacite		
— Purple tuffs, tuffaceous sandstones & shales — Purple Rhyodacite		
— Pink Rhyolite		

1 Registered
2 Named by Link 1971, replaces Laidlaw Volcanics
3 Appeared in BMR record Malcolm 1954

REFERENCE

40+00 Tunnel line with tunnel station in metres

SHAFT 1 GST. 3 Shaft

FAULTS

- Fault number referred to in text
- Position accurate
- Position approximate
- Fault inferred
- Fault breccia

N MN 12°

GEOLOGICAL BOUNDARIES

- Position accurate
- Position approximate
- Boundary inferred

FOLDS

- Anticline
- Syncline

BEDDING

- 30 Dip and strike of bedding

DRILL HOLES

- G.S.T. 20 Diamond drill hole
- 75840101 Specimen locality and registered number
- A Locality referred to in text

SCALE

500 0 500 1000m.

Coordinants are in metres
Contours are in feet above Sea Level

LEGEND

Road, sealed	Co-axial cable	Dam, Tank			
Road, not sealed	Telephone or telegraph line	Edge of timber			
Vehicle Track with grid	Power transmission line	Cutting, Embankment			
Railway line	Contours with contour value	Scour, Rock outcrop			
Bridge, Culvert	Trigonometrical station, Bench mark	Sand, Marsh			
Property boundary, fenced	Spot elevation	Territorial boundary			
Property boundary unfenced	Watercourse, intermittent	District boundary			
Fence with gate	River or stream, perennial	Division boundary			

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

SCALE 0 100 200 300 400 500m
Base map/survey: ACT PLANNING SERIES P19 & P27
Geology by P.A. LANG
Compiled and checked: P.A.L. Project geologist
Checked and approved: D.C.P. Senior geologist
E.G.W. Supervising geologist
TITLE: SOLID GEOLOGY
PROJECT: GINNINDERRA SEWER TUNNEL
To accompany Record 1981/5
Drawn by: D.G. T.K.
Drawing No. 55/A8/2323

AMENDMENTS

No.	Description	Author	Checked
A1	Localities referred to in text added	DCP	27/11/76 DCP
A2	G.S.T. 6 & G.S.T. 8 added	DCP	29/11/76 DCP
A3	Sample locations corrected for 75840019, 75840018, 75840020 and 75840101	DCP	10/12/76
A4			
A5			

Plate 1

TUNNEL STATION (metres)	20+00 · 19+00 · 18+00 · 17+00 · 16+00 · 15+00 · 14+00 · 13+00 · 12+00 · 11+00 · 10
ACTUAL CONDITIONS — OVERBREAK (% outside C-line and above A-line invert)	9% · 24% · 31% · 44% · 19% · 29% · 71% · 130% · 54% · 39% · 23% · 14% · 24% · 7% · 14% · 29% · 44% · 57% · 24% · 54% · 24% · 44% · 29% · 23% · 24%
SUPPORTED SECTIONS	3 · 10 sets · 8 Sets · 13 Sets · 27 sets · 23 Sets · 3 · 18 Sets · 6
ROCK CONDITION NUMBER	3 · 3-4 · 4 · 3-4 · 3 · 2-3 · 3-4 · 4 · 4-5 · 3 · 2-3 · 3 · 3-4 · 3 · 2-3 · 3 · 2-3 · 3 · 3-4 · 3 · 4 · 3 · 3-4 · 4 · 3-4 · 3 · 4 · 3-4 · 3 · 3-4 · 4 · 3-4 · 3 · 3-4 · 3 · 4-5 · 3 · 3-4 · 3 · 3-4 · 3
ROCK TYPE + WEATHERING	SW grey Dacite in crown, Black Shale on walls · Black Shale · SW Dark grey Dacite · Dark grey FS Dacite · Interbeds of shale + dacite · SW-MW with some HW Granite Porphyry · HW Granite Porphyry · SW-HW Dacite · SW-HW Dacite · Rhyolite · SW-FS Rhyodacite · HW-SW Pink + grey Dacite
ADVANCE (metres/week)	96m 13 to 18·3·78 · 49 20 to 23·3·78 · 36m · 68m 3 to 8·4·78 · 30m 10 to 12·4·78 · 26m 17·4·78 to 20·4·78 · 79m 1 to 6·5·78 · 85m 8·5·78 to 13·5·78 · 71m 15 to 20·5·78 · 74m 22 to 27·5·78 · 65 29·5·78 to 2·6·78 · 55m · 62m 12 to 17·6·78 · 69m 19 to 24·6·78 · 68m 26·6·78 to 1·7·78 · 67m 3 to 9·7·78

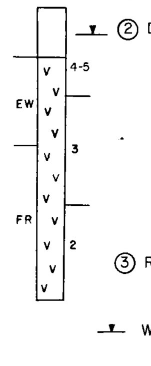
PREDICTED CONDITIONS	20+00 to about 15+00	about 15+00 to 13+00	13+00 to 10+00
ROCK HARDNESS AND STRENGTH	Dacite UCS 150–250 MPa, av. 200 MPa. Av. hardness 72 Shore Units	No data from GST 6 and GST 8	Mostly extremely hard and strong. UCS 173 to 492 MPa, av. 300 MPa. Zones of partly epidotised rock with UCS 173 – 273 MPa, av. 220 MPa. Av. hardness 100 Shore Units
ROCK MASS DEFECTS	Mainly competent dacite with joints spaced mostly 30 cm – 1 m but up to 3 m. Joints generally tight and cemented with calcite. Possibly some minor faults and fractured and seamy zones. Possibly some thin lenses of shale	Main defects will be confined to contacts. Granite contact with dacite to the south probably a narrow fractured zone. Contact with welded dacite to north probably fractured and sheared from 13+20 to about 14+00	Zones of very strong and competent rock with very few defects. Joints spaced up to 3 m, very tight. Zones of close jointed mod tight rock (joint spacing generally 10–60 cm but up to 1 m) with surfaces generally weakly cemented with pink powdery calcite. Many qtz - epidote veins. Some joints slightly open. Some narrow seamy zones.
PREDICTED OVERBREAK Due to rock mass defects only	Mostly negligible but in blocky zones blocks up to 30 cm may fall out beyond C line. Unfavourable orientation of prominent defects may cause > 30 cm overbreak beyond C line. Shale lenses may cause more overbreak	Overbreak 7 1m possible at north contact; if accompanied by moderate to large water inflows overbreak could approach 2m in places. Overbreak elsewhere < 30cm, but up to 1m possible at south contact	In competent rock negligible overbreak. In blocky zones, blocks generally < 30 cm may fall out beyond C-line. Unfavourable orientation of some defects may cause > 60 cm overbreak beyond C line (rare)
PREDICTED TUNNEL CONDITION	Mostly 2 – 3 probably some 4	Mostly 3. 4 at south contact and 5 at and near north contact and fault zone.	Mostly 2 to 3. Some 4
PREDICTED SUPPORT REQUIREMENTS	Possibly some steel sets but total for section probably < 50 m. Probably some random rock bolts in blocky areas in dacite or in any stably shale	Up to 100 m of tunnel may need steel set support – mainly confined to north contact and fault zone.	Very little expected. Possibly some steel sets in 2600 m/sec zone. Total for section probably < 30 m
PREDICTED WATER INFLOWS	Mostly dry to damp. Persistent seepages and dripping from some fractured zones. Some minor initial inflows (< $1 m^3/hr$) from some open joints or fractured zones. Inflows up to $5 m^3/hr$ are possible but very unlikely.	Mostly damp away from contacts. Up to $3m^3$ initial inflow south contact. Up to $10m^3$ initial inflow north contact and fault zone. Inflows at contacts may continue at up to $1m^3$ (south) and $2m^3$ (north contact)	Mostly dry to damp. Persistent seepage and dripping from some fractured zones. Possibly some defects with initial inflows up to $1m^3/hr$. Inflows up to $10 m^3/hr$ very unlikely. Initial inflows will decrease rapidly after excavation

TUNNEL STATION (metres)	10+00 · 9+00 · 8+00 · 7+00 · 6+00 · 5+00 · 4+00 · 3+00 · 2+00 · 1+00 · 00
ACTUAL CONDITIONS — OVERBREAK (% outside C-line and above A-line invert)	4% · 33% · 45% · 49% · 16% · 12% · 12% · 12% · 23% · 36% · 60%
SUPPORTED SECTIONS	7 Sets · 26 Sets · 16 Sets · 7 Sets
ROCK CONDITION NUMBER	3 · 2-3 · 3 · 3-4 · 4-5 · 3 · 5 · 3-4 · 5 · 4 · 3-4 · 3 · 3-4 · 3 · 2-3 · 3 · 3-4 · 3 · 3-4 · 3 · 3-4 · 4 · 3 · 2-3 · 3 · 3-4
ROCK TYPE + WEATHERING	HW-SW Grey Dacite · Dark grey SW Dacite · Dark grey FS Dacite
ADVANCE (metres/week)	56m 10 to 15·7·78 · 45 · 49m 24 to 29·7·78 · 76m 31·7·78 to 5·8·78 · 68m 7 to 12·8·78 · 73m 14 to 19·8·78 · 65m · 50m 28·8·79 to 2·9·79 · 10m · 14m · 28m 18 to 21·9·78

PREDICTED CONDITIONS	10+00 to 4+55	Open cut excavation			3+00 to 00
ROCK HARDNESS AND STRENGTH	Mostly extremely hard and strong. UCS 173 – 492, av. 300 MPa. Zones of partly altered and epidotised rock at GST 2 and GST 4 with UCS 173 – 273 MPa. Av. hardness 100 Shore Units	OPEN CUT EXCAVATION Generally excavatable by bulldozer with ripper. Some blasting necessary near invert. Sides of excavation will need to be battered or supported	Mostly soft and fairly weak	UCS average 300 MPa	OPEN CUT EXCAVATION
ROCK MASS DEFECTS	Zones of very strong and competent rock with very few defects. Joints spaced up to 3 m very tight. Zones of close jointed mod tight rock (joint spacing generally 10 – 60 cm but up to 1 m) with surfaces generally weakly cemented with pink powdery calcite. Many quartz – epidote veins. Some joints slightly open. Some narrow seamy zones		Weathering is the main defect. Rock EW to MW. Possibly some SW near invert	Strong and fairly tight SW – FS dacite	1. Extremely to highly weathered dacite to base of excavation along most of section — Excavatable by large backhoe without preblasting
PREDICTED OVERBREAK Due to rock mass defects only	In competent rock negligible overbreak. In blocky zones, blocks generally < 30 cm may fall out beyond C line. Unfavourable orientation of prominent defects may cause > 60 cm overbreak beyond C line (rare)		If very carefully excavated, overbreak could be kept to a minimum	Small to negligible	2. Probably a few boulders of fresh dacite generally < 2 m in diameter sitting in extremely weathered dacite — need blasting and/or jack picking
PREDICTED TUNNEL CONDITION	Mostly 2 – 3, some 4		Mainly 5 to 6. Possibly some 4 near invert	Mainly 3	3. Some moderately to slightly weathered dacite near stn 2+00 – Probably need blasting or jack picking
PREDICTED SUPPORT REQUIREMENTS	Very little expected. Probably < 50 m total of steel sets. Possibly some rock bolts		100% steel set support indicated	Probably none	
PREDICTED WATER INFLOWS	Mostly dry to damp. Persistent seepage or dripping from some fractured zones. Possibly some fractured zones with initial inflows up to $1 m^3/hr$ decreasing after excavation. Inflows up to $10 m^3/hr$ are possible but very unlikely		Initially < $5m^3/hr$. Most will flow from the intermediate – bedrock velocity interface	Initially < $5m^3/hr$ and rapidly decreasing	Mostly dry. Possibly some minor seepages

REFERENCE

SUMMARY LOG OF DRILL HOLES



① Rock-material type

② Degrees of weathering
- EW Extremely weathered
- HW Highly weathered
- MW Moderately weathered
- SW Slightly weathered
- FS Fresh stained
- FR Fresh

③ Rock Condition Number (see text for definitions)

Water level in drill hole

ROCK TYPES

- Granite Porphyry
- Welded dacite, light grey
- Welded dacite, dark grey
- Dacite, Sandstone, Shale — interbedded
- Purple rhyodacite

SEISMIC

- Intermediate seismic velocity refractor
- Highest seismic velocity refractor
- (600) Seismic velocity in metres per second

GEOLOGICAL

- Boundaries approximate
- Boundaries inferred
- Fault zone approximate
- Trend line of bedding
- GST 3 Drill hole number and location
- GST 6 Angle drill hole number and location
- 100 Groundwater inflow (l/h)

Clay seams
- 1cm – 0·1m wide
- 0·1m – 1 m wide
- Fragmented rock } actual widths
- Shear zone } actual widths

AMENDMENTS

No	DESCRIPTION	AUTHOR CHECKED	DATE
1			
2			
3			

GEOLOGY BY P.H VANDEN BROEK

COMPILED AND CHECKED	CHECKED AND APPROVED
P.H. VANDEN BROEK, PROJECT GEOLOGIST	D.C PURCELL, SENIOR GEOLOGIST

E.G. WILSON, SUPERVISING GEOLOGIST

Scale 0 10 20 30 40 50 m; $\frac{V}{H} = 1$

TITLE: GEOLOGICAL CONDITIONS: TUNNEL STATION 04+55 TO 20+00

PROJECT: GINNINDERRA SEWER TUNNEL

TO ACCOMPANY RECORD 1981/5	SHEET 1 OF 3
DRAWING NUMBER I55/A16/2324	PLATE 2

GEOLOGICAL SECTION ALONG TUNNEL LINE

TUNNEL STATION (metres)	40+00 · 39+00 · 38+00 · 37+00 · 36+00 · 35+00 · 34+00 · 33+00 · 32+00 · 31+00 · 30
ACTUAL CONDITIONS	
OVERBREAK (% outside C-line and above A-line invert)	2·5; 9·1; 14·1; 19; 19; 48·8; 58·7; 33·9; 28·9; 45·5; 9·1; 4·1; 9·1; 5·8; 5·8; 40·4; 114 (enlarged section); 24; 17·4; 22·3; 9·1; 16·5; 9·1; 4
SUPPORTED SECTIONS	8 Sets; 49 Sets; 42 Sets; 8 Sets; 7 Sets; 4 sets; 6 Sets
ROCK CONDITION NUMBER	3; 2-3; 3; 3-4; 3; 4; 3-4; 3; 2-3; 3; 4-5; 4; 3-4; 4-5; 4; 3-4; 3; 3-4; 4-5; 3-4; 4; 3-4; 3; 2-3; 3; 2-3; 3; 2-3; 3; 2-3; 3-4; 3; 2-3; 3; 2-3; 3; 3-4; 3; 3-4; 4-5; 3-4; 2-3; 3; 3-4; 4; 2-3; 3
ROCK TYPE + WEATHERING	Mostly SW grey Dacite and some interbedded black slicken sided siltstone; SW Grey Dacite; SW Grey Dacite; MW Granite Porphyry; Pale grey SW Adamellite; Pale grey SW coarse grained granite; Pinkish grey SW coarse grained granite; Medium grey SW granite porphyry; HW Fault?; SW Granite porphyry
ADVANCE (metres/week)	76m 18 to 23·7·77; 72m 25 to 30·7·77; 60m 1 to 6·8·77; 48m 8 to 13·8·77; 62m 15 to 21·8·77; 74m 22 to 27·8·77; 73m 29·8·77 to 3·9·77; 69m 5 to 10·9·77; 74m 12 to 17·9·77; 61m 19 to 24·9·77; 32m 27 to 30·9·77; 69m 4 to 8·10·77; 9m; 70m 18 to 22·10·77; 70m 24 to 29·10·77; 74m 31·10·77 to 5·11·77
PREDICTED CONDITIONS	
ROCK HARDNESS and STRENGTH	Rock breaks fairly easily across the rock fabric. Probably break to pieces from 10-30 cm when blasted
ROCK MASS DEFECTS	Rock mass is mostly tight with joints spaced 30-60 cm (10-40 cm in some areas) and generally cemented with calcite. Probably blocky in places. Probably some fractured and seamy areas especially near granite contact; Mostly tight but probably some fractured and seamy areas; The rock mass is very tight with joints generally spaced 30 cm - 1m and commonly cemented with calcite. Possibly some narrow fractured or sheared zones. (None detected during drilling); Up to 60 m (total) of sheared and/or fractured and/or blocky and seamy rock with mostly tight sound rock elsewhere
PREDICTED OVERBREAK due to rock mass defects only	Generally very little to negligible. Small to moderate in some fractured, seamy or blocky zones; Small to moderate in fractured and seamy areas, negligible elsewhere; Very little to negligible; Small to moderate in sheared fractured or blocky zones. Negligible elsewhere
PREDICTED TUNNEL CONDITION	Mostly 3. Some 4.; Mostly 3-4; Mostly 2-3; Mostly 3 Some sections of 4-5
PREDICTED SUPPORT REQUIREMENTS	Possibly some random rock bolts in blocky sections. Possibly some short lengths of steel set support (Probably < 30 m total); Possibly some rock bolts and/or steel sets; Very little if any; Up to 60 m of steel sets. Probably some random rock bolts
PREDICTED WATER INFLOWS	Mostly dry to damp. Persistant seepages and dripping from some fractured zones. Possibly some small to moderate initial inflows; Possibly some small to moderate initial inflows from some fractured zones; Mostly dry to damp; Small to moderate initial inflows in fractured or sheared zones. Dry to damp elsewhere

GEOLOGICAL SECTION ALONG TUNNEL LINE

TUNNEL STATION (metres)	30+00 · 29+00 · 28+00 · 27+00 · 26+00 · 25+00 · 24+00 · 23+00 · 22+00 · 21+00 · 20
ACTUAL CONDITIONS	
OVERBREAK (% outside C-line and above A-line invert)	4; 4; 9·1; 4·1; 0·8; 19; 28·9; 48·8; 53·7; 57; 48·8; 31·4; 16·5; 19; 33·9; 33·9; 9·1; 24; 9·1; 16·5; 14; 14; 9; 9
SUPPORTED SECTIONS	64 Sets; 14 Sets; 21 Sets
ROCK CONDITION NUMBER	2-3; 3; 3-4; 4; 3-4; 2-3; 3; 3-4; 3; 3-4; 3; 3-4; 3; 5; 4; 4-5; 3-4; 4-5; 3; 3-4; 3; 3-4; 4; 3; 3-4; 3; 2; 2-3; 3-4; 2-3; 3-4; 2-3; 3
ROCK TYPE + WEATHERING	Medium grey SW granite porphyry; Pale grey SW coarse grained Granite; Thinly laminated SW-FS Black shale, occasional interbeds of siliceous sst.; SW dark grey bedded tuff & black shale interbeds; FS dark grey, fine grained dacite (bedded tuff); FS dark grey dacite interbedded with paler more crystalline dacite; Strongly interbedded shale, siltstone & some dacite tuff.; EW granite stock intruding shale; Mostly SW bedded siltstone, some tuffaceous sandstone interbeds; SW Dacite with interbeds of black shale and siltstone
ADVANCE (metres/week)	71m 7 to 12·11·77; 83m 14 to 19·11·77; 77m 21 to 26·11·77; 80m 28·11·77 to 3·12·77; 72m 5 to 10·12·77; 58m 12 to 18·12·77; 38m 19 to 23·12·77; 76·5m 23 to 28·1·78; 73m 30·1·78 to 4·2·78; 73m 6 to 11·2·78; 87m 13 to 18·2·78; 82m 20 to 25·2·78; 65m 27·2·78 to 4·3·78; 75m 6 to 11·3·78
PREDICTED CONDITIONS	
ROCK HARDNESS and STRENGTH	
ROCK MASS DEFECTS	The Rock mass is mostly very tight with joints generally spaced 30 cm - 1m and commonly cemented with calcite. Probably some narrow fractured or sheared zones (<40 m total), some blocky zones; Probably some fractured rock; Mainly competent dacite with tight joints mostly spaced 30 cm - 1m. Some thin lenses of shale mostly competent and with tight bedding planes but possibly some zones with up to 1 cm of clay on bedding planes. Slabbing ? Probably some minor to moderate folding in places. Possibly some minor faults and fractured and seamy zones
PREDICTED OVERBREAK due to rock mass defects only	Negligible for most of section. Small to moderate in some fractured, sheared or blocky zones; Small to moderate in fractured zone; Negligible in most of section but may be moderate in shale due to drilling up bedding planes. May be moderate in fractured areas or in areas of minor folding and clay on bedding planes
PREDICTED TUNNEL CONDITION	Mostly 2-3 Probably some 4; Probably some 4; Mostly 2-3 Probably some 4
PREDICTED SUPPORT REQUIREMENTS	Possibly some random rock bolts if any blocky sections. Possibly some short lengths of steel set support. Total for section probably 0-30 m; Possibly some steel sets or rock bolts; Possibly some steel sets but total for section probably < 50 m. Probably some random rock bolts in blocky areas in dacite, or in slabby areas in shale
PREDICTED WATER INFLOWS	Mostly dry to damp. Persistant seepages and dripping from some fractured zones. Possibly some small to moderate initial inflows from some fractured zones; Probably < 10 m^3/hr initially decreasing to < 2 m^3/hr; Mostly dry to damp. Persistant seepages and dripping from some fractured zones. Possibly some small to moderate initial inflows from some fractured zones

REFERENCE

SUMMARY LOG OF DRILL HOLES

② ① ③

① Rock-material type

② Degrees of weathering
- EW Extremely weathered
- HW Highly weathered
- MW Moderately weathered
- SW Slightly weathered
- FS Fresh stained
- FR Fresh

③ Rock Condition Number (see text for definitions)

Water level in drill hole

ROCK TYPES

- Soil and slope wash
- Granite Porphyry
- Dacite, Sandstone, Shale, Siliceous siltstone — Interbedded

SEISMIC

- Intermediate seismic velocity refractor
- Highest seismic velocity refractor
- (600) Seismic velocity in metres per second

GEOLOGICAL

- Boundaries approximate
- Boundaries inferred
- Fault inferred
- Trend line

$\oplus^{100}$ Groundwater inflow (litres/hour)

Clay seams — 1cm to 0·1m wide; 0·1m to 1m wide

Fragmented rock, Shear zone — actual widths

AMENDMENTS

No	DESCRIPTION	AUTHOR	CHECKED
1			
2			
3			
4			
5			
6			

GEOLOGY BY P.H. VANDEN BROEK

COMPILED AND CHECKED	CHECKED AND APPROVED
P.H. VANDEN BROEK, PROJECT GEOLOGIST	D.C. PURCELL, SENIOR GEOLOGIST

E.G. WILSON, SUPERVISING GEOLOGIST

Scale 0 10 20 30 40 50 metres $\frac{V}{H} = 1$

TITLE: GEOLOGICAL CONDITIONS: TUNNEL STATION 20+00 TO 40+00

PROJECT: GINNINDERRA SEWER TUNNEL

TO ACCOMPANY RECORD 1981/5 — SHEET 2 OF 3

DRAWING NUMBER I 55/A16/2325 — PLATE 3

GEOLOGICAL SECTION ALONG TUNNEL LINE

TUNNEL STATION (metres)	60+00	59+00	58+00	57+00	56+00	55+00	54+00	53+00	52+00	51+00	50

ACTUAL CONDITIONS

OVERBREAK (% outside C-line and above A-line invert)	NOT AVAILABLE FOR DOWNSTREAM SECTION
SUPPORTED SECTIONS	7 sets; 23 sets
ROCK CONDITION NUMBER	4, 3-4, 3, 3-4, 3, 3-4, 3, 2-3, 3, 2-3, 3, 4, 3-4, 2-3, 3, 3-4, 3-4, 4, 3, 2-3, 3, 2-3, 3, 2-3, 3, 2-3, 3, 2-3, 3, 3-4, 4, 3-4, 3, 3-4
ROCK TYPE + WEATHERING	TUNNEL END; SW-HW green-grey Dacite; SW-FS grey Dacite; SW-FS Blue-grey Dacite; SW grey-green DACITE; SW-FS grey-green Dacite
ADVANCE (metres/week)	45m 25 to 30·4·77; 66m 18 to 23·4·77; 41m 13 to 16·4·77; 35m 4 to 8·4·77; 48m 28·3·77 to 2·4·77; 55m 21 to 26·3·77; 53m 14 to 19·3·77; 35m 8 to 12·3·77; 50m 28·2·77 to 5·3·77; 51m 21 to 26·2·77; 51m 14 to 19·2·77; 48m 7 to 12·2·77; 42m 1 to 5·2·77; 44m 24 to 29·1·77; 32m 17 to 22·1·77; 42m 10 to 15·1·77; 33m 4 to 8·1·77

PREDICTED CONDITIONS

ROCK HARDNESS AND STRENGTH	Mostly very hard and very strong. UCS 200-218 MPa, av. 207 MPa. Av. hardness 88 shore units. Zones of blue grey dacite will be harder and stronger than these figures. Zones of green grey will be slightly weaker and softer. Generally drill penetration is slow and drill wear rate high
ROCK MASS DEFECTS	Recomend portal at Stn 57+55 (See text for details). Rockmass is mostly competent. Occasional sections of less competent rock (fractured, sheared or seamy zones). Joint spacing variable, mostly 30 to 60 cm; joint surfaces generally rough and tight
PREDICTED OVERBREAK Due to rock mass defects only	In competent rock generally negligible over break, but some blocks up to 30 cm may fall out beyond C line. Fall out of some blocks up to 60 cm beyond C line in blocky zones or where the prominent joints 20°/SW/130° (bedding) and 90°/070°, 60°/NW/040° intersect the tunnel. Unfavourable orientation of prominent defects (e.g. "greasy backs") may cause > 60 cm overbreak beyond C line (rare)
PREDICTED TUNNEL CONDITION	Generally 3 (55%). Some zones of 2 (20%) and 4 (23%). Narrow zones of 5 (2%). Percentages in brackets are from same rock type in Pine Ridge tunnel
PREDICTED SUPPORT REQUIREMENTS	Some narrow sheared and/or fractured zones will require short length (6-15 m) of steel set support. Total for section probably less than 30 m (excluding portals). Some random rock bolts in blocky zones
PREDICTED WATER INFLOWS	Mosty dry to damp. May be a few fractured zones with initial inflows up to 10 m³/hr decreasing rapidly after excavation. Total outflow at portal expected to be < 10 m³/hr during excavation decreasing to 3 m³/hr after excavation completed

GEOLOGICAL SECTION ALONG TUNNEL LINE

TUNNEL STATION (metres)	50+00	49+00	48+00	47+00	46+00	45+00	44+00	43+00	42+00	41+00	40

ACTUAL CONDITIONS

OVERBREAK (% outside C-line and above A-line invert)	NOT AVAILABLE; 67·7; 66·7; 60·3; 57; 38·8; 58·7; 53·7; 58·7; 43·8; 48·8; 45·5; 24; 19; 26; 16; 9·1; 19; 14; 2·5
SUPPORTED SECTIONS	26 sets; 30 sets; 55 Steel sets; 91 Sets; 65 Sets; 118 Steel support sets; 13 Sets; 15 Sets; 5 Sets; 10 Sets
ROCK CONDITION NUMBER	4, 3-4, 4, 3-4, 4; 5, 4-5, 4, Mainly 3-4, in places 4, 4, 3-4, 4-5, 4, 4-5, 4, 4-5, 5, 4, 5, 4-5, 5, 4, 5, 4, 5, 4, 3-4, 5, 4, 3, 3-4, 3, 2-3, 2, 2-3, 4, 3, 3-4, 3, 5, 3-4, 3
ROCK TYPE + WEATHERING	SW-FS grey-green Dacite; MW grey-green Dacite; HW-EW yellow brown Rhyolite; MW purple Rhyolite; MW-HW purple Rhyolite; Mostly MW-HW grey Dacite but EW where rock is broken & shattered; MW-SW grey Dacite; EW to HW grey Dacite; SW blue-grey Dacite; SW grey Dacite with slickensides of some joints; MW grey Dacite; EW Dacite; SW grey Dacite
ADVANCE (metres/week)	13m 20 to 22·12·76; 18m 13 to 18·12·76; 16m 6 to 11·12·76; 28m 29·11·76 to 4·12·76; 25m 22 to 27·11·76; 21m to 20·11·76; Face on 21·10·76; Excavation; 20m 18-23·4·77; 47m 25 to 30·4·77; 48m 2·5·77 to 7·5·77; 65·6 9 to 14·5·77; 56·5m 16 to 21·5·77; 54·5 23 to 28·5·77; 59m 30·5·77 to 4·5·77; 61m 6 to 11·6·77; 63·6m 14 to 18·6·77; 71·9m 20 to 25·6·77; 81·1m 27·6·77 to 2·7·77; 73·5m 4 to 9·7·77; 70·5m 11 to 16·7·77

PREDICTED CONDITIONS

ROCK HARDNESS AND STRENGTH	Av. UCS 96-145 MPa, av. hardness 68 Shore Units (GST 18)	Recommend portal at station 47+40. Slumping expected in east wall of open cut. Initial water inflows up to 10 m³/hr from portal face. Rock at portal face close jointed and fractured; bolts and mesh will be required to stabilise face	UCS 220-322 MPa, av. 260 MPa. Av. hardness 56 Shore Units	UCS (from Point load) 110 MPa. Av. hardness 78 Shore Units	UCS (from Point Load) av 170 MPa. Hardness and strength expected to be similar to Stn 50+00 to 57+00 in most zones but may be weaker in some zones
ROCK MASS DEFECTS	Bedding planes dip 15° South (dip of tunnel drive); probably sheared in part. Some crushed seamy up to 20 cm thick. Clay coated joints common		Close jointed (10-30 cm); loose and open in places	Blocky and mostly seamy; clayey fractures and sheared zones common	Rockmass is mostly competent. Possibly some sections of less competent rock (fractured, sheared or seamy zones). Joint spacing generally 10-30 cm but up to 1 m, and generally tight
PREDICTED OVERBREAK Due to rock mass defects only	Most overbreak probably associated with greasy bedding planes: blocks generally < 60 cm may fall out beyond C line		Where loose and open blocks generally < 60 cm may fall out beyond C-line	Where blocky and seamy, blocks < 60 cm may fall out beyond C line. Some fractured or sheared zones may produce section of overbreak > 60 cm beyond C line	In competent rock, blocks < 30 cm may fall out beyong C-line; larger overbreak may be associated with some defect zones
PREDICTED TUNNEL CONDITION	Mostly 4 Probably some 5		Mainly 3 to 4	Mainly 4. Long sections of 5 possible	Probably mostly 3-4
PREDICTED SUPPORT REQUIREMENTS	Up to 80 m of steel sets Portal face probably require some bolts and mesh		Probably < 50 m of steel set support	Up to 250 m of steel set support	Probably less than 50 m of steel set support. Possibly some random rock bolts in any blocky zones
PREDICTED WATER INFLOWS	Probably only seepages; any initial inflows < 0·5 m³/hr decreasing		Initially high close to portal (possibly up to 20 m³/hr). Gradual decrease to < 5 m³/hr	Mostly damp with seepages. Possibly some minor initial inflows (< 3 m³/hr) from any open joints or fractured zones	Mostly damp. Persistent seepage or dripping from some fractured zones; initial inflows up to 10 m³/hr possible from some open jointed or fractured zones

REFERENCE

SUMMARY LOG OF DRILL HOLES

① Rock-material type
② Degrees of weathering
EW Extremely weathered
HW Highly weathered
MW Moderately weathered
SW Slightly weathered
FS Fresh stained
FR Fresh
③ Rock Condition Number (see text for definitions)
Water level in drill hole

ROCK TYPES

Soil and slopewash
Scree and colluvium
Dacite, blue-grey to purple
Rhyolite, green
Rhyodacite, purple
Dacite grey

SEISMIC

Intermediate seismic velocity refractor
Highest seismic velocity refractor
(600) Seismic velocity in metres per second

GEOLOGICAL

Boundaries approximate
Boundaries inferred
Fault zone approximate
Trend line of bedding
1 cm to 0·1 m wide } clay seams
0·1 m to 1 m wide
Groundwater inflow (ℓ/hr)
GST 20 Drill hole number and location
GST 17 Angle drill hole number and location
GST 15 Trace of drill hole in plane of section
Fragmented rock } actual width
Shear/Fault zone

AMENDMENTS			
No	DESCRIPTION	AUTHOR	CHECKED
1			
2			
3			
4			
5			

GEOLOGY BY P.H. VANDEN BROEK

COMPILED AND CHECKED: P. Vanden Broek, PROJECT GEOLOGIST
CHECKED AND APPROVED: D.C. Purcell, SENIOR GEOLOGIST
E.G. Wilson, SUPERVISING GEOLOGIST

Scale 0 10 20 30 40 50 metres; H/V = 1

TITLE: GEOLOGICAL CONDITIONS: TUNNEL STATION 40+00 TO 57+88

PROJECT: GINNINDERRA SEWER TUNNEL

TO ACCOMPANY RECORD 1981/3 — SHEET 3 OF 3

DRAWING NUMBER I 55/A16/2326 — PLATE 4

083647