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MELBOURNE CABLE TUNNELS, GEOLOGICAL INVESTIGATIONS

1978 SUPPLEMENTARY REPORT

VOL.I

by

D.C. PURCELL, G. TRAND AND E.G. WILSON

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PLATES

1. INTRODUCTION

This report describes the geological investigations carried out for the proposed Telecom Cable Tunnels under Queen, Lonsdale, Russell, Exhibition and Rathdowne Streets, Melbourne. The Department of Construction is the design and construction authority for the Australian Telecommunication Commission.

The first report on geological investigations for the Melbourne Cable Tunnels, BMR Record 1978/16, was issued in July 1978 (Purcell and Trand, 1978). Since then, the drilling of another 13 holes in August 1978 has provided additional geological information, and changes have been made in the route and invert levels of the proposed tunnel. This report updates the July 1978 BMR Record by amending the tunnel alignment and the inclusion of results of the additional drilling, but it does not duplicate information already included in the appendices to the earlier Record such as drillhole logs and core photographs.

The tunnel locations, the location of shafts, chambers and investigation drillholes and geology are shown on Plates 1 to 8.

Design of the works,including location of tunnel invert, chambers and shafts was not finalised until August 1978. Consequently, some drillholes do not now coincide with the final location of the engineering structures that they were originally drilled for. Because of changes in tunnel locations, drillholes 28 and 29 in Exhibition Street are some distance removed from the final tunnel alignments, and drillholes 1, 2A and 4 are located on the alignment for a future tunnel in Queen Street.

Queen, Lonsdale, Russell and Rathdowne Street tunnels will be "single" tunnels with a maximum width of 3.1 m and a height of 3.3 m(B-line to B-line) (Plate 2B). The Exhibition Street tunnel (Lonsdale to Victoria Streets) will have an enlarged profile with a width of 4.4 m and a height of 3.9 m (B-line measurements) (Plate 2A). The total length of the tunnels (including chambers) is about 1850 m.

Depths of cover above tunnel crown will vary from about 5-9 m in Queen Street, 6-7 m in Lonsdale Street, 4-6 m in Exhibition Street, 6 m in Russell Street, and about 4-9 m in Rathdowne Street.

The site investigations were carried out between July 1977 and August 1978 by Mr G. Trand (Department of Construction) and Mr D.C. Purcell (Bureau of Mineral Resources). [illegible]ty-one holes were drilled for a total depth of 631 m.

2. SUMMARY OF CONCLUSIONS

Following the site and laboratory investigations it can be concluded that:

1. Construction of the tunnels, chambers and other appurtenant works are feasible.

2. The geological information available for the Lonsdale, Russell, Exhibition and Rathdowne Street tunnels is regarded as satisfactory for a reasoned prediction to be made of the distribution of the various geological formations other than dykes, and for an assessment of their tunnelling characteristics to be made. However, the relationship between the various Cainozoic formations that overlie the Silurian Dargile Formation in Queen Street, namely the Werribee Formation, the Older Volcanics and the Brighton Group, is so complex that the drillhole information is reliable only for assessing the tunnelling characteristics of the formations, and not for making a reasoned prediction of the distribution of the various formations.

3. The tunnels will be driven through the stratigraphic units listed below. Tunnelling conditions will be extremely variable within individual units and between units; the best conditions will be in zones 3 and 4 mudstone, and the worst in the Colluvium , Zone 1 mudstone and the Elizabeth Street Formation.

Rock type	Weathering*	Approximate length (m)	Approximate total length in unit (m)
Mudstone	Zones 1 and 1-2	490	
	Zone 2 and 2-3	330	
	Zones 3 and 4	480	1300
Older Volcanics			135
Brighton Group and Werribee Formation			70
Colluvium			200
Elizabeth St. Formation			145
	**TOTAL LENGTH OF TUNNELS		1850

* Definitions in Appendix 1

** Including chambers

4. The presence or absence of groundwater will determine tunnelling

conditions and stability more than any other factor. Geological formations will have a fairly low permeability, except the fractured Older Volcanics, and the formations most sensitive to changes in groundwater levels for stability purposes will be the Colluvium, Werribee and Elizabeth Street Formations, and Zone 1 Mudstone. Whilst no major sustained inflows are expected, draining of wet formations would greatly improve tunnelling conditions; constant pumping from a deep bore in MW to SW Dargile Formation could be expected to dewater such materials.

5. Rock loads should not be very high, the largest vertical load being about 290 kPa (Zone 1 Mudstone) and the smallest about 50 kPa (Zone 3 Mudstone). Rock loads in the Colluvium may be close to the strength of the material. Initially the tunnel face in clay (Zone 1 Mudstone or Elizabeth Street Formation) is expected to be stable in all cases, but a decrease in strength associated with dissipation of pore water pressure may reduce stability in the longer term.

6. Some loss of ground can be expected from all units; the loss could be potentially large from the Colluvium if it is water saturated. Good tunnelling techniques should minimise both ground losses and rock loads; ground surface settlements should be small, possibly ranging to 15 mm in places.

7. Most of the tunnels and all appurtenant excavations will require support during construction. A concrete sub-invert may also be required in places. Combinations of rockbolts, mesh and shotcrete, or of steel sets, lagging and shotcrete are likely to be the dominant support systems. Shotcreting may not be possible in Zone 1 Mudstone, Colluvium and the Elizabeth Street Formation, particularly if these units are water saturated. The option of chemical grouting of the Colluvium from the surface has been assessed as not economically feasible due to the extremely low water injection rates achieved during investigation.

8. The most appropriate excavation methods would be as follows:

Method	Approximate length of route (m)	Percent of route
Conventional drill-blast-muck		
Zones 3-4 Mudstone (90 m)	140	(8)
Basalt (50 m)		
Road Header (or like) machine		
Zones 2 and 3 Mudstone (720 m)		
Basalt (85 m)		
Elizabeth Street Formation, if dry (145 m)	950	(51)
Hand mining or/and overhead mucker		
Zone 1 and 1 to 2 Mudstone (490 m)		
Colluvium (200 m)		
Brighton Gr. & Werribee Fm (70 m)	760	(41)
TOTAL	1850	

9. Chamber excavation conditions will be fair to good in basalt and zones 2 and 3 mudstone, but poor where Cainozoic sediments are at or near crown. The potential for loss of ground during underground excavation is high, and if not carefully excavated and supported, caving to the surface is possible. Settlements above the chambers will be greater than that above tunnels and traffic loads should be added to rock load computations.

10. Excavation conditions for the shafts will be poor and support in the form of steel rings and full timber lagging will be required.

11. Manholes and ventilation shafts can be readily drilled and cased to prevent caving.

3. SITE INVESTIGATIONS CARRIED OUT

3.1 REVIEW OF EXISTING INFORMATION

The geology of the central business district of Melbourne is described by J.C. Brumley (1974) in "Explanatory notes on the 1:5,000 stratigraphic Map of Melbourne Central Business District" and "An Engineering Geologic Mapping System for the Central Business District of Melbourne, Australia" (1975). Additional information on the geology of the project area has been obtained from rock exposed in nearby building and civil engineering projects. In compiling this report reference has been made to many published papers on the properties of the Melbourne mudstone.

3.2 DRILLING

Twenty eight holes were drilled by Soilmech Pty Ltd between July and November 1977; 6 were angled and 22 were vertical. The planned holes were numbered consecutively, but decisions not to drill some holes account for missing numbers in the drillhole logs.

In August 1978, another 13 vertical holes were drilled; some were required to gain additional geological information at key tunnel points, and others were required by Golder Associates as part of an assessment of the feasibility of grouting the colluvium in the vicinity of Russell Street (Golder Associates Pty Ltd, 1978). The holes were drilled to an average depth of about 15 m. Of the 35 vertical holes six were augered to their full depth. A total of 631 m was drilled. Tube samples were taken in unconsolidated materials and piezometers were installed in appropriate drillholes (see geological logs of drillholes, Appendix 5).* Cores 1 to 29 were photographed in the core barrel prior to sealing (against moisture loss) and all cores were photographed in the core boxes prior to selection of samples for mechanical testing (Core photographs, Appendix 4). *

3.3 ROCK TESTING

Selected samples of drillcore have been subjected to rock strength tests. Appendix 2 summarises results of these tests. A more detailed report on methods and results has been prepared by the Department of Construction (Department of Construction, 1978).

4. GENERAL GEOLOGY

Plate 1 shows a plan of the tunnel layout and the interpreted geology of the tunnel route, based on the drilling and records of construction in Melbourne, and the Stratigraphic Map of the Central Business District of Melbourne, first edition, 1974.

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* Geological logs [illegible] photographs of drillholes 1 to 29 available only in appendices to [illegible] 1978/16 (Purcell and Trand, 1978).

Queen Street Tunnel

The Queen Street tunnel line bears north-northwest and intersects the general bedding and structural trend of the Silurian sediments at an acute angle ranging from 10 to 40°. The tunnel, 266 m long, will be driven through extremely weathered Silurian sediments, marine sediments of the Werribee Formation, basalt and tuff of the Older volcanics and shallow marine and alluvial sediments of the Brighton Group. These formations are separated from each other by an unconformity and two disconformities.

Tunnelling conditions will vary greatly between the formations, and in some cases within the formations themselves.

Lonsdale Street Tunnel

The Lonsdale Street Tunnel line bears east-northeast and intersects the trend of the Silurian sediments at an angle ranging from 25 to 90 degrees. The tunnel is 1200 m long and will be driven through extremely to slightly weathered sediments of the Dargile Formation, and unconsolidated sediments of the Elizabeth Street Formation and an unnamed colluvium near Russell Street.

Tunnelling conditions will vary greatly within the Dargile Formation itself, and the unconsolidated sediments provide two sections of potentially difficult tunnelling.

Russell, Exhibition and Rathdowne Street Tunnels

Russell, Exhibition and Rathdowne Street tunnels are short tunnels, 128, 120 and 134 m long respectively.

The Russell Street tunnel is aligned in the same direction as the Queen Street tunnel and will be driven mainly through unconsolidated colluvium, with minor sections of extremely weathered Dargile Formation at each end of the tunnel.

The Exhibition Street tunnel is also aligned in the same direction as the Queen Street tunnel and will be driven through moderately weathered Dargile Formation.

The Rathdowne Street tunnel consists of 3 sections that range about a general northerly direction, and it will be driven through extremely weathered to moderately weathered Dargile Formation, and possibly weathered dyke rock.

4.1 PHYSIOGRAPHY AND WEATHERING

Construction fill covers most of the city area; it is usually less than about 1 m thick but may be deeper where it overlies Quaternary sediments. The Silurian Dargile Formation of mudstone or more precisely claystones and clayey siltstones with minor beds of fine sandstone (Nielson, 1970) has been weathered to varying degrees depending on the structure, defects, and proximity to dykes and/or sills, and can be highly weathered to depths in excess of tunnel invert. Weathering and lithologic boundaries may be quite irregular. The igneous intrusions are also weathered to varying degrees and may be extremely weathered to a stiff, whitish-grey siliceous kaolinite; some are only slightly weathered.

Five zones of weathering in the mudstones have been recognised by Neilson (1970) and are defined in Appendix 1. These zones have been used in the weathering description of mudstone in this report, but the weathering of other lithologies (e.g. sandstone, basalt) is described in accord with the 'Degrees of Rock Weathering' also set out in Appendix 1.

4.2 ROCK TYPES AND STRATIGRAPHY

Silurian mudstones and sandstones crop out over about half of the city area and elsewhere they underlie Cainozoic sediments and basaltic lavas.

SILURIAN

Dargile Formation - The formation is composed of interbedded mudstone (claystones and clayey siltstones) and fine-grained sandstone and is intruded by acid igneous dykes and sills. Where weathered this formation is yellow-brown. The most common bed thickness is between 25 and 50 mm; some sandstone beds are much thicker (1 m and more). The strike of the beds within this formation varies mainly from about 45° to 020° *, and the beds range in

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* All bearings refer to grid north.

dip from horizontal to vertical.

The weathered profile of the Dargile Formation is characterised by a gradual transition from clays at the surface to fresh rock at depth. The progress of weathering is facilitated by close joint spacing associated with fold axes, shear zones and igneous intrusions. With increasing depth, the water content of weathered rock decreases and both hardness and strength increase. Reversals of the weathered sequence have been noted in profiles, but are generally associated with a local condition such as close jointing or shearing.

TERTIARY

Werribee Formation - This formation was intersected below the Brighton Group in holes 8, 40 and 41 in Queen Street and below basalt in hole 10 at the Queen Street-Lonsdale Street intersection.

The material is an orange to white clayey silt with a 0.4 m thick gravel-silt marking the base of the Formation. It is a shallow water coastal marine deposit.

The formation rests unconformably on weathered Silurian rocks that form a surface of low relief. Over a distance of about 350 m along Queen Street, the formation was encountered in only 4 of the 7 holes; it ranges in thickness to 6 m (hole 40) and should be regarded as discontinuous.

The Werribee Formation is overlain by basalt and/or by sediments of the Brighton Group, and there are some marked changes in relief over short distances at the top of the formation. At hole 40, Little Bourke Street, the formation is 6 m thick and extends from below tunnel invert to above crown level of the nearby cable chamber (R.L. 18.59); however, 13 m away on the other side of the cable chamber at hole 8, the formation is only 2.7 m thick and will intersect only the lower third of the tunnel below R.L. 14.69. Similarly at hole 41, Little Collins Street, the Werribee Formation is 2 m thick, intercepts the crown of the cable chamber, and the top of the formation is at R.L. 10.44 m; at hole 4, 22 m further south, the Werribee Formation was not present.

The nature of the Werribee Formation is such that it would erode readily and form an irregular surface, and the complete removal of sections of the Werribee Formation is to be expected prior to extrusion of the Older Volcanics, and during a later period prior to deposition of the Brighton Group.

Later sediments of the Werribee Formation elsewhere in Victoria overlie some basalts of the Older Volcanics; however, Werribee sediments overlying basalt have not been recorded in Melbourne central district and the Werribee Formation is considered to underlie the basalt.

Older Volcanics -

Basaltic lava flows occurred periodically throughout the deposition of the Werribee Formation in Victoria. The basalt was intersected in drillholes 4, 5A and 6 in Queen Street and in hole 10 at the Lonsdale-Queen Street intersection, but was missing from holes 41, 40 and 8. Drillcore shows the basalt to be variably weathered, mostly dense, and vesicular in parts (up to 40% vesicles were logged in a section of hole 5A). The basalt is confined almost entirely to the Queen Street sections of the route, and does not form a continuous sheet. It ranges in thickness to about 10 metres in hole 5A. The base of the basalt, where it overlies the Werribee Formation, is likely to be an irregular surface.

Brighton Group - This group is composed of shallow water marine and alluvial clayey sands and sandy clays, and was intersected in Queen Street in drillholes 6, 8, 40 and 41, and was missing from holes 4 and 5A. The sediments are partly or poorly consolidated with a variable degree of limonite cementation.

The Brighton Group sediments are also discontinuous and range in thickness to 7 m (hole 8). They rest on the irregular upper surface of the Werribee Formation and also overlie the basalt.

QUATERNARY

Colluvium - The Colluvium at the Lonsdale and Russell St. intersection was recovered in drillholes 21A, 22 23, 23A and 24; and 33, 34, 35, 36, 37 and 38. Stiff silty clays to depths of about 5 m overlie interbedded clayey sands and sandy clays. Sand grains are sub-angular to angular (minor rounded). The Colluvium appears to fill an erosional depression striking roughly in a northerly direction, across Russell, Lonsdale and Exhibition Streets, and it ranges in thickness to about 15 m. Weathered dyke material was recovered from beneath the Colluvium in drillholes 21A, 23 and 23A.

Elizabeth Street Formation - This is a fluviatile deposit of soft to stiff sandy clay with some rounded sand and gravel. Drillholes 11, 12, 13, 14, 15, 16, 17 and 39 intersected this Formation along Lonsdale Street down to a depth of 14 m. The mudstone underlying the thickest part of the Formation is generally moderately weathered.

The upper surface of the Dargile Formation is irregular and the location of this geological boundary is likely to vary considerably from the approximate boundaries where they are shown in the accompanying sections. The upper surfaces of the Werribee Formation and basalt are also irregular and both formations lack continuity; it is not possible to show boundaries between these formations or their boundaries against underlying or overlying formations with any confidence.

4.3 STRUCTURE

4.3.1 Folding

The Dargile Formation was folded in Devonian time into major folds with many superimposed minor folds that consist of closely spaced pitching anticlines and synclines. The bedding in the drillcores varies greatly even over a few centimetres in the one drillhole. The strike of the fold axes varies from 340° to 040° grid bearing. Drag folding adjacent to dykes has been observed in the area, and a sharp change in the dip of bedding in drill core can sometimes be attributed to intrusion of a nearby dyke (e.g. core from drillhole 21).

Inferred fold axis locations are shown on Plates 1 to 8.

The Tertiary sediments and volcanics, and Quaternary sediments are not folded.

4.3.2 Faulting

Faulting within the Melbourne area is common with faults generally of limited displacement. The main faults strike 010° grid with a steep dip to the east or west, and a second set strikes 290° grid with a steep dip to the north or south. Major faults are rare, however fractures zones are common in the mudstone (and sandstone) and such zones are to be expected in tunnelling. Sheared rock may be associated with dyke intrusions.

Faulting may have affected the Tertiary rocks; evidence of such faulting was not found during the investigation, but if faults are present, the displacement will be small and is not expected to significantly affect tunnelling operations.

4.3.3 Jointing

No statistical analysis of joint orientations in the mudstone was possible during this investigation due to lack of outcrop and the fact that only 2 core orientations were obtained.

There are three predominant joint sets in the Silurian strata:

(i) joint planes that cut across the bedding planes approximately at right angles,

(ii) those that have a strike of 290° grid and a steep dip to the north or south, and

(iii) bedding plane joints.

At tunnel level, joints will mostly be closely spaced although joints in zone 3 and 4 mudstone may often be moderately close to moderately spaced (see Appendix 1 for definitions of joint spacing).

Joints in the basalt are often irregular and closely spaced; some are rough and open, and others are tight or cemented to varying degrees.

Close jointing is likely to be more common near the axes of folds.

4.3.4 Dykes and Sills

Within the Melbourne area many dykes and sills have been found to intrude Silurian strata. As weathering of the igneous intrusions within the Melbourne area is often near complete, an accurate petrological classification is often difficult.

An acid dyke (position indefinite) is present near the corner of Exhibition and La Trobe Streets. This dyke which has a thickness of approximately 14 metres is composed of quartz and minor feldspar with disseminated fine pyrite. Intermediate and basic dykes are common; the identifiable constituents are coarse biotite flakes disseminated in a groundmass of kaol...

Most dykes are probably aligned parallel to the main fold axis and most are near vertical. Bedding in the mudstone has been dragged adjacent to some of the intrusions and has caused some shearing, fracturing and close jointing near the contacts. Most dykes are highly to extremely weathered (holes 14, 21 and 26) but some are moderately to slightly weathered (holes 21A, 23 and 23A). Known and interpreted dyke locations are shown on Plate 1.

4.4 GROUNDWATER CHEMISTRY

From 1965 to 1973 several hundred groundwater samples from MURL* shafts and bores were chemically analysed to determine whether the groundwater was aggressive to construction materials. It was found that groundwater under the north and east parts of MURL in the vicinity of the proposed Telecom Tunnel is a slight to moderately aggressive sodium chloride type water. Detailed analyses are given by Brumley, 1977. Contours of the potentiometric surface prior to MURL excavations are shown on Plate 1.

4.5 SEISMICITY

An extract from the "Earthquake Risk Map of Australia (1978)" is included in Appendix 3, BMR Record 1978/16 (Purcell and Trand, 1978), with a print out of earthquake data relevant to construction in Melbourne.

The best defined cluster of earthquake epicentres is near Wilsons Promontory about 150 km southeast of Melbourne City. Another cluster occurs to the southwest of the city off Otway Coast. In southeast N.S.W., the return period of an earthquake of M5.5 (Richter) and 6.5 is about 30 years and 300 years respectively (Drake, 1976); the Melbourne area is probably less active than this. Although it is unlikely, it is not impossible that an earthquake of M6.5 or 7 could occur in the area. Ground displacement along faults is most unlikely but liquifaction associated with ground movements in saturated unconsolidated deposits (such as the colluvium in Russell and Lonsdale Streets) is possible, even with earthquakes lower than M5.5.

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*MURL - Melbourne Underground Rail Loop

An isoseismal map of the 20/6/69 Gippsland Earthquake (M5.9 ML) with its epicentre about 30 km south of Morwell, shows Melbourne City to lie within zone III felt intensity (Modified Mercalli) (Wilkie, 1970).

Seismic risk calculations for a 50 year return period for Hastings (a few km south of Melbourne City) give peak horizontal accelerations of 85 cm/sec^2, and a peak velocity of 5 cm/sec (Underwood, 1969).

5. ENGINEERING GEOLOGY

5.1 DARGILE FORMATION

Silurian mudstone (and sandstone) may comprise about 20 percent of the Queen Street tunnel, 70 percent of the Lonsdale Street tunnel, approximately 30 percent of the Russell Street tunnel, and all of Rathdowne and Exhibition Street tunnels. Seventy percent of the entire project may be located in this Formation. About 75 percent of the Dargile Formation may be mudstone (siltstone and claystone) and about 25 percent is interbedded sandstone. Drilling and excavations indicate that the sandstone content will increase east of Elizabeth Street, although at tunnel level most of the sandstone will be moderately weathered.

5.1.1 Weathering

The degree of weathering of the Dargile Formation at tunnel level varies considerably along the tunnel routes, and conditions at the tunnel face may range from Zone 3 at invert to Zone 1 or 2 at crown.

Because mudstone weathers readily to form clay minerals, its presence in the formation is significant. There is a preponderance of mudstone over sandstone, and a mudstone bed can be weakened by weathering to a partly plastic condition whereas an adjoining sandstone bed may retain its hardness and strength. Thicker sandstone beds may be extremely hard and resistant to weathering owing to a siliceous cement between quartz grains; thin sandstone bands are generally somewhat silty and clayey and lacking in siliceous cement and weather far more readily.

Weathering of sandstone bands makes them friable and finally, with increasing intensity, reduces them to clayey sands and sandy clays.

Zones 1 and 2 mudstones are soft and have low strength; they are generally yellow-brown in colour with a high clay content, and bedding is almost always indiscernable.

Zone 3 mudstone is of moderate strength and hardness; clay seams (extremely weathered beds) and clay-coated joint surfaces occur occasionally. The mudstone is generally pale brown-grey with clearly defined bedding.

Zone 4 mudstone is hard and strong, and defect surfaces are generally tight and clean; it is greyish in colour.

Zone 5 mudstone was not present in the drill cores and is not expected in the tunnels.

An estimate of the percentage lengths of tunnel in the various weathering categories is given below:

Degree of weathering	Zone of mudstone weathering	Length (m)	Percent of Dargile Formation	Percent of tunnel
EW	1	140	11	8
EW-HW	1 to 2	350	27	19
HW	2	120	9	5
HW-MW	2 to 3	210	16	11
MW	3	390	30	21
MW-SW	3 to 4	90	7	5
	TOTAL	1300	100	69

NOTE: These lengths and percentages are approximate only as they rely on interpretation between widely spaced drillholes. In calculating these percentages, the stability of the tunnel crown has been considered; for example, if Zone 3 rock occurred up to crown level and was immediately overlain by Zone 1 rock, then the length of tunnel involved would be classed as Zone 1. Where more competent material above the springline, such as dry Elizabeth Street Formation, overlies damp Zone 1 rock, then for stability reasons, the section would be omitted from the Dargile Formation figures. The percentages given therefore, should be regarded as "effective" percentages with regard to crown stability.

5.1.2 Rock strength

A number of samples from drillcore were tested at the Department of Construction Central Investigation and Research Laboratory (C.I. and R.L.) Melbourne. Parameters were obtained from cores in different states of weathering where possible. The ranges of the various parameters are summarised below. Full results are given in Appendix 2.

Degree of weathering	Zone 1	Zone 2	Zone 3
Dry Density (kg/m^3)	1700 to 2000	2000 to 2300	2200 to 2500
Moisture Content (%)	7 to 20	5 to 10	3 to 8
**UCS (MPa)	-	1.3 to 1.6	4.1 to 10.1
UCS equivalents derived from *Point load (MPa)	-	1.8 to 11.4 (mostly 3.2)	3.7 to 27.0 (mostly 8.0)
Shear Stress (kPa)	127(single test only)		

* Point Load values have been converted to UCS equivalents using a conversion factor of times 16 in accord with the results in Appendix 2.

** Unconfined compressive strength.

Most of the Zone 3 mudstone at and above tunnel levels occurs in Lonsdale Street between hole 17 and Swanston Street, and between Exhibition Street and Spring Street. Zones 1 and 2 mudstones intersect the tunnel elsewhere.

Zones 1 and 2 can be regarded as incompetent rock (Appendix 1) as far as tunnel stability is concerned; Zone 3 rock is generally competent and Zone 4 rock is very competent but difficult to excavate without blasting.

5.1.3 Groundwater and the Potentiometric surface*

Groundwater levels and piezometer locations are shown on the geological sections (Plates 3 to 8) and in Appendix 6.

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* See Appendix 1 for definitions of potentiometric surface and RQD.

MURL construction has depressed the potentiometric surface below tunnel invert ; however, now that the MURL excavations have been closed, recovery of the potentiometric surface is expected, and piezometers have been placed to monitor its recovery.

Groundwater will seep into excavations from the more permeable formations and will maintain the less permeable formations in a saturated condition wherever the potentiometric surface is above the material under consideration.

Permeability of the mudstone varies considerably. Groundwater inflows through open joints and fractures will affect tunnelling. Permeability in Zone 1 and 2 material will be low, possibly less than about 1 x 10^{-5} cm/sec, due to the high clay content. Water inflows into the tunnel through open and clean defects will probably be confined to Zone 3 or 4 rock where open fractures are more likely. Groundwater inflows and seepages are to be expected from the base of any formation overlying the Dargile Formation.

The presence of groundwater flow or seepage along clay-coated and poorly oriented defects in otherwise competent rock will decrease tunnel stability.

5.4.1 Rock quality

In order to give an indication of "rock quality" or degree of fragmentation of the mudstone, the core was assessed for rock quality designation (RQD)* for weathering Zones 2-3 and 3 and 4. The figures are given as percentages and are considered somewhat subjective due to the difficulty in deciding whether some bedding plane partings were parted in situ, or were caused by drilling and handling of the core.

RQD RATING

	0-25 (very poor)	25-50 (poor)	50-75 (fair)	76-90 (good)	90-100 (excellent)	Length of core (m)
Zone 2 to 3	22%*	10%	35%	23%	10%	35.4
Zone 3 and 4	18%	30%	22%	10%	20%	123.0

* Length of core with this RQD category as a percentage of total length of core examined for the particular zones.

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* See Appendix 1 for definitions of potentiometric surface and RQD

5.1.5 Rock defects

5.1.5.1 Bedding planes

Bedding planes are generally closely to moderately spaced, and vary from planar and smooth, to rough; some planes are tight, others are partly open and clay-coated and some are limonite cemented. Bedding attitudes are variable, and may vary from horizontal to vertical in the one drillhole.

Gently dipping sandstones interbedded with mudstone in the tunnel crown may become unstable with large sandstone blocks becoming detached; this is referred to as slabbing. When beds are steeply dipping, generally greater than 40°, blocks may become detached from the tunnel walls.

In Zone 1, bedding planes are mostly indiscernable and in most instances are not expected to play a significant role in tunnel stability. Bedding planes in Zones 2, 3 and 4 are easily recognised and will affect tunnel stability where they are clay-coated.

Queen Street. Bedding attitude along Queen Street is expected to be about 65°-70° W/360°, and will intersect the tunnel alignment at about 10 to 40 degrees.

Lonsdale Street. Bedding attitudes will vary considerably. From Queen Street (hole 10) to about Stn. 413 m (hole 16), bedding is generally expected to be steeply dipping ($>50^\circ$), and strike will be controlled by the fold axes near Elizabeth Street (Plate 1). Eastwards from hole 17 to beyond Swanston Street (hole 20), the beds probably dip east at about 35°. Beyond hole 20, the beds probably dip west at 20° to 30°, steepening to 80° towards Russell Street. Bedding to the east of Russell Street flattens to 20° to 35° west and probably persists to Spring Street, The strike of the bedding varies, but is generally favourably oriented for tunnel stability. Some sections of tunnel will intersect unfavourably oriented bedding planes and some fracturing and crumpling of the rock may be present at fold axes.

Russell Street. Bedding along Russell Street will probably be about 45° W/360° intersecting the tunnel alignment at about 20°; however, the Zone 1 mudstone below the colluvium is not expected to fail along bedding planes.

Exhibition Street. Bedding along Exhibition Street will probably be about 45° W/360° intersecting the tunnel alignment at about 20°.

Rathdowne Street. Bedding attitude will probably be about 35° W/360°, sub-parallel to tunnel alignment. Failures along bedding planes will be facilitated by the presence of joints, particularly along clay-coated continuous surfaces in the east wall. Major failures due to bedding planes are unlikely if the tunnel is carefully excavated and supported.

5.1.5.2 Joints

Joints are mostly closely spaced as indicated by a predominance of low RQD values in the drillcores. In steeply dipping beds most joints will either follow the bedding or be perpendicular to the bedding (with the same strike). In gently dipping beds, jointing normal to the bedding planes will steepen and be more favourably oriented in a tunnel that intersects the bedding planes at an angle greater than 45°.

Joint strengths will vary from weak to strong, depending on

(i) degree of rock weathering

(ii) degree of limonite cementation (stronger in Zone 3 and Zone 4 rock)

(iii) orientation of joints relative to alignment of tunnel walls

(iv) joint roughness (bedding plane joints often smooth and planar, whereas others may have rough surfaces).

The degree of limonite cementation is variable and will depend on the groundwater conditions and the mineralogy of the surrounding rocks (e.g. a higher percentage of limonite occurs in rock below the basalt flow in hole 5A). Strongly cemented defect planes are almost as strong as intact rock. Laboratory shear strength tests on joint or bedding planes were not made.

Clay is common on joint surfaces and will significantly reduce stability; clay may be more common on low angle planes in highly weathered rock.

Joint plane stability will depend largely on its degree of surface roughness, its tendency to dilate, the presence of clay, the grain size, and joint orientation to tunnel line. The drill logs give an indication of surface roughness, grain size (i.e. claystone, siltstone or sandstone), presence of clay coatings, and dip from horizontal (vertical holes only), but the strike of joint planes is not available. Zone 1 and Zone 1-2 mudstone can be treated essentially as a clay soil and joints will generally have little effect on the stress-strain behaviour of the rock mass.

5.1.5.3 Faults, sheared and fractured zones

Several sheared or fractured zones were intersected in drilling even though most drillholes were vertical (e.g. holes 1, 12, 20, 21A, 26); others may not have been recognised in highly or extremely weathered rock.

Large fault zones were not detected in drilling. Faults, and sheared and fractured zones may be present between drillholes. Most will probably strike parallel to the major structural trends (005° to 025°). A large percentage of faults and shears will follow bedding trends and dip at greater than 45°, but will be only a few centimetres wide.

5.1.5.4 Contacts between formations

Contacts between the Dargile Formation and the other geological formations will generally be weak and constitute possible failure planes. Over-break of mudstone up to its contact with the basalt or other formations may occur if the contact is near tunnel crown level (e.g. between holes 5A and 6 along Queen Street).

It should not be assumed that such a contact would cause catastrophic ground losses. Catastrophic failures would only occur during or immediately following a sudden and unexpected formational change to a vastly less competent material, such as from Zone 3 mudstone to water saturated colluvium. The contacts between rock units in these tunnels are not expected to contain large volumes of water.

5.2 ELIZABETH STREET FORMATION

Approximately 145 m will be tunnelled in this formation.

5.2.1 Formation properties

Approximate ranges of mechanical properties are given below, and these figures have been used in assessments of rock loads and tunnel stability (section 6.2).

General material classification: mostly CH but variable (CL, SC). Average moisture content: variable, mostly near 20%, but ranging to about 50%.
Wet density: 1500 - 2100 kg/m^3
Permeability: close to zero (estimated 10^{-6} to 10^{-8} cm/year), but variable.
Unconfined compressive strength (UCS): 300 - 350 kPa
Shear stress: about 300 kPa

The major clay minerals are kaolinite, illite and montmorillonite, with lesser amounts of mixed-layer clays (illite-montmorillonite).

5.2.2 Groundwater

As MURL excavations are now closed, recovery of the potentiometric surface is to be expected. As the base of the formation is more than 2.58 m below sea level, the lower part of this formation would probably have been below the potentiometric surface prior to the excavation for MURL.

5.3 TERTIARY OLDER VOLCANICS

Approximately 135 m of this unit will be tunnelled.

5.3.1 Rock strength and weathering

Strength of the rock material is variable and depends on the degree of weathering. Thick sections of basalt were cored in holes 5A and 10. Weathering appears more advanced in the basalt from hole 5A, possibly due to the high percentage of vesicles that are generally clay-filled (c.f. hole 10). Where the basalt is slightly weathered to fresh as in the bottom of hole 5A and in most of hole 10, the basalt is hard and strong, but the strength of the rock mass is weakened by closely spaced open joints and fractures.

Only 2 UCS tests of the basalt were made due to lack of suitably sized cores. Comparison of the UCS tests with two point load results gives a ratio between the two of 6.75, whereas 24 is the generally accepted ratio from other work, although a range from 10 to 30 may occur. Point load results in Appendix 2 have been converted to UCS equivalents by a factor of times 24 in line with that proposed by Broch & Franklin (1972). A summary of tests results is given below.

Dry density: 1760 (MW-HW Tuff) to 2820 (SW-MW basalt) kg/m^3
Moisture content: 30% (MW-HW tuff) to 1% (SW-MW basalt)
Point load: 0.10 (EW-HW basalt) to 1.36 (MW-SW basalt) Is(50) MPa
UCS: 2.02 (SW-HW basalt) to 5.26 (SW basalt) MPa (Point Load on these two samples gave 0.26 and 0.82 Is (50) MPa respectively.)

The maximum point load value of 1.36 MPa was obtained from slightly to moderately weathered basalt from hole 10, and is equivalent to 9.2 MPa(UCS) using a conversion of times 6.75. The minimum value of 0.10 from highly weathered basalt from hole 5A, is equivalent to 0.75 MPa (UCS).

Unconfined compressive strength testing of SW to fresh basalt from the Older Volcanics in the Melbourne area often produces results as high as 200 MPa.

5.3.2 Joints

Core recovered from holes 5A and 10 is closely jointed and highly fractured in places. Some joints are limonite cemented but many are open and clay-coated. The action of drilling has further fractured the core, probably along the numerous incipient partly healed fractures. The very low RQD values that were logged for most of the basalt may be conservative as it is likely that many fractures in the core were intact prior to drilling.

5.3.3 Groundwater

Groundwater may be present with the basalt forming a perched aquifer on top of highly weathered mudstone. The basalt in hole 5A was dry at the time of drilling, but a complete loss of drilling water between 8 and 9 m gives an indication of the high permeability of the variably weathered vesicular basalt. The potentiometric surface is expected to be below the basalt, and inflows from the basalt are not expected.

5.4 WERRIBEE FORMATION

The Werribee Formation is likely to intersect the Queen Street tunnel over a distance of 60 m near Little Bourke Street, and 25 m, mainly in the upper part of the tunnel, near Little Collins Street; it may also underlie the basalt between holes 5A and 6 as discontinuous lenses. It is also present near the invert level of the Lonsdale Street tunnel in the vicinity of Queen Street.

5.4.1 Formation strength

When drained of groundwater, the strength of this clayey silt formation is increased. In its damp state immediately after core recovery, strength readings of 0.3 MPa to 0.5 MPa were obtained using a pocket penetrometer (direct readings). Laboratory tests that were done on this formation are shown in Appendix 2 , Sheets 3 and 4.

5.4.2 Groundwater

The potentiometric surface is expected to underlie this formation. Any inflows are expected to fall off quickly to seepage from near the base of the formation.

As MURL excavations are now closed, the potentiometric surface is expected to rise and piezometers in this formation at Little Collins and Little Bourke Street intersections with Queen Street are being monitored (Holes 40 and 41).

5.5 BRIGHTON GROUP

Up to about 25 m of tunnel may intersect the Brighton Group; it will be confined to the Queen Street tunnel mainly in the region of Little Bourke Street, mainly in the tunnel crown.

5.5.1 Strength

Mechanical properties within the Brighton Group will vary; the lower strength readings were obtained from a stiff, damp clayey silt layer (5.5 m, hole 8) and the higher readings from a limonite-cemented sand and silt layer (6.8 to 7.0 m, hole 8).

The range in values obtained from limonite cemented cores from hole 8 are as follows:

Dry density: 1890 - 2100 kg/m^3
Moisture content: 11 - 16.5%
Point load strength: 0.21 to 0.72 Is(50) MPa (equivalent to about 5.04 to 17.28 MPa (UCS), using a conversion factor of times 24.

5.5.2 Groundwater

The potentiometric surface is expected to be below the Brighton Group. Small inflows only are to be expected. As some beds in this group are permeable, recharge from rainfall may temporarily boost inflows into the tunnel, possibly causing some instability in the uncemented parts of the group.

5.6 DYKES

5.6.1 Rock strength and weathering

Hardness and strength of the dyke material is variable and will depend on mineral composition and degree of weathering. Most dykes will be highly weathered, soft and fairly weak. Pocket penetrometer readings in extremely to highly weathered dyke material range from about 100 kPa to 350 kPa for allowable bearing capacity. The strengths of less weathered dyke material will increase to a point where it will at least be as competent as the surrounding rock. Laboratory tests on dyke material were not carried out.

5.6.2 Joints

The dykes are generally closely jointed, although jointing in extremely and highly weathered dykes is partly or wholly obscured, with joint surfaces and openings filled with weathered material and clay. Some joints in moderately or less weathered dykes will remain open and clay-filled, or only partly cemented. Attitudes of joints in the dykes have not been obtained, but rock cores indicate that at least 4 closely spaced sets exist.

5.6.3 Faults

Bedding adjacent to dykes may be steeply dipping, closely jointed and fractured; this could be attributed to drag folding of the mudstone associated with faulting at the plane of the dyke.

5.6.4 Groundwater

Weathered dykes, where fractures and joints are filled with clay, will be relatively impermeable. Moderately weathered (or less weathered) closely jointed dykes will be much more permeable, and will show limonite staining on fracture surfaces as in drillcore in holes 21A and 23A. The greater permeability of open-jointed dykes would facilitate groundwater circulation and may have accelerated weathering of adjacent mudstone.

5.7 COLLUVIUM

5.7.1 General

Colluvium will be present for a total distance of about 200 m.

It is potentially a difficult material for tunnelling. Colluvium is also present in Exhibition Street, but is expected to be more than 2 m above tunnel crown.

5.7.2 Mechanical properties

The properties will vary with depth and the weakest material will be a fairly clean fine sand (50% clay) at tunnel level. The cleanest sands had about 13-15% fines content that consisted almost entirely of clay-size particles with virtually no silt-sized material (Golder Associates, 1978). CI & RL test results are shown in Appendix 2. A summary is given below:

Moisture content: 15% to 25%
Density: 1400 to 1700 kg/m^3
Shear stress: 156 to 179 kPa

The major clay minerals are kaolinite and illite. The results of X-ray diffraction analysis of samples from holes 23, 23A and 24 are listed in Appendix 2. The classification of the material ranges from CL to SC.

5.7.3 Groundwater

Drainage of the MURL excavations has depressed the potentiometric surface within the area of the colluvium to an unknown depth below tunnel invert. Piezometers in the colluvium range from dry to water levels at 7-10 m (14.9.78) and are being monitored. The potentiometric surface is expected to rise as a result of closure of MURL excavations. The colluvium may have been saturated at tunnel level prior to excavation of MURL.

The report on investigation into the permeability of sands in the Colluvium by Golder Associates contained the following conclusion:

> "These sands were found to have a surprisingly low permeability (of the order of 0.5 x 10^{-6} cm/sec) in laboratory tests and this was attributed to the

> fact that the fines were clay-sized particles. The equipment used for the packer tests in the boreholes was not sensitive enough to measure the low flows associated with such low permeabilities. Some small inflows were recorded, but they could have been due to small leakages as much as to injections into the ground." (Golder Associates, 1978).

The July 1978 report by BMR (Purcell and Trand) recorded the results of a pump-in test in drillhole 23A between 5.5 and 13.0 m, and gave a figure for the permeability of the material of 3.9 x 10^{-4} cm/sec; however, the water pressures in that test were well in excess of the overburden pressure, and the water losses are not considered reliable for permeability calculation.

6. TUNNEL EXCAVATION AND SUPPORT

6.1 DARGILE FORMATION

6.1.1 General rock conditions

About 38 percent (490 m) of the tunnel will be located in Zones 1 and 1 to 2 of the Dargile Formation. The remainder of the tunnel in the formation will be driven through Zone 2 or less weathered rock. The 90 m of tunnel in Zone 3 to 4 mudstone could be considered as hard rock tunnelling, and constitutes about 7 percent of the Dargile Formation to be tunnelled (see also 5.1.1).

Attitudes of bedding and joint planes will affect tunnel stability particularly in Zone 2 and 3 or less weathered mudstone. Zones 1 and 1 to 2 have a high clay content associated with joints, and the cohesion exhibited by the clays in such material causes weathered rock to behave more like a soil. Assessment of structural attitudes and their effect on tunnel stability have been made on Plates 3 to 8. Harder and more competent sandstone beds in highly weathered mudstone may break away from the crown or walls (depending on orientation of defects) due to weak bedding plane contacts and this is commonly referred to as "slabbing"; if thick enough, the sandstone bed may initially span the opening without failing.

Sharp changes in rock hardness and strength can be expected when dykes are intersected. Some indication of changing conditions such as drag of bedding, change in major joint orientations or an increase in the degree of weathering may be observed; however, in other instances the change from mudstone to dyke may give no indication of lithological change.

Groundwater inflows may take place from rock below the potentiometric surface mainly from open joints and fractures in Zone 3 and 4 rock. Inflows from Zone 1 and 2 rock will be insignificant; however, if the rock is in a saturated state, a marked decrease in its strength and stability will be evident. If groundwater is present, there will be a decrease in stability of clay-coated defects in Zone 3 and 4 mudstone; there will be little change in stability if defects are clean, unless they carry groundwater under pressure, a situation that is considered unlikely. Large groundwater inflows are not expected from the mudstone.

6.1.2 Stand-up times

The stand-up time or bridge action period gives an indication of the time available after exposure to erect support before disintegration and loosening of the rock has progressed to the stage where fall-outs start to occur.

Stand-up times have been estimated by Bienawski's method (1974), using data from drillcores and mechanical tests performed on the core; they are presented in two tables. Table 1 presents the calculations for stand-up times for the various rock zones and weathering categories. The range of conditions in the rock mass have been rated from the cores of each weathering category, and the table shows how the range in rating affects the calculation of stand-up time. The regular calculation of stand-up times at the tunnel face during construction is essential wherever rock conditions are variable. Table 2 presents the stand-up times calculated for a number of drillhole cores at tunnel level.

When considering the stand-up times in the tables and on the accompanying plates, it should be noted that:

(i) unsupported spans equal to the tunnel width are assumed (i.e. full face tunnelling);

(ii) the values in Table 2 apply to the rock obtained at a particular drillhole location, and conditions between holes are likely to vary considerably;

(iii) no allowance has been made for the cohesive strength of extremely to highly weathered rock (particularly with respect to Zone 1 mudstone, which would be considered by Bienawski to be a soil and not a rock with its UCS of less than 1 MPa);

(iv) joint orientations are not known with any certainty, and therefore the orientations have been assumed to be "fair to unfavourable" for rating purposes;

(v) the area will be fairly well drained soon after excavation commences and inflows generally of less than 25 litres per hour have been assumed for rating purposes;

(vi) stand-up time values given are considered conservative, particularly in Zone 1 and 1 to 2 mudstone due to (iii) above, and experience in the MURL tunnels would appear to confirm this; and

(vii) in calculating stand-up times in Table 2, the condition of the rock from tunnel invert to about 2 m above crown has been used.

The above comments regarding stand-up times apply to all rock types to be tunnelled in this project.

6.1.3 Settlement and rock loads

The mudstone is subject to loosening loads and deterioration by water softening. Loading on the support system and settlement will depend on the amount of loosening that is allowed to take place and this will depend on the type of support, how quickly it is erected and how close to the face it is placed (hence the importance of the calculated stand-up times in the preceding Tables). Loads on steel and timber will be lower where shotcrete is also used, as the shotcrete will restrict loosening that would otherwise take place.

Loosening will be greater if the tunnel is drilled and blasted than if it were excavated by mechanical means.

TABLE 1

Geomechanics Classification
(Bieniawski, 1974)

Rock Classification and Stand-up times for the Weathering Zones and Weathering categories of the Dargile Formation

ZONE MUDSTONE	STRENGTH RATING	RQD RATING	JOINT RATINGS			GROUND WATER	TOTAL* RATING	ROCK CLASS	STAND-UP TIMES
			SPACING	ORIENTATION	CONDITION				
1	0	3	10	10 6	5 0	10 8	38 27	POOR(IV) POOR(IV)	about 2 hrs > 10 mins
2	0	8 3	10 5	10 6	5	10 8	43 27	POOR(IV) POOR(IV)	about 8 hrs > 10 mins.
2-3	0	8	10 5	10 6	10 5	10 8	48 32	POOR(IV) POOR(IV)	> 10 hrs > 1 hr
3	0	14 8	10	10 6	15	10	59 49	FAIR(III) POOR(IV)	1 week 1 day
4	0	14	20	10 6	15	10 8	69 63	FAIR(III) FAIR(III)	> 1 month about 3wks
WEATHERING CATEGORY SANDSTONE									
HW-MW	0	8	5	10 6	15	10 8	48 43	POOR(IV) POOR(IV)	about 10hrs about 5 hrs
HW	0	3	5	10 6	5	10 8	33 27	POOR(IV) POOR(IV)	about 45min about 20min
MW	0	14 8	5	10 6	15 5	10 8	54 32	FAIR(III) POOR(IV)	about 2days about 50 min

* out of a possible 100

TABLE 2

DARGILE FORMATION - ESTIMATED STAND-UP TIMES AT TUNNEL LEVEL

HOLE NUMBER		WEATHERING ZONE	RATING*	ESTIMATED STAND-UP TIME
11	Lonsdale Street	1 (Qe about 1 m above crown)	13 (very poor)	less than 10 minutes
12		3	48	about 1 day
13		1 to 2 (Qe about 1 m above crown)	13	less than 10 minutes
17		1 (Qe above crown)	13	less than 10 minutes
19		3	58 (fair)	about 4 days
20		3	48	about 1 day
20A		2 (mainly)	40 (poor)	about 8 hours
25		3 (mainly)	33 (poor)	less than 3 hours
26		3	42 (poor)	about 8 hours
27		3 (mainly)	50 (fair)	about 1 day
22	Russell** Street	2 to 3 (Colluvium at crown)	48 (poor)	about 1 day

* Maximum possible rating is 100

** Colluvium occurs about at the tunnel crown at this location.

Stand-up time would be much less than calculated as the height of loosened rock arch is in the colluvium. The same would apply to other drillhole locations where the loosened rock arch would extend into less competent material (e.g. holes 11 and 13 where the Elizabeth Street Formation lies 1 m above the crown).

The experience of others (MURL) in the mudstone (Dargile Formation) indicates that downward deformation at the tunnel crown is unlikely to be greater than about 12 mm if steel sets and shotcrete are used as primary support. In addition, the zone of deformation is unlikely to extend beyond about 2 to 3 tunnel diameters above the crown.

6.1.3.1 Vertical rock loads

Estimates of vertical rock loads are based on the extent of upbreak (Terzaghi, 1946). The estimates are probably conservative, especially if the tunnel is to be machine excavated. A range of rock load is given, which should cover all orientations of bedding and jointing.

Estimates for zone 3 mudstone have been calculated using the following assumptions:

Tunnel diameter: 3.5 m

Cover above tunnel crown: $>$ 3 times tunnel diameters

Average rock density: 2100 kg/m^3

Unconfined compressive strength (UCS): 10 MPa

Traffic loads have not been considered

where: Hp = height of loosened rock arch

P_z = total rock load

B = tunnel width

H = tunnel height

It has been assumed that shotcrete has not been used and that loosening loads have had time to develop. The height of loosened rock (Hp) is assumed to be zero initially, but increasing with time to 0.25(B) to 0.35(B+H).

Hp = (0.25).(3.5) to (0.35).(7)

= 0.875 to 2.45

P_z = 0.18 to 0.51 kg/cm^2

or 18 kPa to 50 kPa

These values can probably be reduced by about 50% if the tunnel is above the water table.

Face stability in Zone 1 and 1 to 2 mudstone

To determine the short term stability of the tunnel face it is assumed that the face will be stable if $^{P}z/_{c} < 6$, where c equals undrained shear strength (Deere, 1969).

Using overburden pressures of between 150 and 288 kPa (using initial terzaghi values of Hp = (1.10 to 2.10) (B + H)) :

where wet: $150/_{130}$ = 1.15

or $288/_{130}$ = 2.21

where dry: = 0.57

or = 1.10

In all cases the face should be stable initially, but a decrease in strength associated with dissipation of pore water pressure may reduce long term stability.

Final support loads in zone 1 mudstone will probably be carried by a ground cylinder.

6.1.3.2 Lateral (side) pressures and heave

Initially vertical rock loads are expected to be greater than lateral pressures, even in zone 1 mudstone where some swelling pressure may act on the side walls. If moderate lateral pressure were to occur, invert struts may be required (possibly in zone 1 mudstone).

An estimation of lateral pressure in zone 3 mudstone is given below.

$$\text{Side pressure} = 0.3 \times 2100\ (0.5 \times 3.5 + 2.45)$$
$$= 0.26\ \text{kg/cm}^2 \quad \text{(wet)}$$
$$(25\ \text{kPa})$$

Bottom heave as well as lateral pressure is possible if the potentiometric surface is such as to maintain clays in a saturated condition, even though very little water enters the excavation. Highly plastic clays do occur in the mudstone (zone 1 mainly) and in the overlying colluvium and the Elizabeth Street Formation. Dissipation of the pore water pressure over a period of time may lead to swelling and a decrease in strength such that the ratio P_z/c may be greater than 6 and the face become unstable (Deere, 1969). Rapid advancement of the face through such material is therefore recommended.

6.1.4 Support

Most of the Dargile Formation will require support during construction; however, there are sections of tunnel in zone 3 to 4 mudstone that would be self supporting for several days at least during construction (section 6.1.2. stand-up times). The type of primary support required during construction will depend on the rock conditions, estimated stand-up times, rock loads, groundwater conditions and the method of excavation.

A concrete sub-invert may be necessary, to prevent deterioration of the invert during construction.

Rock mass quality (Q)

According to Barton, Lien and Lunde (1974), the following calculations can be made:

Using $Q = (RQD/_{Jn})\ (Jr/_{Ja})\ (Jw/_{SRF})$

where Q = rock mass quality
RQD = rock quality designation
Jn = joint set number
Jr = joint roughness number
Ja = joint alteration number
Jw = joint water reduction factor
SRF = stress reduction factor

In zone 1 and 1 to 2 mudstone

$$Q = (^{10}/15)\ (^{1}/8)\ (^{1}/5)$$

$$= 0.016^{*}$$

* Assumes 4 or more joint sets and swelling clay fillings; these conditions are considered exceptional and not representative.

According to Barton et al., a Q figure of 0.016 corresponds to Terzaghi Class 7 (squeezing rock) with P_z between 1.54 and 2.94 kg/cm^2 (as calculated above); support pressure would be about 8.0 kg/cm^2 and this would correspond to their support category No. 35 i.e. steel sets, mesh and shotcrete as the primary support.

In zone 3 mudstone

$$Q = (^{60}/15)\ (^{1.5}/2)\ (^{1}/1)$$

$$Q = 3.0$$

According to Barton et al., a Q value of 3.0 corresponds to Terzaghi Class 4 (moderately blocky and seamy) and agrees fairly well with Terzaghi's rock load assessment based on Hp = 0.25 B to 0.35 (B + H) (see previous calculation). Q = 3.0 corresponds to a support pressure of about 1.0 kg/cm^2 which is on the borderline for requirement of support. Shotcrete with steel would probably be ideal for rock slightly poorer in quality, i.e. zone 2 to 3 and zone 2 mudstone.

Table 3 presents the calculations for rock mass quality (Q number) for the various rock weathering zones and weathering categories. The ratings for the various parameters used by Barton, Lien and Lunde (1974) for each weathering category were derived from the drillcores. From the Q number, Barton, Lein and Lunde derived the permanent roof support pressure in kg/cm^2 by an empirical method based on case studies, and they also prepared recommendations for permanent roof support for 38 categories of rock mass. Table 3 also sets out the support pressures and support categories.

Table 4 lists the support measures for those rock mass categories relevant to this project; it was compiled directly from the tables of Barton, Lien and Lunde. Their permanent roof support system is based on various combinations of rock bolts, mesh and shotcrete. If the stand-up time is short, the placement of steel sets and shotcrete, or steel sets with timber lagging may be quicker to install.

Effective use of shotcrete will generally obviate the use of heavy timber lagging between steel sets, with the possible exception of "very poor" conditions, mainly in zone 1 where the use of shotcrete may not be practical.

Steel sets spaced 1 to 1.5 m and shotcrete will probably be the most effective form of support in zones 2, 3 and 4 mudstone, and will be effective in reducing loosening loads

TABLE 3

ROCK MASS QUALITY, ROOF SUPPORT PRESSURES, AND SUPPORT CATEGORIES DARGILE FORMATION, ACCORDING TO THE METHODS OF BARTON, LIEN AND LUNDE, 1974

	RQD/Jn	Jr/Ja	Jw/SRF	SPAN/XX /ESR	Support Pressure $\mathrm{kg/cm^2}$	Q	Support Categories
Mudstone							
Z1	10/9 -1.1	1/4	1/5	3.1/1.6-1.94	6.	0.06	33
	10/2 -5	1/4	1/5	4.4/1.6-2.75	3.5	0.25	29
Z2	10/9 -1.1	1/4	1/5	"	6.	0.06	33
	60/9 -6.6	1/4	1/5	"	3.	0.36	29
Z2-3	25/9 -2.78	1/4	1/5	1.94 2.75	4.	0.14	29 30
	60/9 -6.6	1/1	1/5	1.94 2.75	2.	1.32	No support 21
Z3	30/9 -3.3	1/3	1/5	1.94 and 2.75	3.5	0.22	29
	30/6 -5	1.5/3	1/5	" "	2.1	0.5	25
	80/9 -8.1	1/1	1/5	1.94 2.75	1.7	1.62	No support 21
	80/6 -13	1.5/2	1/1	1.94 & 2.75	1.	10	No support
	80/6 -13	1.5/2	1/5	1.94 & 2.75	1.1	1.95	No support
Z4	80/9 -8.1	1/4	1/5	1.94 & 2.75	2.8	0.41	25
			1/1	1.94 & 2.75	1.7	2.05	No support
Sandstone							
HW	17/9 -1.89	3/4	1/5	1.94 & 2.75	1.1	0.28	29
HW-MW	40/9 -4.44	3/1	1/5	1.94 & 2.75	0.5	2.67	No support
MW	30/9 -3.33	2/4	1/5	1.94 & 2.75	1.2	0.33	29
	60/9 -6.66	2/2	1/5	1.94 2.75	1	1.33	No support 21

XX SPAN/ESR is represented by two values derived from the tunnel diameters of 3.1 and 4.4 m and the Excavation Support Ratio (ESR) for such a tunnel is 1.6.

TABLE 4

Support Measures for Rock Masses

Support category	Q	Conditional factors		SPAN/ESR (m)	P $\mathrm{kg/cm^2}$ approx.	SPAN/ESR (m)	Type of support
		RQD/Jn	Jr/ja				
Rock Masses of "Fair" and "Poor" Quality (Q range: 10-1)							
21	4-1	≥12.5	≤0.75	-	1.5	2.1-6.5	B (utg) 1 m + S 2-3 cm
		<12.5	<0.75	-			S 2.5-5 cm
		-	>0.75	-			B (utg) 1 m
Rock Masses of "Very Poor" Quality (Q range: 1.0-0.1)							
25	1.0-0.4	>10	>0.5	-	2.25	1.5-4.2	B (utg) 1 m + mr or clm
		≤10	>0.5	-			B (utg) 1 m+S (mr) 5 cm
		-	≤0.5	-			B (tg) 1 m+S (mr) 5 cm
29	0.4-0.1	5	>0.25	-	3.0	1.0-3.1	B (utg) 1 m+S 2-3 cm
		= 5	≥0.25	-			B (utg) 1 m+S (mr) 5 cm
		-	≤0.25	-			B (tg) 1 m+S (mr) 5 cm
30	0.4-0.1	≥ 5	-	-	3.0	2.2-6	B (tg) 1 m+S 2.5-5 cm
		< 5	-	-			S (mr) 5-7.5 cm
		-	-	-			B (tg) 1 m + S (mr) 5-7.5 cm
Rock Masses of "Extremely Poor" and "Exceptionally Poor" Quality (Q range: 0.1-0.001)							
33	0.1-0.01	≥ 2	-	-	6	1.0-3.9	B (tg) 1 m + S (mr) 2.5-5 cm
		<2	-	-			S (mr) 5-10 cm
		-	-	-			S (mr) 7.5-15 cm
35	0.1-0.01	-	-	≥ 15 m	6	6.5-28	B (tg) 1 m + S (mr) 30-100 cm
		-	-	≥ 15 m			CCA (sr) 60-200 cm + B (rg) 1 m
		-	-	<15 m			B (tg) 1 m + S (mr) 20-75 cm
		-	-	<15 m			CCA (sr) 40-150 cm + B (tg) 1 m

B = systematic bolting
(utg) = untensioned, grouted
(tg) = tensioned, (expanding shell type for competent rock masses, grouted post-tensioned in very poor quality rock masses.
S = shotcrete
(mr) = mesh reinforced
clm = chain link mesh
CCA = cast concrete arch.

Bolt spacings are given in metres (m). Shotcrete thickness is given in centimetres (cm)

(Table derived from Tables 12, 13 and 14, Barton, Lien and Lunde, 1974) on steel sets and timber lagging. Shotcrete may not be practical in zones 1 or 1 to 2 mudstone in which case steel sets and timber lagging will be required. The quantity of timber lagging will increase with weathering of the mudstone; lagging in zone 1 mudstone will cover up to about 80% of the tunnel profile. Very short stand-up times have been estimated for zone 1 mudstone and forepoling may have to be applied, especially if the clays are saturated owing to a high potentiometric surface.

If it is assumed that shotcreting of zone 1 mudstone is not practical and that steel sets and timber lagging are used for support, the estimation of "pay" timber quantities in paragraph 6.1.4 (Purcell and Trand, 1978) would be relevant.

6.1.5 Methods of construction

6.1.5.1 Conventional mining

Although the conventional drill-blast-muck method is probably not the most practical method of excavation in the mudstone, it may be necessary in those sections where zone 3 to 4 or less weathered rock is encountered, particularly if the rock is not closely jointed. Up to about 90 m of zone 3 to 4 mudstone may require blasting.

Zone 1 mudstone will probably need to be excavated by hand or hand-operated excavating equipment without the use of explosives. Forepoling may be necessary, especially where the tunnel is below the water table.

Overbreak in blasted sections may be greater than in machine excavated sections, but will ultimately depend on the contractor's skill and the time taken to support the rock. Overbreak may increase with a decrease in degree of weathering, but will depend on the degree of cementation, continuity, spacing and orientation of defects.

Ground vibrations associated with blasting may also be a problem and vibrations will need to be monitored.

The rate of progress of drilled and blasted sections will probably be less than in machine excavated sections, but greater than hand mining in zone 1 rock.

6.1.5.2 Tunnel excavating machine ("Road Header" type)

A Road Header type machine (such as the "Alpine AM 50) would be suitable for excavating zones 2 to 3 mudstone, as has been shown in MURL excavations. Zone 4 mudstone may prove too strong for a Road Header unless the rock is highly fractured. Assessment of the drilling would indicate that about 55% or 720 m of the mudstone section could be successfully excavated by a Road Header machine; these figures are approximate due to the variable nature of the weathering, and the difficulty that could be encountered if combinations of zones 2, 3 and 4 rock were present at a working face.

6.2 ELIZABETH STREET FORMATION

6.2.1 General Tunnelling conditions

Tunnelling conditions in this formation will depend largely on whether the tunnel is below or above the potentiometric surface during excavation. Tunnelling conditions will be substantially better if the formation is dry. Approximately 145 m of tunnel will pass through this formation.

It is likely that the tunnel invert in this formation will be wet at some time during construction; in addition, the possibility of inflows of surface runoff into the excavation during rainstorms should be considered. The potentiometric surface should be monitored by recording the piezometer and standpipe levels during construction.

Drainage of the Elizabeth Street Formation would take place through the tunnel if it were driven upslope, but this may not improve invert conditions. Dewatering of this formation by pumping from a deep bore in the moderately to slightly weathered Dargile Formation below the Elizabeth Street Formation could be expected to improve invert conditions.

6.2.2 Properties and stand-up times

SPT, shear, and UCS tests show this formation to be very stiff in parts, with strengths between 200 and 400 kPa. However, the formation is soft in parts also, and the tunnelling conditions will be variable. Different strata may be exposed in the tunnel face such as silty sand overlying clayey sand, with part of the face being initially unstable (silt-sand, especially if wet) and the clayey sand initially stable, but possibly becoming unstable with time, especially if wet.

6.2.3 Stability

Stability calculations have been made using the following data:

Tunnel diameter = 3.5 m
Cover above crown = >3 tunnel diameters
Material density = 1200 - 2000 kg/m^3
Undrained shear stress = 200 - 300 kPa
Unconfined compressive strength = 150 - 400 kPa

Vertical rock load

$$
\begin{aligned}
Hp &= 0.62 \text{ to } 1.38\ (B + H)\\
&= 4.35 \text{ to } 9.7\\
P_z &= 4.35 \times 2000 \text{ (density) to } 9.7 \times 2000\\
&= 8700 \text{ to } 19400\ kg/m^3\\
&= 0.87 \text{ to } 1.9\ kg/cm^2
\end{aligned}
$$

or 85 to 186 kPa (wet)
42 to 93 kPa (dry)

Lateral pressure

Assuming side pressure = 0.3 γ(density) (0.5 H + Hp)
Side pressure = 0.3 x 2000 (1.75 + 9.7) (wet)
= 0.69 kg/cm^2 (68 kPa) (wet)

Stability of face

Assuming stability if $P_z/c < 6$

(where c = undrained shear strength)

then if wet: $^{186}/_{300} = 0.6$

if dry: $^{93}/_{300} = 0.3$

Initially the face is stable where the tunnel is being excavated in the typical stiff dense Elizabeth Street Formation. The critical value of $^{P}z/c$ may increase with time especially if silt layers are present, as they are very sensitive to pore water pressures. The long term stability may be less than indicated in the above calculations, as dissipation of pore water pressure may cause swelling and result in a decrease in strength, particularly if the tunnel is below the potentiometric surface and highly plastic clay is present.

Stand-up times have not been calculated, but they will be determined more by water content than any other factor. In general it is expected that stand-up times will be long enough for support to be erected before significant ravelling can occur. Assuming the tunnel is above the potentiometric surface, the stand-up times for a 0.5 m wide strip of SC-GC material would be greater than about 1 hour, but for a silty sand with some clay binder it would be about 10 minutes.

6.2.4 Support

When excavated this formation will probably be damp. Steel sets spaced at about 1 m centres with timber lagging will be required. It is unlikely that side pressures will be great enough to require the use of invert struts, unless the potentiometric surface is above tunnel invert level.

6.2.5 Methods of construction

In the worst possible case, which assumes that the material is soft and weak and subject to swelling pressures, hand mining and forepoling would be required. The worst conditions are likely to be found in the lowest part of the tunnel near drillhole 15 in Lonsdale Street at chainage 374.

The most likely condition is for the material to be damp, and hand mining or a mechanical shovel would be the most effective excavation method.

It is considered that a Road Header, or similar machine, may be unsatisfactory if the formation has not been drained due to the plasticity of the clay and the likely sloppy conditions of the invert. A concrete sub-invert may be required.

6.3 TERTIARY OLDER VOLCANICS

6.3.1 General rock conditions

Basalt may be present in the tunnel crown for as much as 150 m of the Queen Street tunnel (Plate 3); possibly less than 40 m of this distance will have a full tunnelling face in the basalt. The remainder will have zone 1 mudstone at invert level, or possibly the Werribee Formation which is known to be discontinuous below the basalt, and could underlie it between holes 5A and 6. The competence of the basalt will vary considerably.

Drillhole 5A (Queen Street) shows the basalt to be mostly slightly to moderately weathered at tunnel level and for about 2 metres above tunnel crown level. Jointing is generally close and rough; some joints are clay filled.

In drillhole 6 (Queen Street), about 2 m of highly and extremely weathered basalt was intersected, and this was at and above tunnel crown level. At this location the tunnel is mainly in zone 1 mudstone. Further north, towards hole 8, the tunnel intersects the Werribee Formation. The rock contacts mudstone-basalt, mudstone-Werribee Formation are weak and resulted in losses of drillcore. The upper surface of the basalt below the Brighton Group is likely to be highly to extremely weathered.

The Lonsdale Street tunnel will be in basalt from drillhole 10 to about midway to drillhole 11 (Plate 4). Basalt in the tunnel will be mostly slightly weathered, but is very closely jointed or fractured; however, many of the fractures in the drillcore were caused by drilling stress on previously healed or partly healed natural fractures.

6.3.2 Stand-up times

Stand-up times have been estimated using data from drillholes 5A, 6 and 10 (Table 5). Stand-up times derived from drillhole 6 data will probably only apply to a short section of tunnel where highly weathered basalt occurs in the tunnel crown, just west of hole 6.

6.3.3 Rock Loads

The ultimate rock load will depend on the extent of the loosening of the arch. If shotcrete is used soon after excavation, the loads on steel sets will be smaller than if the steel and timber lagging were used. Estimates of final loads are calculated below.

Vertical rock load for slightly weathered basalt

Assuming density = 2800 kg/m^3
UCS = 5260 kPa
tunnel diameter = 3.5 m

Hp = 0.35 (7) to 1.1 (7)
= 2.45 to 7.7
P_z = 2.45 x 2800 to 7.7 x 2800
= 6850 to 20150 kg/m^2
or 0.68 to 2.0 kg/cm^2 (67 to 196 kPa)

Vertical rock load for highly weathered basalt

Assuming density = 1750 kg/m^3
UCS = 2000 kPa (drillhole 5A)

P_z = 0.35 (7) x 1750 to 1.1 (7) x 1750
= 0.43 to 1.35 kg/cm^2 (42 to 132 kPa)

Side pressures have not been calculated.

The rock mass quality ratings have been calculated according to Barton et al. (1974) for extremely to moderately weathered, and moderately to slightly weathered basalt (Table 6).

TABLE 5

Geomechanics Classification
(Bieniawski, 1974)

Rock Classification and Stand-up times for Weathering categories of basalt, and drillcore from basalt at tunnel level

WEATHER-ING CATEGORY	STRENGTH RATING	RQD RATING	JOINT RATINGS SPACING	JOINT RATINGS ORIENTATION	JOINT RATINGS CONDITION	GROUND WATER	XX TOTAL RATING	ROCK CLASS	STAND-UP TIMES
EW-HW	0	3	5	10	5	10	33	POOR(IV)	abt 45min
				6		8	27	POOR(IV)	abt 20min
MW-SW	0	3	5	10	5	10	33	POOR(IV)	abt 45 m
		8		6		8	32	POOR(IV)	abt 45m
Hole 5A	0	8	10	10	10	10	48	POOR(IV)	abt 1 day
				6		8	42	POOR(IV)	abt 4hrs
Hole 6	0	3	5	10	5	10	33	POOR(IV)	abt 45min
				6		8	27	POOR(IV)	abt 20 min
Hole 10	0	3	5	10	10	10	38	POOR(IV)	abt 2 hrs
				6		8	32	POOR(IV)	abt 45 min

XX out of a possible 100

Note: These stand-up figures are regarded as conservative, and the assumptions applicable to this method should be referred to (6.1.2).

TABLE 6

ROCK MASS QUALITY, ROOF SUPPORT PRESSURES, AND SUPPORT CATEGORIES FOR BASALT, ACCORDING TO THE METHODS OF BARTON, LIEN AND LUNDE, 1974

WEATH-ERING CATEG'Y	RQD/Jn	Jn/Ja	Jw/SRF	XX SPAN/ESR	Support pressure kg/cm^2	Q	Support categories
Basalt							
EW-HW	10/6 - 1.6	3/8	1/5	3.1/1.6-1.94	1.5	0.12	29
MW-SW	10/6 - 1/6	3/3	1/5	1.94	1.1	0.32	29
		3/2			1.0	0.48	25
""""	30/6 - 5	3/3	1/5	1.94	0.5	1.0	No support

XX SPAN/ESR is represented by two values derived from tunnel diameters of 3.1 & 4.4m and the Excavation Support Ratio (ESR) for such a tunnel is 1.6.

6.3.4 Support

Selection of support for the Queen Street tunnel must take account of the poor invert conditions in zone 1 Dargile Formation and the mixed face tunnelling that is expected. As far as the basalt itself is concerned, combinations of rock bolts and mesh with shotcrete as required would be satisfactory (Table 6), but the flexibility of steel sets, shotcrete and/or timber lagging may be desirable in such variable conditions. A concrete sub-invert may be required in EW basalt at the contact with the underlying mudstone.

Slightly weathered basalt would probably require support (although not immediately). Extremely to moderately weathered basalt would require steel and lagging support as soon as possible. If hand mining is required, then steel and timber lagging will need to be erected close to the face. In addition, shotcrete (5 cm to 7 cm thick) could be used if found to be practical in this tunnel, as it would reduce the amount of timber lagging required.

6.3.5 Methods of construction

There appear to be three construction alternatives, of which the first is the most likely for most of the basalt section:

(i) Road Header should be suitable especially where basalt is moderately to slightly weathered and closely jointed.

(ii) Blasting will be required in slightly weathered or fresh and less jointed rock.

(iii) Near the contact with the Brighton Group above and the Werribee Formation below, the basalt is extremely and highly weathered, and hand mining is the likely option.

The base of the basalt is expected to be irregular, and competent rock may be interspersed with highly weathered basalt, zone 1 mudstone, and Werribee Formation.

6.4 WERRIBEE FORMATION

This formation may intersect the tunnel between holes 10 and 11 in Lonsdale Street. It will occur between holes 6 and 8 in Queen Street rising from near invert level at hole 8 to above crown level at hole 40, only 13 m away (Plate 3). It will also be present in the chamber crown at and near hole 41.

Excavation properties of the Werribee Formation should be similar to zone 1 mudstone unless it is making water, in which case close support will be required to prevent flow into the tunnel. Hand mining or mechanical shovel would be satisfactory. Tunnel invert may be "sloppy" and a concrete sub-invert may be required.

6.5 BRIGHTON GROUP

This group will probably occur in the upper part of the tunnel near hole 8. As this group is more competent than the Werribee Formation, the excavation and support measures used for the underlying Werribee Formation would be adequate for the Brighton Group.

6.6 DYKES

Most dykes at tunnel level will probably be near vertical and will generally be soft and clayey. They may require hand mining if they are found to be highly plastic and wider than a metre or so. The amount of timber lagging in dyke sections will probably be more than in the adjacent mudstone, unless the mudstone is zone 1.

6.7 COLLUVIUM

6.7.1 General conditions

The Colluvium will be intersected in Lonsdale Street (125 m) and Russell Street (75 m) (Plates 5 and 6).

Tunnelling conditions will generally be poor through the colluvium. The density of the material will vary from loose to firm, but is generally expected to be fairly dense.

The colluvium is potentially unstable with very short stand-up times. Stability of the Colluvium will depend more on the water content than any other factor; the water content will depend on the level of the potentiometric surface.

6.7.2 Rock loads

Calculation of final vertical loads according to Terzaghi have been based on the following formula:

$$Hp = 0.62\ (B + H)\ \text{to}\ 1.38\ (B + H)$$

This assumes that (i) wet conditions prevail (below potentiometric surface)

@ (ii) colluvium is dense, and

(iii) initial rock loads will be slightly less.

@If the sand is loose, then initial rock loads will be a little higher, but final loads will be much the same as those calculated below. If loose sand occurs at and below invert, the vertical rock load may be greater than calculated due to compression of the base.

Calculation:

$$Hp = 0.62\ (7)\ \text{to}\ 1.38\ (7)$$

$$P_z = 0.62\ (7) \times 1400\ \text{to}\ 1.38\ (7) \times 1400\ (\text{kg/m}^3)$$

$$= 0.61\ \text{kg/cm}^2\ \text{to}\ 1.35\ \text{kg/cm}^2$$

(60 kPa) (132 kPa)

Note: shear stress = 156 to 179 kPa (Appendix 2)

Side pressure values have been calculated below:

where: $Ph = 0.3\ \gamma(0.5\ H + Hp)$

$Ph = 0.3 \times 1400\ (0.5 \times 3.5 + 9.7)$

$= 0.48\ \text{kg/cm}^2$

(47 kPa)

This value is about one-third the higher limit of the vertical load calculated above.

6.7.3 Support and method of construction

There are two alternatives for this section of tunnel:

(i) The tunnel may be constructed by the cut and cover method, or

(ii) the formation may be tunnelled.

If the tunnel in the colluvium is below the potentiometric surface, the method of excavation and support would require special techniques such as the use of face boards and forepoling or a tunnelling shield. If the colluvium is above that level, excavation by hand mining or mechanical bucket with steel set support and timber lagging would be required.

Dewatering of the Colluvium. Dewatering of the colluvium would seem to be required if use of special excavation techniques is to be avoided. If there is hydraulic continuity between the colluvium and the underlying Dargile Formation, then pumping from a deep bore in moderately weathered to fresh mudstone will lower the potentiometric surface and dewater the colluvium. The fact that permeabilities in the intervening materials, such as extremely and highly weathered mudstone and parts of the colluvium itself, are very low may retard the process, but will not prevent dewatering of the colluvium.

6.8 SETTLEMENTS

Settlements and the extent of loosening will depend on the tunneller's expertise and care, and suitability of the excavation method and type of support for the particular formation. Estimates of settlements are not given here, but it can be noted that:

(1) Some loss of ground will be associated with each formation tunnelled and consequently some settlements at and above tunnel crown will occur. However, in all formations except possibly in saturated Elizabeth Street Formation, zone 1 mudstone and colluvium, the resultant surface settlements will probably be less than about 10 to 15 mm.

(2) Loss of ground in the exceptions noted in (1) above may be more serious if groundwater is present, and poor tunnelling techniques fail to contain unstable ground.

(3) The presence or absence of groundwater will probably be the most important factor in determining surface settlements. It should be possible to keep surface settlements in zone 1 mudstone to a minimum, assuming loss of ground does not occur through accident; however, larger settlement may occur where the clay is more plastic and subject to swelling that would bring about inward squeezing of the clays. Very little surface settlement would be expected in the Elizabeth Street Formation above the water table; if saturated, greater settlements may be associated with loss of strength and possibly with swelling clays. Drainage of the Colluvium is considered a prerequisite for minimum settlement.

7 CHAMBERS

7.1 GENERAL

Location and geology of the 11 chambers are shown on Plates 3 to 8 inclusive. Regarding stand-up times, the comments and provisos set out in 6.1.2 will also apply to any discussion of stand-up times for the chambers.

7.2 QUEEN STREET CABLE CHAMBER

This chamber is located at chainage 100 (Plates 3 and 8).

The geology is expected to be similar to that of the nearby chamber described below (7.3) and the same comments are expected to apply. This chamber was not investigated by drilling and the thicknesses of formations is not known. As this chamber is smaller in size, stand-up times, rock loads and stability will be marginally better, although excavation conditions are still considered to be poor.

7.3 QUEEN - LITTLE BOURKE STREET CABLE CHAMBER

This chamber is located at chainage 126.50 m between holes 8 and 40 (Plates 3 and 8).

The Werribee Formation will be present in the lower part of the chamber, generally below the spring line, but rising to the southern crown of the chamber. The remainder of the chamber is expected to be located in the Brighton Group. Initially groundwater may flow into the excavation, but flows should decrease rapidly to seepage.

Excavation conditions will be poor, although parts of the Brighton Group may be well cemented and reasonably competent. Steel sets and timber lagging will be necessary.

Vertical loads on the crown of the chamber will include all the material between the chamber and the road. Traffic loads will also need to be considered. Stand-up times can be expected to be short. Hand mining will probably be required.

The Brighton Group is variable in its compactness and strength, but the potential for loss of ground and settlement of the road surface is high. The presence or absence of groundwater will be crucial for stability. The groundwater level is being monitored (holes 8 and 40).

7.4 QUEEN - LITTLE COLLINS STREET CABLE CHAMBER

This chamber is located at chainage 359.88 m near hole 41 (Plates 3 and 8).

The chamber crown will be located in the Werribee Formation which overlies zone 1 mudstone. The contact between the Z1 mudstone and Werribee Fm. could be irregular. The major excavation will be in the zone 1 mudstone. Water inflows should be negligible.

Excavation conditions will be poor and hand mining will probably be necessary. Careful excavation of the Werribee Formation in the chamber crown will be required to minimise settlement. Steel sets and full timber lagging will be required.

Vertical rock loads will include all rock and soil from chamber crown and tunnel level to road surface (maximum depth of about 8 m). The vertical loads will be in the order of 220 kPa, but are potentially greater due to traffic loads. Stand-up time can be expected to be short, and will depend on the method of excavation and support.

Ground settlement above the chamber will probably be greater than that resulting from tunnelling on either side of the chamber, but will depend on the method of excavation and support.

7.5 LONSDALE - QUEEN STREET CABLE CHAMBER

This chamber is located at chainage 100, Lonsdale St. tunnel near hole 10 (Plates 4 and 8).

The chamber is located entirely in the basalt, and the Werribee Formation is expected to underlie the basalt, 1-2 m below tunnel invert. If the Werribee Formation is intersected, it may be necessary to pour a concrete sub-invert. Initial small groundwater flows are expected to dry out.

Although the basalt is hard and strong it has been weakened considerably by the high degree of fracturing. Excavation conditions are therefore expected to be fair, with an estimated stand-up time of less than about 5 hours. Vertical rock loads should be in the order of 170 kPa, but will be modified according to traffic loads.

Ground settlement may be greater than that caused by the tunnel adjacent to the chamber. Hand mining with some blasting will be required; a tunnel excavating machine could prove suitable for much of this excavation.

7.6 LONSDALE STREET WEST OF ELIZABETH STREET, LOADING COIL CHAMBER

This chamber is located at chainage 297.9 in Elizabeth Street Formation and zone 1 mudstone, between holes 13 and 14, 19 and 30 m away respectively. (Plates 4 and 8). Open cut excavation should be good, especially if above the groundwater table. The chamber walls will require support during construction; particular note should be taken of the chamber-tunnel junction where the Elizabeth St. Formation rests on zone 1 mudstone at about tunnel crown level, and where the greatest instability may be found. Unless groundwater levels rise to chamber levels before commencement of excavation, the excavation will be dry.

7.7 LONSDALE-RUSSELL STREET CABLE CHAMBER

This chamber is located at chainage 807.75 in zones 1 and 2 mudstone with colluvium above chamber crown level (Plates 4 and 8). Hole 36 is located at this chamber.

Excavation conditions will be poor even if the excavation is above the groundwater table. Stand-up times could probably be less than about 10 minutes. Full support with steel and timber lagging erected during hand mining operations will be required; shotcrete may not be practical, especially if the rock is wet. Loosening of the rock above chamber crown could potentially reach ground surface level if poor excavation techniques are used. Rock loads in the order of 120 kPa are possible if loosening up to the surface is allowed.

Groundwater levels are being monitored by piezometers in hole 36.

7.8 LONSDALE STREET EAST OF RUSSELL STREET, LOADING COIL CHAMBER

This chamber is located at chainage 874 and holes 23 and 34 pass through the site (Plates 5 and 8). It is located entirely in Colluvium.

Excavation conditions will be poor, particularly if the colluvium is water saturated. Dewatering of the colluvium should be examined, including the option of pumping from bores down to SW rock in the Dargile Formation; this would prevent exceptional loss of ground and would improve stability in the excavation. Piles and lagging or other methods of support will be required.

7.9 LONSDALE-EXHIBITION STREET CABLE CHAMBER

This chamber is located at chainage 1047.9 in zone 3 mudstone; hole 32 was drilled to test this structure (Plates 5 and 8). Leaky sewers have been reported in this area and therefore seepage other than groundwater may occur, and most inflows are expected at the top of the mudstone. The mudstone will be closely jointed and has an estimated stand-up time of more than 10 hours (hole 32). Vertical rock loads up to about 120 kPa can be expected. Steel, timber lagging and shotcrete support will be required.

7.10 LONSDALE-SPRING STREET TERMINATING CHAMBER

This chamber is located at about chainage 1300; however, no holes have been drilled to test the site (Plates 5 and 8). Most of the structure will probably be in mudstone ranging from zones 1 and 2 to zones 2 and 3; prediction of weathering boundaries has not been attempted. Initial groundwater inflows will be small and will decrease rapidly to seepage.

Excavation conditions should be good. The stability of open cut walls will depend on joint and bedding plane orientations. Dip of bedding may be greater than the angle of friction, and could lead to failure of wall sections. Assuming the beds dip west, then the west facing wall may be unstable. If the dip of the bedding is around 35°, then the factor of safety of the unfavourably oriented excavation wall will probably be less than 1.0. Dykes may be present in the mudstone.

With careful excavation, overbreak should be small. Rock bolts, mesh and shotcrete below about 2 m may give adequate support. Some overbreak may occur at the chamber-tunnel junction if not well supported with steel sets or rock bolts, particularly if the corner is cut by unfavourably oriented defect planes.

7.11 RUSSELL-LITTLE BOURKE STREET CABLE CHAMBER

This chamber is located at chainage 216 in Russell Street, only 5 and 10 metres respectively from holes 38 and 22 (Plates 6 and 8). The chamber crown will be close to the Zone 1 - Zone 2 and 3 weathering boundary; most excavation will be in zone 2 to 3 mudstone. Small groundwater inflows from the colluvium will decrease rapidly to seepage.

The chamber crown will be unstable, and without support the stand-up times would be about 10 minutes. Steel sets with shotcrete or lagging should provide adequate support in the mudstone. Careful excavation will be required in the crown to minimise loss of ground.

7.12 VICTORIA-RATHDOWNE STREET TERMINAL CHAMBER

This chamber is located in Victoria Street, and hole 30 was drilled to test the site (Plates 7 and 8). The chamber will be in colluvium, zone 1 and zone 2 to 3 mudstone.

Excavation conditions will be fair, with some improvement towards invert level. Little if any groundwater inflows are expected, and at worst the excavation will be damp. Piles and timber lagging or other support methods will be required to support the walls. The tunnel-chamber junction will need to be supported with steel sets and timber lagging.

Dykes have been mapped in the vicinity of Rathdowne Street and could be found in the excavation.

8 SHAFTS

Locations and brief geological descriptions of the shafts are shown on Plates 3 to 8.

8.1 MANHOLE - LONSDALE STREET, CHAINAGE 436.5

Most of this manhole will be in the Elizabeth Street Formation, with about 3 m of zone 1 mudstone close to the manhole-tunnel junction (see hole 17). There should be no problems associated with drilling and casing a hole at this location. Water seepage will be small.

8.2 MANHOLE AND VENTILATION SHAFT , LONSDALE STREET, CHAINAGE 652

The Manhole will intersect zones 1 and 2 mudstone and no problems associated with drilling and casing are anticipated. If the shaft is to be excavated by means other then boring, then steel ribs and full timber lagging would be necessary to prevent excess loss of ground. Water seepage will be small.

9 RECOMMENDATIONS

1. All piezometers should be monitored regularly prior to and during construction.

2. Four large auger holes to either sub-invert level or groundwater level would be useful as inspection pits for tenderers; they should be prepared immediately prior to the inspection day. The pits could be located as follows:

(i) Near drillhole 19, Lonsdale Street - to exposure the various weathering Zones of the mudstone (Z1 to Z3).

(ii) Near drillhole 39, Lonsdale Street - to expose sediments of the Elizabeth Street Formation.

(iii) Near drillhole 40, Queen Street - to expose sediments of the Brighton Group and the Werribee Formation.

(iv) Near drillhole 34, Lonsdale Street - to expose the Colluvium.

3. Owing to the likelihood of surface settlements along the route, a detailed survey of the ground surface should be carried out prior to construction.

4. During excavations of the tunnels and appurtenant works, the rock conditions should be regularly monitored and logged by an engineering geologist.

10 ACKNOWLEDGEMENTS

The authors wish to thank John Brumley and John Nielson (Mines Dept Victoria) for their co-operation in providing information on the geology and hydrogeology of the Melbourne City area and J. Bailey* for supervising the drilling and logging of the cores during the absence of G. Trand in August and September 1977.

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* Geologist, John Connell-Mott-Hay & Anderson, Hatch-Jacobs (Consulting Engineers).

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APPENDIX 1

DEFINITION OF TERMS

APPENDIX 1

DEFINITION OF TERMS

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.

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).

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.

Defect Spacing

Very close - joints spaced < 5 cm
Close - joints spaced 5 cm to 30 cm
Moderately close - joints spaced 30 cm to 1 m
Wide - joints spaced 1 m 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

Potentiometric Surface

The potentiometric surface is an imaginary surface connecting points to which water would rise in tightly cased wells from various points in an aquifer. The water table is a particular potentiometric surface that relates to an aquifer affected solely by atmospheric pressure.

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.

Rock Competence

The terms "competent" and "incompetent" are relative ones, combining properties such as weathering, degree of fracturing, and ultimately estimated stand-up times. The terms also relate to tunnelling in the Melbourne City area such that zone 3 mudstone may be termed competent in Melbourne but would be considered incompetent in comparison with tunnelling through dacites in Canberra.

Zones 1 and 1-2 mudstone are incompetent due to a high degree of weathering, softness and very short stand-up times. Zone 2 is more competent than zones 1 and 1 to 2 but less competent than zone 3, unless zone 3 is highly fractured with a shorter stand-up time. For this tunnel, rock with a stand-up time of more than about 8 hours is considered competent.

DEGREES OF ROCK WEATHERING

FRESH	: No discolouration or loss in strength.
FRESH STAINED	: Limonitic staining along fractures; rock otherwise 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 drill core generally cannot be broken by hand across the rock fabric.
HIGHLY WEATHERED	: Rock is discoloured and weakened; N-size 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.

Zone Number	Degree of Weathering	Material Type	Typical Colour *	Mohs' Hardness	Reaction to Blow from 2 lb. Hammer	Visibility of Bedding	Soil or Rock **
1A	Extreme	Silty clay or sandy clay (usually stiff to hard)	Yellow brown	Max 0.5	–	Bedding indiscernible	Soil
1B		Silty clay or sandy clay containing harder rock fragments					
2	High	Soft mudstone, with clay seams common. Clay is often from decomposition of mudstone beds; often it is in joints, with iron oxide also. Strength low.	Yellow brown	0.5–1.0	Shatters easily with light blow.		Rock
3	Moderate	Moderately hard mudstone. Thin mudstone bands weathered to clay are known, but uncommon. Joints sometimes carry thin clay deposits, or often iron oxide. Strength moderate.	Pale brown & pale grey mottled	1.0–1.5	Only fractures with light blow. Shatters with fairly heavy blow.	Bedding mostly discernible	
4	Slight	Hard mudstone. Joints sometimes contain thin clay films and often iron oxide staining. Strength fairly high.	Pale grey	1.5–2.5	Shatters only with very heavy blow.	Bedding clearly visible	
5	Fresh	Very hard mudstone. Joints clean or with pyrite films or occasionally calcite. Strength very high.	Dark blue grey	> 2.5	Fractures, but not shatters, by very hard hammer blow.		

* Colour can be much paler if leaching has occurred.
** In engineering sense.

Weathering Zone in Melbourne Silurian Mudstone (Neilson 1970)

APPENDIX 2

SUMMARY OF LABORATORY AND FIELD TEST RESULTS ON SOIL AND ROCK SAMPLES

(For X-ray diffraction analyses of clay minerals and field permeability tests, see BMR Record 1978-16)

TELECOM TUNNEL, MELBOURNE. SUMMARY OF TESTS ON SOIL AND ROCK SAMPLES.
APPENDIX 2

Sample Details				Classification Results							Unconfined compressive strength			Triaxial - undrained								Direct Shear - total stress					Point Load			
														Total stress				Effective stress												
Bore Hole No.	Depth (m)	Sample No. 13-0-	Lithology and/or Formation	Unified Soil Classification	Liquid Limit (w_L) %	Plastic Limit (w_P) %	Plasticity Index (I_p) %	Linear Shrinkage (LS) %	Passing 4.75 mm %	Passing 0.075 mm %	Unconfined Compressive Strength (σ_1) MPa	Dry Density t/m^3	Moisture Content %	Cohesion (c) Angle of friction (ϕ) c/ϕ	Cell Pressures (σ_3) kPa	Dry Density t/m^3	Moisture Content %	Effective cohesion (c^1) Effective angle of friction (ϕ^1) c^1/ϕ^1	Effective Stress ($\sigma_3{}^1$) kPa	Dry Density t/m^3	Initial Moisture Content %	Cohesion (c) Angle of Friction (ϕ) c/ϕ	Normal Stress (σ_1) kPa	Shear Stress (s) kPa	Initial Dry Density t/m^3	Initial Moisture Content %	Indicated Unconfined Compressive Strength MPa Is (50) x 24	Point Load Index Is (50) MPa	Diameter (mm) rock cores	Height (mm) rock cores
1	2.25	63	EW basalt?	CH	58	13	45	14.0	100	71				167/15	45/90/ 180	1.79	16.4	60/4	45/90/ 180	1.77	16.4									
"	7.6	10	Z1, mudstone	CL	23	16	7	4.5	100	94													110	127	1.74	18.1				
"	10.4	10/1	HW–MW sandstone								–	2.26	6.8														17.04	0.71	52.0	–
"	10.75	10/2	) Z2								1.25	2.02	12.6														2.64	0.11	51.7	92.7
"	11.05	10/3	) mudstone								–	2.02	11.2														3.60	0.15	51.5	–
5A	6.07	11/1	) EW–HW								–	1.88	16.8														2.40	0.10	51.5	–
	11.7	11/2	) Basalt								2.02	2.18	11.2														6.24	0.26	47.0	99.0
	12.1	11/3	MW basalt								–	2.34	7.3														12.24	0.51	47.0	–
	13.8	11/4	SW basalt								5.26	2.41	6.4														19.68	0.82	47.2	100.6
6	4.5	9	Brighton Group	CH	73	24	49	16.5	100	95				58/1	90/180 360	1.18	43.8													
8	1.5	62	Brighton Group	SC	20	11	9	3.0	100	19								63/24	30/60/ 120	1.92	7.0									
	5.2	36	Ironstone											100/8	100/200 /400	1.76	17.2													
	5.5	35	) Brighton Group								–	1.89	16.5														5.04	0.21	46.0	–
	6.8	37	) Ferruginous								–	2.03	12.1														10.32	0.43	47.0	–
	7.0	38	) Sandstone								–	2.10	11.1														17.28	0.72	47.0	–
10	8.35	39	) SW–MW								–	2.68	2.7														5.28	0.22	47.0	–
	8.90	40	) basalt								–	2.82	1.0														31.2/9.6	1.3/0.4	47.0	–
	10.05	41	)								–	2.69	2.4														32.64/ 22.8	1.36/ 0.95	47.0	–
	11.0	42	MW–HW tuff								–	1.76	29.9														2.64	0.11	46.5	–
12	3.0	4	Eliz. St Fm	CL	32	16	16	9.0	100	91																				
	7.0	43	) Z3, mudstone								7.06	2.23	7.9														5.52	0.23	51.5	124.8
	7.7	44	)								4.34	2.24	7.9														7.68	0.32	51.5	99.0
13	1.5	64	Eliz. St Fm	CH	67	14	53	17.0	100	77				150/13	30/60/ 120	1.72	19.7	10/23	30/60/ 120	1.55	23.8									
14	1.0	65	Eliz. St Fm	CH	53	14	39		100	76				80/7	20/40/ 80	1.70	21.2	16/21	20/40/ 80	1.66	21.9									
	7.0	7/1	EW dyke	CH	124	28	96	25.0	100	94				101/3	~~140/280~~ ~~560~~	~~1.07~~	54.7	85/15	100/200 /300	1.22	44.4									
	9.0	7/2	Z1 mudstone	CL	30	15	15	6.5	100	78												–	180	249	1.86	7.7				

TELECOM TUNNEL, MELBOURNE. SUMMARY OF TESTS ON SOIL AND ROCK SAMPLES.
APPENDIX 2

Sample Details				Classification Results							Unconfined Compressive Strength			Triaxial – Undrained								Direct Shear – Total Stress					Point Load			
														Total Stress				Effective Stress												
Bore Hole No.	Depth (m)	Sample No. 13-0-	Lithology and/or Formation	Unified Soil Classification	Liquid Limit (w_L) %	Plastic Limit (w_P) %	Plasticity Index (I_p) %	Linear Shrinkage (LS) %	Passing 4.75 mm %	Passing 0.075 mm %	Unconfined Compressive Strength (σ_1) MPa (*kPa)	Dry Density t/m^3	Moisture Content %	Cohesion (c) Angle of friction φ c/φ	Cell Pressures (σ_3) kPa	Dry Density t/m^3	Moisture Content %	Effective cohesion (c^1) Effective angle of friction(ϕ^1) c/φ	Effective Stress ($\sigma_3{}^1$) kPa	Dry Density t/m^3	Initial Moisture Content %	Cohesion (c) Angle of Friction (φ)	Normal Stress (σ_1) kPa	Shear Stress (s) kPa	Initial Dry Density t/m^3	Initial Moisture Content %	Indicated Unconfined Compressive Strength MPa (Is (50) x 24)	Point Load Index Is (50), MPa	Diameter (mm) rock cores	Height (mm) rock cores
15	1.5	66	Elizabeth Street Formation	CL	43	13	30	9.5	100	79				59/10	30/60/ 120	1.75	19.3	7/30	30/60/	1.73	19.3	88/ 19	Refer report sheet		1.73	18.3				
	3.0	3/1		SC	45	12	33	11.0	100	43																				
	7.5	3/2		CH	79	20	59	16.0	100	95	306*	1.48	29.7																	
16	6.0	8		CH	83	21	62	16.5	100	94	345*	1.55	26.2									–	115	312	1.55	27.0				
17	9.6	46	MW sandstone								–	2.34	6.5														11.28	0.47	51.5	–
	10.6	47									6.48	2.44	4.3														23.76	0.99	51.7	127.0
19	8.3	48	Z3 mudstone								6.38	2.37	3.9														13.20	0.55	51.5	125.5
	9.7	49									10.08	2.42	4.3														14.61	0.61	51.5	88.5
	11.0	50									9.07	2.37	5.3														12.0	0.50	51.5	116.9
20	0.5	67	Z1, mudstone	CL	44	18	26	11.0	91	86				56/22	10/20/ 40	1.77	17.4					76/ 37	Refer re-port sheet		1.84	17.4				
	7.6	51	Z3, mudstone								6.80	2.31	6.1														9.12	0.38	52.0	109.4
	9.5	52	MW sandstone								4.14	2.42	3.3														15.12	0.63	52.0	120.8
	11.0	53	Z3-4 mudstone								–	2.48	3.0														42.24	1.76	52.0	–
20A	7.8	54	HW-MW sandstone								3.13	2.15	12.3														4.56	0.19	46.9	95.5
	9.4	55									–	2.22	6.9														3.36	0.14	46.2	–
	10.1	56									–	2.16	9.1														4.32	0.18	46.0	–
	11.0	57	Z2, mudstone								1.61	2.13	10.0														4.56	0.19	46.2	84.2
21	1.5	68	soil	CL	37	15	22	10.0	100	94				48/9	30/60/ 120	1.7	18.7													
23	1.0	69	Colluvium	CH	52	15	37	12.0	100	76				74/16	20/40/ 80	1.61	24.0													
	3.0	6		CL	41	15	26	13.0	100	70				76/20	60/120/ 240	1.71	18.5													
23A	2.0	70	Colluvium	CH	54	19	35		100	78				64/10/	40/80/ 160	1.52	27.8	25/22	40/80/ 160	1.57	25.8									
	4.0	2/1		CL	48	15	33	16.0	100	71																				
	5.5	2/2		SC	30	11	19	9.0	100	47												–	110	156	1.92	12.9				
24	1.5	71	Colluvium	CL	26	9	17	8.0	100	70				35/19	30/60/ 120	1.71	17.8	10/36	30/60/ 120	1.93	13.3	45/ 29	30/60 120	57/80 107	1.67/ 1.71/ 1.73	21.4/ 18.3/ 17.0				
	3.0	5		CH	63	20	43	13.5	100	85				24/16		1.77	16.0					117/ 13	60/120 /240	124/ 154/ 179	1.58	26.0				
	5.5	60												140/0	110/220 /440	1.67	21.6													
	6.0	61		CL	48	17	31	10.0	91	87				219/0	120/240 /480	1.78	20.2													
26	8		Z3, mudstone																								19.2	0.8	52	110
27	8		Z3, mudstone																								28.7	1.2	52	110
28	11		MW sandstone																								23.7	1.2	52	110
																											28.7	1.2	52	110

Sheet 3

Form W. 382 (O. 11/74)

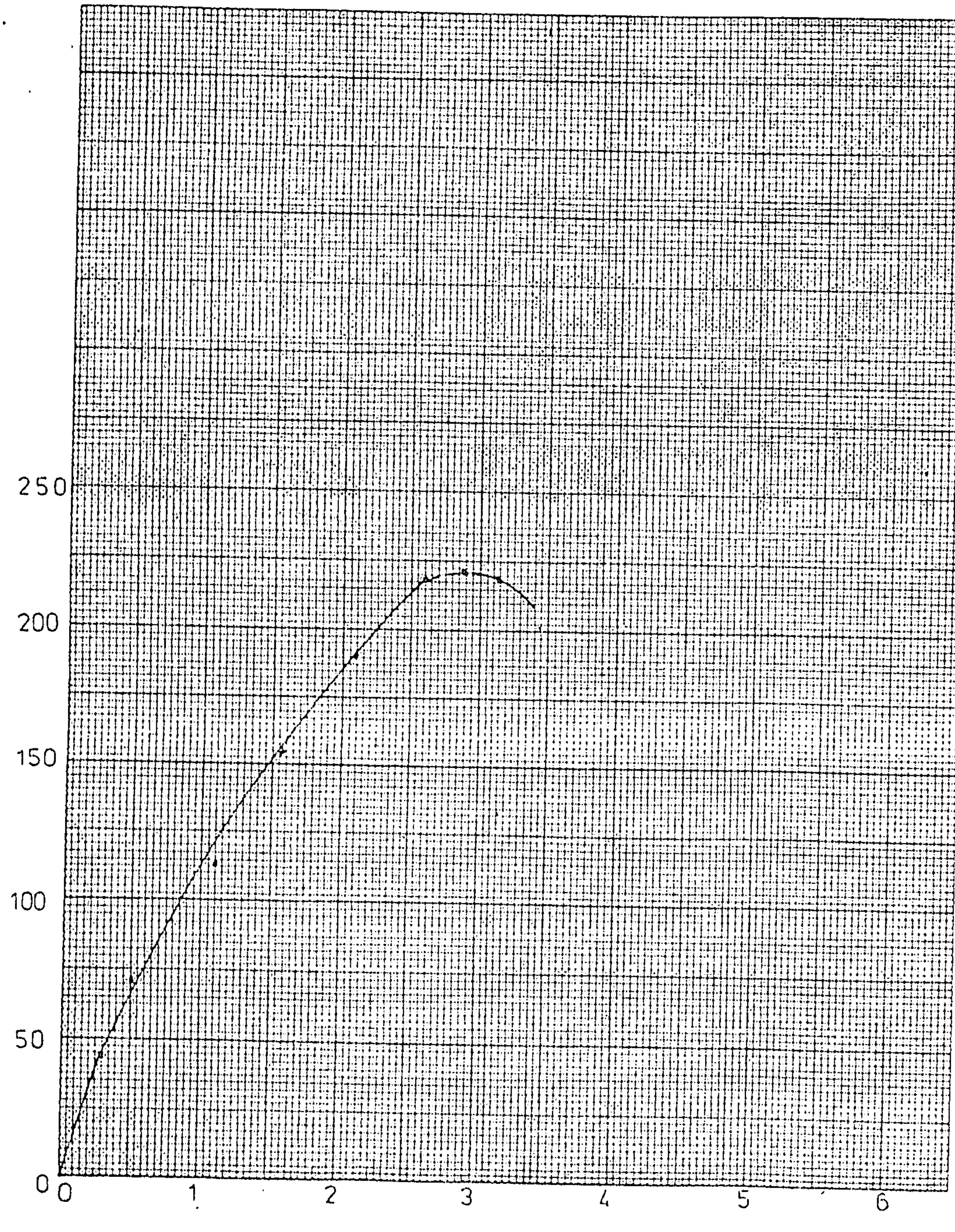
DEPARTMENT OF HOUSING AND CONSTRUCTION

MATERIALS LABORATORY

Werribee Formation

UNCONFINED COMPRESSIVE STRENGTH REPORT SHEET

Curve Number		1	2	3	4
Sample Number		13-0-79			
Unified Classification		CL	Corrected Compressive Strength		
Hole Number		40			
Depth	(m)	7·76-787	$C = \frac{Ca}{\cdot 88 + \cdot 24\ D/L}$		
Dry Density	(t/m3)	1·78			
Moisture Content	(%)	14·1	$= \frac{220}{\cdot 88 + \cdot 24\ 64/95\cdot 5}$		
Degree of Saturation	(%)				
Unconfined Compressive Strength	(kPa)	220	= 211 kPa		
Secant Modulus	(kPa)	11 200			



Failure Diagram
(1)
(2)
(3)
(4)

Sheet No. ....

GENERAL TEST REPORT SHEET – SOILS & GRAVEL

Werribee Formation

state Vic project Geelong Tunnel sheet 1

Sample No.	13-0-79	13-0-80	13-0-81	13-0-82
Location Bore no	40	40	40	40
Depth (m)	7.76 - 7.87	5.94 - 6.38	8.35 - 8.81	6.38 - 6.84
Colour	white	white	white	white
Unified	CL	CL	CL	CL
Description	silty clay	silty clay	silty clay	silty clay
Field Moisture	14.7	17.7	15.3	13.9
Passing 75 mm %				
37.5 " %				
19.0 " %				
9.5 " %				
4.75 " %				
2.36 " %				
1.18 " %				
600 um %				
425 " %	100	100	100	100
300 " %				
150 " %				
75 " %	95	98	94	93
0.05 mm %				
0.02 " %				
0.005 " %				
0.002 " %				
Liquid Limit	32	35	29	28
Plastic Limit	21	20	20	19
Plastic Index	11	15	9	9
Linear Shrinkage	6.5	7	5.5	6
Solid Density t/m³				
O.D.D. Std/M t/m³				
Optimum M.C.				

APPENDIX 3

EARTHQUAKE MAP OF VICTORIA

(Not included in this report; see
Appendix 3, B.M.R. Record 1978-16)

DEPARTMENT OF NATIONAL RESOURCES

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD 1978/90

~~(LIMITED DISTRIBUTION)~~

MELBOURNE CABLE TUNNELS, GEOLOGICAL INVESTIGATIONS

1978 SUPPLEMENTARY REPORT

VOL. II

by

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APPENDIX 4

DRILL CORE PHOTOGRAPHS

DRILLHOLES 30 TO 42

(For drill core photographs of
drillholes 1 to 29, Appendix 4,
BMR Record 1978/16)

APPENDIX 5

GEOLOGICAL LOGS OF DRILLHOLES

30 TO 42

(For logs of drillholes 1 to 29, see
Appendix 5, BMR Record, 1978-16)

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 99 + 20, RATHDOWNE ST.
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 30.58

HOLE No. 30

SHEET 1 OF 2

Method	Water	Lift & % core recovery	Depth (metres)	Substance description	Weathering	R.Q.D.	Defect description
NOT CORED			0 – 1.5	NO CORE			
DIAMOND	TERMINAL CHAMBER	100	1.5 – 3.0	Brown-grey and red clay; quartz sand, and silt.			Unconsolidated sediments, possibly some colluvium.
		55	3.0 – 3.7	DARGILE FORMATION Siltstone, grey clay, minor limonite.	Z1		Extremely weathered contact, siltstone blocks in clay matrix.
			3.7 – 4.5	CORE LOSS			CORE LOSS
		60	4.5 – 5.1	Siltstone, grey clay, minor limonite.	Z1		Siltstone blocks in clay matrix.
			5.1 – 6.0	CORE LOSS			CORE LOSS
		100	6.0 – 7.5	Siltstone, sandstone, minor mudstone, mica and limonite.	Z2 to Z3	0 32	Highly to moderately weathered. Beds about 30 cm thick; thin bedding joints, limonite coated; bedding 40°. Joints at 75° normal to bedding; joints generally recemented with limonite.
		100	7.5 – 8.9				
	12.4m	100	8.9 – 10.0				

Drill type GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driller I. Morgan
Commenced 10/8/78
Completed 11/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▽ 10 Oct 73 water level data shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour
1.5 - 13.5	5670B	5671B

I55/A16/2162

M (Pt) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 99+20, RATHDOWNE ST
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 30.58m

HOLE No. 30

SHEET 2 OF 2

Drilling information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 Is(50)(KPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
DIAMOND			TERMINAL CHAMBER		100				Z2 to Z3			32		
						11.0		Sandstone, mudstone, clay.	Z3			0	Clay seams intercalated between very hard sand-stone layers, 3-8 cm thick.	
					100	12.0		Sandstone, mudstone, clay.	Z4			98	Bedding at 40-45°. Thin bedding joints recemented (limonite or clay). Bed thickness ranging to 1m.	
					100	13.0							5 cm thick bedding joint, clay filled.	
								END OF HOLE 13.50m (R.L. 17.08m)						

Drill type GEMCO
Feed HYDRAULIC
Core barrel type NMLC
Driller J. Morgan
Commenced 10/8/78
Completed 11/8/78
Logged by G. TRAND
Vertical scale 2m: 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour
1.5-13.5	5670B	5671B

ISS/A16/2162

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 196+00 RATHDOWNE ST.
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 26.73m

HOLE No. 31
SHEET 1 OF 1

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test ✻	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength Is(50)(kPa) 30 100 300 1000	Defect spacing (cm) 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
	1 2 4 5			Px		1.0 2.0 3.0		FILL Light brown silty clay, some sand and gravel. NO CORE						
DIAMOND	Samples held by C.I. & R.L.	TUNNEL			99	4.0 5.0		DARGILE FORMATION Grey brown sandstone, siltstone, mudstone, minor limonite, some clay seams.	Z2	113 kPa		0	Hard sandstone, blocky in clay matrix, gradually becoming coherent mudstone. Bedding 35°. Bedding joints, limonite stained, 2-3 cm thick.	
					100	6.0 7.0			Z2 to Z3	150 kPa		30	Recemented joints, less clay along joints.	
					100	8.0 9.0			Z3	195 kPa		75	Bedding 35°, joints normal and parallel to bedding. Joints normal to bedding (70°) at 7.9m and 8.7m, limonite stained.	
									Z2 PP	110 kPa			Becoming softer	
						10.0		END OF HOLE 9.6m (R.L. 17.13m)						

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc
Commenced 29/7/78
Completed
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P.P. Pocket Penetrometer
Px Piezometer

Water
▼ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✻ Water Pressure Tests

Core Photography Negative No		
Depth (m)	B & W	Colour
3.75 - 9.6	5670D	5671D

I55/A16/2163

M (PI) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 1Q47 + 05, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 22.77m

HOLE No. 32
SHEET 1 OF 1

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 Is(50)(KPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
NOT CORED						0–1.0		FILL						
	1 2					1.0		Stiff yellow brown and grey sandy clay						
DIAMOND	SAMPLES HELD AT C.I. & R.I.				100	2.0		DARGILE FORMATION Mudstone, grey brown clay.	Z1				Clayey layer of EW silurian mudstone. Some hard blocks of mudstone in clayey matrix.	
					90	3.0		Grey brown mudstone, few sandstone bands.	Z3	390 KPa		0	Horizontal, thickly bedded; vertical joints, mostly uncemented or poorly cemented.	
			CHAMBER		100	4.0 5.0						30	Beds 10 cm thick, separated by clay filled joints; 5cm thick clay seam at 4.75m; poorly cemented joints.	
					100	6.0 7.0 8.0				481 KPa 481 KPa		78	Thin horizontal joints 3-12 mm apart 15cm thick sandstone band.	
				Px	100 100	9.0 10.0			Z3 to Z4	711 KPa		100	30 cm thick beds, sub-horizontal.	

END OF HOLE 10·2m (R.L 12·57m)

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc.
Commenced 19/8/78
Completed 20/8/78
Logged by G. TRAND
Vertical scale 2cm - 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P.P. Pocket Penetrometer
Px Piezometer

Water
▼ 10 Oct 73 water level data shown
▶ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No		
Depth (m)	B & W	Colour
1.5 - 10.2	5670B	5671B

I55/A16/2164

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 902 + 60, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 20.37 m

HOLE No. 33

SHEET 1 OF 2

Drilling information — Method; Drilling rate; Casing; Water; Pressure test ✱; Lift & % core recovery; Depth (metres)

Rock Substance — Graphic log & core loss; Substance description: rock type, grain characteristics, colour, structure, minor components; Weathering; Point load strength 30 100 300 1000 Is(50) (kPa)

Rock Mass Defects — Defect spacing (cm) 3 10 30 100 300; R.Q.D.; Defect description: thickness, type, inclination, planarity, roughness, coating strength; Rock condition No (interpretive)

Method: AUGER

Drilling rate: 3

SAMPLE HELD BY C.I. & R.L.

TUNNEL

Pressure test: 50 KPa/31 in 5 min; 60 KPa/No loss in 6 min; 60-70 KPa/No loss in 5 min

Water: P× (6.0–6.5 m); P× (9.5 m)

Depth (metres)	Substance description	Defect description
0	FILL	
1.0	COLLUVIUM Dark brown silty clay	NOTE: Logging of bag samples only.
3.0	Dark brown clay	Stiff, hard, dry SPT 15 blows / 300 mm
4.0	As above	As above SPT 20 blows/300mm
5.0	Grey silty clay	Very hard, brittle SPT 22 blows/300mm
6.0	Light brown - grey silty clay.	Mottled clay, moist & soft SPT 31 blows /300 mm
7.0	Light brown-grey silty sandy clay.	As above SPT 30 blows/300mm
8.0	As above, decrease in amount of sand.	As above SPT 21 blows / 300 mm
9.0	Grey clayey silt	SPT 11 blows/300mm Poorly consolidated colluvium deposit, soft and moist.
10.0	As above	

Drill type FOX
Feed HYDRAULIC
Core barrel type
Driller I. MORGAN
Commenced 26/7/78
Completed 27/7/78
Logged by G. TRAND
Vertical scale 2cm - 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P× Piezometer.

Water
▽ 10 Oct 73 water level data shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✱ Water Pressure Tests

I55/A16/2165

Core Photography Negative No		
Depth (m)	B & W	Colour

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 902 L 60, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90 DIRECTION
CO-ORDINATES R.L. OF 20.37m

HOLE No. 33

SHEET 2 OF 2

Drilling information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength 30 100 300 1000 Is(50)(kPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
				60-70 kPa / No loss in 5 min		10 11·0 12·0		Grey clayey silt					As above SPT 11 blows / 300 mm SPT 10 blows / 300 mm SPT 25 blows / 50mm	
								END OF HOLE 12·0m (RL 8·37m)						

Drill type FOX
Feed HYDRAULIC
Core barrel type NMLC
Driller J. MORGAN
Commenced 26/7/78
Completed 27/7/78
Logged by G. TRAND
Vertical scale 2cm - 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▼ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2165

Core Photography Negative No		
Depth (m)	B & W	Colour

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

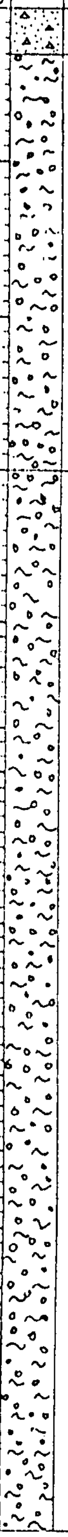
PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 874 L50, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES
R L OF 20.02 m

HOLE No. 34
SHEET 1 OF 2

Drilling Information: Method | Drilling rate | Casing | Water | Pressure test ✱ | Lift & % core recovery | Depth (metres)

Rock Substance: Graphic log & core loss | Substance description: rock type, grain characteristics, colour, structure, minor components | Weathering | Point load strength Is(50)(kPa): 30, 100, 300, 1000

Rock Mass Defects: Defect spacing (cm): 3, 10, 30, 100, 300 | R.Q.D. | Defect description: thickness, type, inclination, planarity, roughness, coating strength | Rock condition No (interpretive)



Depth (metres)	Substance description	Defect description
0	PAVEMENT	
1.0		
2.0	Grey Silty clay	NOTE: Logging of bag samples only 3 – 12·5 m
3.0	COLLUVIUM Brown - grey clay	Hard, mottled SPT 22 blows / 300 mm
4.0	As above	As above SPT 17 blows / 300 mm
5.0	As above	As above SPT 20 blows / 300 mm
6.0	Brown limonitic quartz sand, minor clay	Unconsolidated SPT 34 blows / 210 mm
7.0	As above	As above SPT 12 blows / 60 mm
8.0	Grey silty clay	Hard, well consolidated SPT 40 blows / 300 mm
9.0	Brown limonitic quartz sand	Unconsolidated, loose SPT 25 blows / 140 mm
10.0	Light grey fine quartz sand, minor clay.	

Method: AUGER

Casing: LOADING COIL CHAMBER

Water: P x

Pressure test:
50 KPa / No loss in 5 mins
50 KPa / No loss in 5 min
80-60 KPa / No loss in 5 min

Drill type FOX
Feed HYDRAULIC
Core barrel type NMLC
Driller J. MORGAN
Commenced 2/8/78
Completed 2/8/78
Logged by G. TRAND
Vertical scale 2cm - 1m

Weathering
- Fr - Fresh
- SW - Slightly weathered
- MW - Moderately weathered
- HW - Highly weathered
- EW - Extremely weathered

P x Piezometer

Water
- ∇ 10 Oct 73 water level date shown
- ▷ Water inflow
- ◁ Partial drilling water loss
- ◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✱ Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour

I55/A16/2166

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 874 + 50, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 10° DIRECTION
CO-ORDINATES R L OF 20.02 m

HOLE No. 34

SHEET 2 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres) 10	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 100 300 1000 Point load strength Is(50)(KPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER				80-60 kPa/No loss in 5 min				Light grey fine quartz sand, minor clay.					Unconsolidated, loose SPT 25 blows/70 mm	
						11.0		Light grey fine quartz sand, more clay.					Slight cohesion SPT 28 blows/300mm	
						12.0		As above					Hard, well consolidated SPT 14 blows /300 mm	
								END OF HOLE 12.5m (R.L. 7.52 m)						

Drill type EOX
Feed HYDRAULIC
Core barrel type NMLC
Driller J. MORGAN
Commenced 2/8/78
Completed 2/8/78
Logged by G. TRANO
Vertical scale 2cm: 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▼ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No		
Depth (m)	B & W	Colour

I55/A16/2166

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 857 + 00, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 19·82 m

HOLE No. 35
SHEET 1 OF 2

Drilling Information | Rock Substance | Rock Mass Defects

Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength Is(50)(kPa)	Defect spacing (cm)	R.Q.D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpreting)
AUGER						0		PAVEMENT, FILL						
								COLLUVIUM						
						1.0								
								Dark grey to light brown silty clay.						
						2.0							NOTE: Bag samples to 12·5 m.	
						3.0		COLLUVIUM Dark brown clay, silt, limonite.					Ferruginous stained, silty clay, well consolidated, mottled layer. SPT 18 blows/300 mm	
				40 kPa/No loss in 5 mins		4.0		As above					Hard, as above SPT 15 blows/300 mm	
						5.0		As above, plus sand.					Hard brittle, partly consolidated SPT 35 blows/300 mm	
			TUNNEL			6.0		Grey brown silty clay					Well consolidated, mottled SPT 41 blows/300 mm	
				50-60 KPa/41 in 5 min		7.0		Quartz sand; minor clay silt & limonite					Colluvium - unconsolidated SPT 25 blows/140 mm	
						8.0		Clean quartz sand and silt, minor clay					As above SPT 5 blows/10 mm	
						9.0		As above					SPT 12 blows/150 mm	
						10.0								

Drill type FOX
Feed HYDRAULIC
Core barrel type NMLC

Driller I. MORGAN
Commenced 3/8/78
Completed 4/8/78
Logged by G. IBAND
Vertical scale 2cm : 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P. Piezometer

Water
▽ 10 Oct '73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2167

Core Photography Negative No		
Depth (m)	B & W	Colour
12·5-13·2	5670C	5671C

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BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 857 + 00, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 19.82 m

HOLE No. 35
SHEET 2 OF 2

Drilling information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test ✱	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 100 300 1000 Point load strength Is(50)(kPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER				40 kPa/ 31 in 5 min				DARGILE FORMATION Clay, mudstone.					SPT 21 blows/ 300 mm Extremely weathered mudstone. Soft moist clay, well consolidated becoming hard	
						11.0		As above						
									Z1				SPT 25 blows/ 60 mm	
						12.0		As above					SPT 25 blows/ 120 mm AUGER REFUSAL 12.5 m	
DIAMOND DRILL				Sx	100	13.0		mudstone clay, limonite	Z1				Extremely weathered mudstone.	
								END OF HOLE 13.2 m (R.L. 6.62 m)						

Drill type EQX
Feed HYDRAULIC
Core barrel type NMLC
Driller J. MORGAN
Commenced 3/8/78
Completed 4/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Sx Standpipe

Water
▽ 10 Oct 73 water level data shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✱ Water Pressure Tests

I55/A16/2167

Core Photography Negative No		
Depth (m)	B & W	Colour
12.5 - 13.2	5670C	5671C

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 808+75 , LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 19.59m

HOLE No. 36

SHEET 1 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength 30 100 300 1000 Is(50)(KPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER						0 1.0 2.0		FILL						
	1 2 3 4 5 6 7			Px		3.0 4.0		DARGILE FORMATION Mottled brown and grey silty clay.						
DIAMOND	SAMPLES HELD BY C.T. & R.L.		CHAMBER		92 91 72 100 50	5.0 6.0 7.0 8.0		siltstone brown, grey, clay, limonite	Z2			0	Limonite impregnated siltstones. Soft joints mainly clay filled or stained. Beds generally less than 10cm thick. Bedding joints 35°, joints normal to bedding joints. Occasional lenses of clay.	
				Px	94	9.0 10.0			Z2 to Z3	P.P. 150kPa		25	Smooth and thin bedding joints (35°). Clay filled joints at 8.87, 10.81, 8-10cm thick. Bedding 30°.	

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc.
Commenced 5/8/78
Completed 5/8/78
Logged by G TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P.P. Pocket Penetrometer
P. Piezometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2168

Core Photography Negative No		
Depth (m)	B & W	Colour
4.7-11.25	5670C	5671C

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TILLCOM TUNNEL
LOCATION MELBOURNE CITY
STATION 808 + 75 , LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 19.59 m

HOLE No. 36

SHEET 2 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength Is(50)(kPa) 30 100 300 1000	Defect spacing (cm) 3 10 30 100 300	R.Q.D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
					94	10.0								
					89	11.0		siltstone, brown, grey, clay, limonite.	Z2 to Z3	P.P. 165kPa		25	As above.	
								END OF HOLE 11.26m (RL 8.33 m)						

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc
Commenced 5/8/78
Completed 5/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P.P. Pocket Penetrometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2168

Core Photography Negative No

Depth (m)	B & W	Colour
4.7-11.25	5670C	5671C

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 148+70, RUSSEL STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R L OF 18.09 m

HOLE No. 37

SHEET 1 OF 2

Method	Water	Pressure test *	Depth (metres)	Substance description (rock type, grain characteristics, colour, structure, minor components)	Defect description (thickness, type, inclination, planarity, roughness, coating strength)
AUGER			0	BITUMEN, ROAD METAL, FILL.	NOTE: Bag samples to 12.5m.
			1.0	COLLUVIUM Dark brown, silty clay	Firm to stiff colluvium sediments, increasing in stiffness with increasing depth.
			2.0		
		60-40 kPa/No loss in 5min	3.0	Clay, sand COLLUVIUM	SPT 17 blows/300 mm Dense clay, fine sand,
			4.0	Grey silty sandy clay	Firm clay-sand mixture SPT 19 blows/300 mm
			5.0	As above	As above SPT 20 blows/300mm
	TUNNEL	200 kPa/No loss in 5min.	6.0	Brown silty sandy clay.	Poorly consolidated SPT 25 blows/300mm
			7.0	Clean light grey sand (minor clay).	Loose sand SPT 47 blows/300mm
		60-50 kPa/No loss in 5 min	8.0	As above, some limonitic colour.	As above SPT 30 blows/160mm
			9.0	Clay and quartz sand	Dense, partly consolidated SPT 25 blows/150 mm
			10.0	Sand, silt and clay	Unconsolidated

Drill type EOX
Feed HYDRAULIC
Core barrel type NMLC
Driller J. MORGAN
Commenced 20/7/78
Completed 23/7/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▽ 10 Oct 73 water level data shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour
12.5-14.7	5670D	5671D

I55/A16/2169

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 140+70, RUSSEL STREET
ANGLE FROM HORIZONTAL (θ) 90 DIRECTION
CO-ORDINATES R.L. OF 18.09 m

HOLE No. 37

SHEET 2 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 Is(50) (kPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER				60-70 kPa/ No loss in 5 min		10.0		Sand, clay, silt					Unconsolidated SPT 25 blows/ 120 mm	
						11.0		Sand, clay, sill					Poorly consolidated SPT 25 blows/ 130 mm	
						12.0		Dark grey-brown clays					Well consolidated clays, very hard. SPT 31 blows/300 mm	
DIAMOND				Px	95	13.0		DARGILE FORMATION Grey brown silty clay	Z1				Extremely weathered well consolidated. P.P. 300-500 kPa; some > 500 kPa	
					100	14.0		Grey sandstone, mica and quartz grains.	Z2				Hard mudstone blocks in clayey matrix	
									Z3	170KG			Dip 30°, joints normal to bedding.	
								END OF HOLE 14.6m (RL 3.49 m)						

Drill type EOX
Feed HYDRAULIC
Core barrel type NMLC
Driller I. MORGAN
Commenced 20/7/78
Completed 23/7/78
Logged by G. TRAND
Vertical scale 2cm : 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P.P. Pocket Penetrometer
Px Piezometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour
12.5-14.7	5670D	5671D

I55/A16/2169

M (Pf) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 210+00, RUSSELL STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 16.18 m

HOLE No. 38

SHEET 1 OF 1

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test ✱	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 ts (50)(kPa)	Defect spacing (cm)	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER						0.0		PAVEMENT & FILL						
						1.0		COLLUVIUM Colluvium, sandy clay						
						2.0								
						3.0							SPT 14 blows/300 mm	
						4.0							SPT 18 blows/300mm	
				P		5.0							SPT 28 blows/300 mm	
DIAMOND		TUNNEL		P	97	6.0		DARGILE FORMATION Mudstone, minor limonite	Z2 to Z3	131 kPa		25	SPT 21 blows/300 mm Recemented joints, limonite stained. Bedding joints at 25°-35°, joints normal to bedding joints at 60°.	
					98	7.0 8.0			Z3	172 kPa		72	Beds increasing in thickness, up to 30 cm thick.	
					100 100 100	9.0 10.0		Mudstone, siltstone and clay.	Z2	130 kPa		0	Highly fractured core, some decomposed mudstone seams 1-3 cm thick. Limonite stain on joints, weakly cemented	

END OF HOLE 10.76 m (RL 5.42m)

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc.
Commenced 29/7/78
Completed 30/7/78
Logged by G. TRAND
Vertical scale 2cm : 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

PP Pocket Penetrometer
P Piezometer

Water
▼ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✱ Water Pressure Tests

Core Photography Negative No		
Depth (m)	B & W	Colour
6.18-10.75	5670D	5671D

I55/A16/2170

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 400+00, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 11.42m

HOLE No. 39

SHEET 1 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log Bore loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 Is(50)(kPa)	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER						0		PAVEMENT, CONCRETE, FILL						
CONTINUOUS SAMPLING - UNDISTURBED SAMPLES	3 4 5 6 7 8 9 10 11					1.0 2.0 3.0 4.0		ELIZABETH ST. FORMATION Grey brown clay, quartz sand, minor silt. Slightly more sand					Very stiff clay. Mottled with thin bands of clayey sand. (cohesive). Clayey sand - hard, well consolidated. (cohesive)	
	12 13					5.0		Sand, silt, clay, some					Still coarse to medium size sand bands well consolidated, mottled clay. (uncohesive) SPT 52 blows/300 mm SPT 33 blows/150 mm	
	Samples held at C.I.& R.I. 19 20 21 22 23 24 25 26 27	TUNNEL		100 kPa / 21 in 5 min 100 kPa/ No loss in 5 min.		6.0 7.0 8.0 9.0 10.0		Grey - light brown clay, some silt					Soft, plastic clay, medium consolidated (cohesive). SPT 30 blows/300 mm SPT 12 blows/300 mm	

Drill type GEMCO 500
Feed HYDRAULIC
Core barrel type UD
Continuous Sampling
Driller Golder & Assoc.
Commenced 19/8/78
Completed 19/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Water
▽ 10 Oct 73 water level date shown
▷ Water Inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

Core Photography Negative No		
Depth (m)	B & W	Colour

I55/A16/2171

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 400+00, LONSDALE STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L OF 11.42m

HOLE No. 39

SHEET 2 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	30 Point load 100 strength 300 1000 Is(50)(KPa)	Defect spacing (cm) 3 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
CONTINUOUS SAMPLING - UNDISTURBED SAMPLES						10.0								
	28							Some sand					Occasional specks of sandy clay	
	29													
	30					11.0								
	31													
	32					12.0								
	33				S×									
	34													
	35					13.0								
	36													
	37					14.0								
								END OF HOLE 14.0 m (RL. 2.58m)						

Drill type GEMCO 900
Feed HYDRAULIC
Core barrel type UQ
Continuous Sampling
Driller Golder & Assoc
Commenced 19/8/78
Completed 19/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Sx Standpipe

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

ISS/A16/2171

Core Photography Negative No		
Depth (m)	B & W	Colour

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 135 + 75, QUEEN SREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 22.59 m

HOLE No. 40

SHEET 1 OF 1

Method	Drilling rate	Casing	Pressure test *	Depth (metres)	Substance description (rock type, grain characteristics, colour, structure, minor components)	Defect description (thickness, type, inclination, planarity, roughness, coating strength)
AUGER				0	PAVEMENT & FILL	
				1.0		
	2				NO SAMPLES	
CONTINUOUS SAMPLING — Samples held at C.I. & R.L.	3			2.0	BRIGHTON GROUP	Poorly consolidated, moist
					Brown grey, silty clay	
					Light grey clay, quartz sand & gravel	SPT 60 blows/300mm
	6			3.0	NO SAMPLE	SPT 49 blows/300 mm Dry and hard
					Grey sand, clay & gravel minor limonite.	Wet, partly consolidated
					NO SAMPLE	SPT 46 blows/300 mm
					Biotite rich, gravelly clay, limonite	
				4.0	WERRIBEE FORMATION Clay, minor gravel, limonite. Light grey clayey silt with limonite stains, minor quartz gravels.	SPT 54 blows/300mm Soft stained contact between Brighton and Werribee formations. Friable contact, slightly moist. SPT 48 blows/300mm
				5.0		SPT 65 blows/300 mm Crumbly, slightly moist, poorly consolidated. SPT 57 blows/300 mm
				6.0		SPT 60 blows/300 mm
		TUNNEL				SPT 49 blows/300mm
				7.0		SPT 54 blows/300mm SPT 49 blows/300mm SPT 34 blows/300 mm
	17			8.0		SPT 59 blows/300 mm
			P			SPT 52 blows/300mm
				9.0		SPT 61 blows/300mm SPT 54 blows/150 mm SPT 30 blows/50 mm
				10.0		As above

END OF HOLE 10.0m (RL 12.59 m)

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type
Driller Golder & Assoc
Commenced 5/8/78
Completed 5/8/78
Logged by G. TRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

Pₓ Piezometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2172

Core Photography Negative No
Depth (m) B & W Colour

M (PI) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 359+88 QUEEN STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 15.04

HOLE No. 41
SHEET 1 OF 2

Drilling information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength Is(50)(KPa) 30 100 300 1000	Defect spacing (cm) 3 10 30 100 300	R.Q.D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER	1 2 3 4 5 6					0 1.0 2.0		NO SAMPLE						
DIAMOND	SAMPLES HELD AT C.I. & R.L.				100	3.0 4.0		BRIGHTON GROUP Grey brown silty clayey sand ; Silty clay					Soft and crumbly. Sands poorly consolidated, ranging from sandy clay to clayey sand. PP 200-300 KPa Generally moist	
			CABLE CHAMBER	P X	100	5.0 6.0		WERRIBEE FORMATION Fine light grey to white kaolinitic clay. Grey clay with quartz gravel.					Firm and crumbly PP 200-400 KPa.	
			10.8m		99 100	7.0 8.0 9.0 10.0		DARGILE FORMATION Grey, fine silty sandy clayey Minor muscovite.	Z1 Z1				Horizontally bedded, hard, well consolidated. Extremely weathered beds of siltstone and mudstone.	

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc
Commenced 12/8/78
Completed
Logged by G. TRAND
Vertical scale 2cm : 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

P Piezometer
PP Pocket Penetrometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2173

Core Photography Negative No

Depth (m)	B & W	Colour
2.55-14.2	5670A	5671A

M (P1) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION MELBOURNE CITY
STATION 359 +88 , QUEEN STREET
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
CO-ORDINATES R.L. OF 15.04 m

HOLE No. 41

SHEET 2 OF 2

Drilling Information							Rock Substance				Rock Mass Defects			
Method	Drilling rate	Casing	Water	Pressure test ✱	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength (Is(50)kPa) 30 100 300 1000	Defect spacing (cm) 3 10 30 100 300	R. Q. D.	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
			CHAMBER	P	100			Grey, fine silty sandy clayey minor muscovite.						
						11.0							Blocks of hard sandstone in clayey matrix.	
DIAMOND					100	12.0			Z1				Alternating layers of weathered siltstones and clayey bands. Beds of 50 cm thickness.	
						13.0								
					100	14.0								
								END OF HOLE 14.2m (RL 0.84m)						

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC
Driller Golder & Assoc
Commenced 12/8/78
Completed
Logged by G JRAND
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

R Piezometer

Water
▽ 10 Oct 73 water level date shown
▷ Water inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
✱ Water Pressure Tests

Core Photography Negative No

Depth (m)	B & W	Colour
3.55-4.2	5670A	5671A

E55/A16/2173

M (Pf) 239

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT TELECOM TUNNEL
LOCATION CORNER EXHIBITION and LT. LONSDALE STREETS, STATION 209 + 87
ANGLE FROM HORIZONTAL (θ) 30° DIRECTION
CO-ORDINATES R L OF 23·43 m

HOLE No. 42

SHEET 1 OF 1

Method	Drilling rate	Casing	Water	Pressure test *	Lift & % core recovery	Depth (metres)	Graphic log & core loss	Substance description rock type, grain characteristics, colour, structure, minor components	Weathering	Point load strength 30 100 300 1000 Is(50)(KPa)	Defect spacing (cm) 3 10 30 100 300	R Q D	Defect description thickness, type, inclination, planarity, roughness, coating strength	Rock condition No (interpretive)
AUGER	1 2 3 4 5 6					1·0 2·0		NOT CORED						
DIAMOND	SAMPLES HELD AT C.L. & R.L.				90	3·0		DARGILE FORMATION Brown grey clay. Blocks of mudstone in clayey matrix.	Z1				Stiff to hard clay (PP > 500 KPa) moist, well consolidated.	
								Sandstone	Z3	300 KPa		0	Hard, resistant sandstone band.	
			Px		100	4·0 5·0		Clay some sandstone gravel in clayey matrix.	Z1				Stiff to hard clay well consolidated, slightly moist.	
					100	6·0 7·0		Sandstone, minor clay	Z3	711 KPa		41	Hard layer of sandstone. Dip 30°. Fine bedding joints, poorly cemented separating 20-30 cm thick beds, also joints normal to bedding — Uncemented 2-3 mm width.	
		10·4m TUNNEL WITH INVERT SUMP			100	8·0 9·0		Mudstone	Z2 to Z3	230 KPa		80	Joints parallel to bedding weathered and clay filled. Alternating thin sandstone bands.	
			Px		100	10·0			Z2	140 KPa		30	Highly fractured sequence mainly mudstone, clay filled joints normal to bedding (30°).	

END OF HOLE 10·1 m (RL 13·33 m)

Drill type GEMCO 210
Feed HYDRAULIC
Core barrel type NMLC

Driller Golder & Assos.
Commenced 12/8/78
Completed 12/8/78
Logged by G. TRANR
Vertical scale 2cm = 1m

Weathering
Fr - Fresh
SW - Slightly weathered
MW - Moderately weathered
HW - Highly weathered
EW - Extremely weathered

PP. Pocket Penetrometer
Px Piezometer

Water
▽ 10 Oct 73 water level date shown
▷ Water Inflow
◁ Partial drilling water loss
◀ Complete drilling water loss

Notes
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
* Water Pressure Tests

I55/A16/2174

Core Photography Negative No

Depth (m)	B & W	Colour
2·2 - 4·8	5670A	5671A
4·8 - 7·15	5670D	5671D
7·15 - 10·10	5670B	5671B

M (P1) 239

APPENDIX 6

GROUNDWATER LEVEL MEASURMENTS

MELBOURNE — TELECOM TUNNEL
GROUND WATER LEVEL MEASUREMENTS

LOCATION	PIEZOMETER DEPTH (M)	Water Level depth below surface (m)																				
		27-8-77	25-9-77	2-10-77	11-10-77	3-11-77	18-11-77	27-2-78	12-4-78	1-5-78	8-5-78	26-7-78	8-8-78	15-8-78	22-8-78	28-8-78	14-9-78	20-9-78	26-9-78	3-10-78	10-10-78	17-10-78
Bore 8	8·1								Dry →													
11	5·2	Dry →																				
14	8·6	Dry	—	—	—	—	0·28	Dry	0·5	0·8	0·9	0·3	0·0	0·0	0·0	0·0	0·0	0·0	Unservicable		0·7	0·0
15	12·2	11·0	Dry	Dry	11·0	Dry	Dry	Dry	Dry	10·2	10·2	6·4	9·3	9·3	9·4	9·3	9·4	Dry	7·5	9·2	9·1	9·1
16	17·5	11·0	Dry	Dry	—	Dry	—	Dry	Dry	Dry	10·0	10·1	10·0	10·0	10·0	10·1	10·1	9·9	Dry	9·8	9·8	9·8
16^A	8·8	—	—	—	—	—	—	Dry →						8·6	Dry	Dry	8·8	8·6	Dry	8·6	Dry	8·2
17	4·5	Dry →											0·0	0·0	Dry	Dry	Dry	4·0	Dry	2·8	3·3	3·5
17	6·7	Dry →											6·7	Dry →						1·0	Dry →	
19						6·0	—	Dry →				Covered cannot locate	—	—	—	—	—	—	—	—	—	—
21	10·4	—	—	—	—	—	Dry	—	Dry →					9·7	Dry	Dry	10·3	8·3	Dry	7·8	6·8	2·5
21^A	17·0	(Installed 2-11-77)				6·0	Dry →					15·3	15·2	15·2	15·2	15·0	15·1	15·0	—	13·7	14·8	14·6
23^A	10·0	—	—	Dry →			—	Dry →									10·0	Dry	Dry	—	—	—
23^A	17·5			14·0	14·0	Dry	—	Dry →			2·25	14·9	14·1	14·5	Dry	14·4	14·1	14·1	15·6	—	Dry	—
28	4·7								4·1	0·0	0·55	4·7	4·7	4·7	4·7	Dry →					0·0 Surface water entering tube	3·7
31															Cover 0·0 missing	Hole blocked	—	—	—	—	—	—
32	9·0														6·9	7·3	7·5	7·2	7·1	7·1	7·1	7·1
33	6·2 Installed 26-7-78												Covered by Vehicle		Dry →			Hole Covered	Dry →		—	Dry
33	9·4												"	"	Dry →			Hole covered	Dry →		—	Dry
34	9·0 Installed 2-8-78												Dry →				8·9	Dry	Dry	8·9	Dry	8·9
35	12·75 (Stand pipe)														9·7	9·7	9·9	10·0	10·0	10·1	10·2	10·2
36	3·1														2·5	2·6	2·6	2·7	cover jammed	2·6	2·6	2·5
36	9·0														Dry →				"	Dry →		9·0
37	13·0 Installed 20-7-78														Dry →				—	Dry →		
38	6·5														Dry →				—	—	—	Dry
38	5·2														Dry →					—	—	Dry
39	12·3 (Stand pipe)														1·5	8·8	9·8	9·4	9·4	9·4	9·6	9·5
40	8·7														—	Dry	8·6	Dry →				
41	6·2														Dry	Dry	6·2	Dry →				
41	10·5														Dry	Dry	10·5	Dry →				
42	4·4														3·9	Dry	4·4	3·7	Dry →			
42	9·1														7·7	8·3	9·1	3·9	8·9	Dry →		

DEPARTMENT OF CONSTRUCTION
AUSTRALIA
VICTORIA & TASMANIA REGION

DESIGNED	DESIGN PROJECT LEADER
DRAWN	PROJECT MANAGER
CHECKED	DIRECTOR

TITLE

FOR

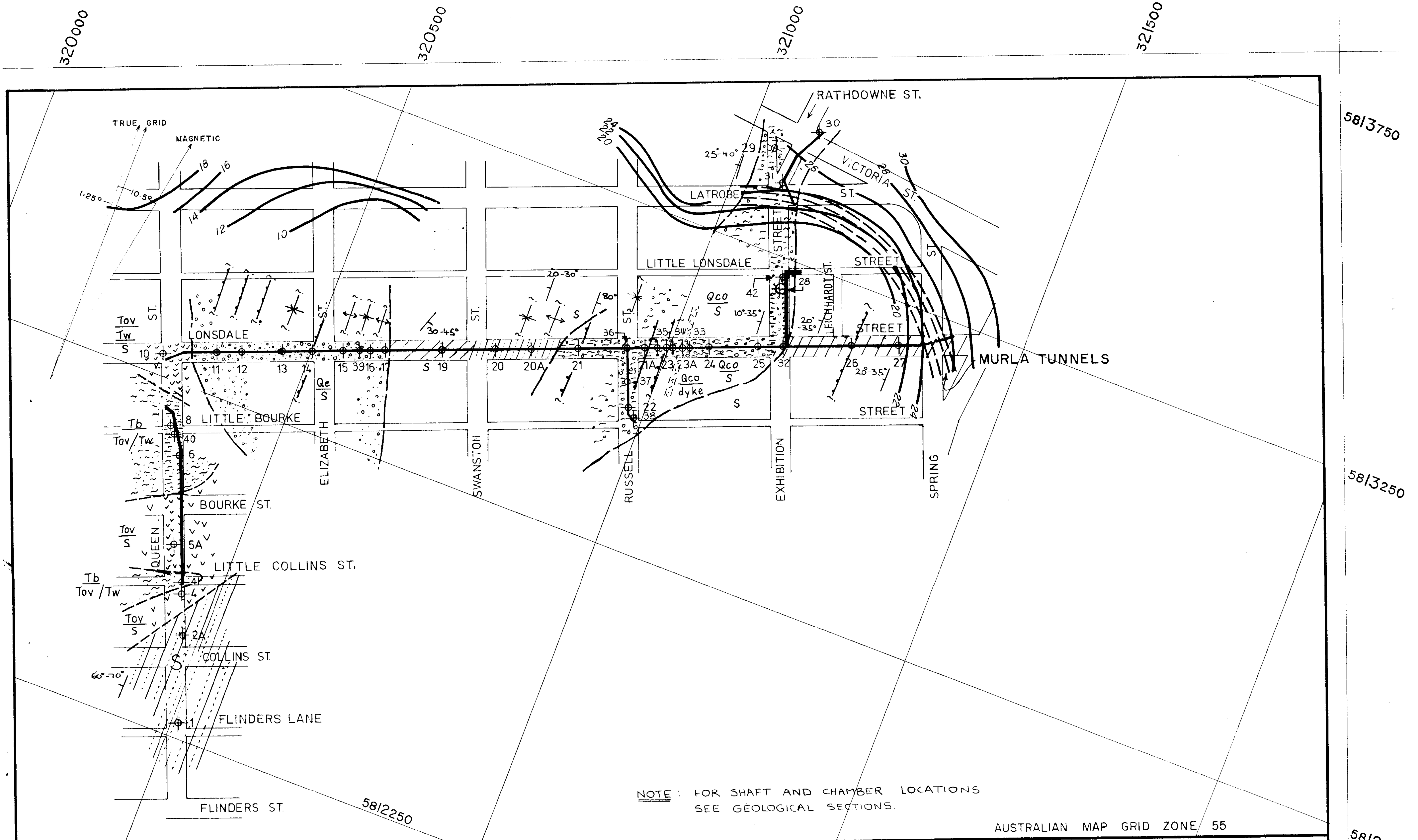
R		A		C		SCALE
		E		S		DATE
D		M				FILE
SPEC.		BILL				D. I. F. S.

PROJECT No. V / - / SHEET AMDT

A1

Record No. 1978/90

J55/A5/17



KEY TO GEOLOGY

Geology based on drill logs and records of construction and the Stratigraphic Map of the Central Business District of Melbourne First edition 1974

QUATERNARY	▨	COLLUVIUM	(Qco)
	▨	ELIZABETH ST. FORMATION	(Qe)
TERTIARY	▨	BRIGHTON GROUP	(Tb)
	▨	BASALT } TERTIARY OLDER VOLCANICS	(Tov)
	▨	TUFF } TERTIARY OLDER VOLCANICS	(Tov)
	▨	WERRIBEE FORMATION	(Tw)
DEVONIAN	▨	DYKE (*Intrudes Silurian sediments only*)	
SILURIAN	▨	MUDSTONE } DARGILE FORMATION	(S)
	▨	MUDSTONE WITH MINOR SANDSTONE } DARGILE FORMATION	(S)
	▨	MAINLY SANDSTONE } DARGILE FORMATION	(S)

LEGEND

―	2 500 TUNNEL
━	3 600 TUNNEL
⌖21	BORE HOLE AND NUMBER
—24—	CONTOURS OF POTENTIOMETRIC SURFACE IN METRES, PRIOR TO MURLA CONSTRUCTION. (Geol. Survey Vic. Unpubl. Rep. 1977/113).
―	GEOLOGICAL BOUNDARY, POSITION APPROXIMATE
✳	INFERRED FOLD AXIS IN DARGILE FORMATION
30°	PROBABLE DIP & STRIKE OF DARGILE FORMATION

GEOLOGIST
G. Trand
D.C. Purcell

CHECKED
EGW.

DATE
1 SEPTEMBER 1978

DRAWING NUMBER
J55/A5/9

TITLE

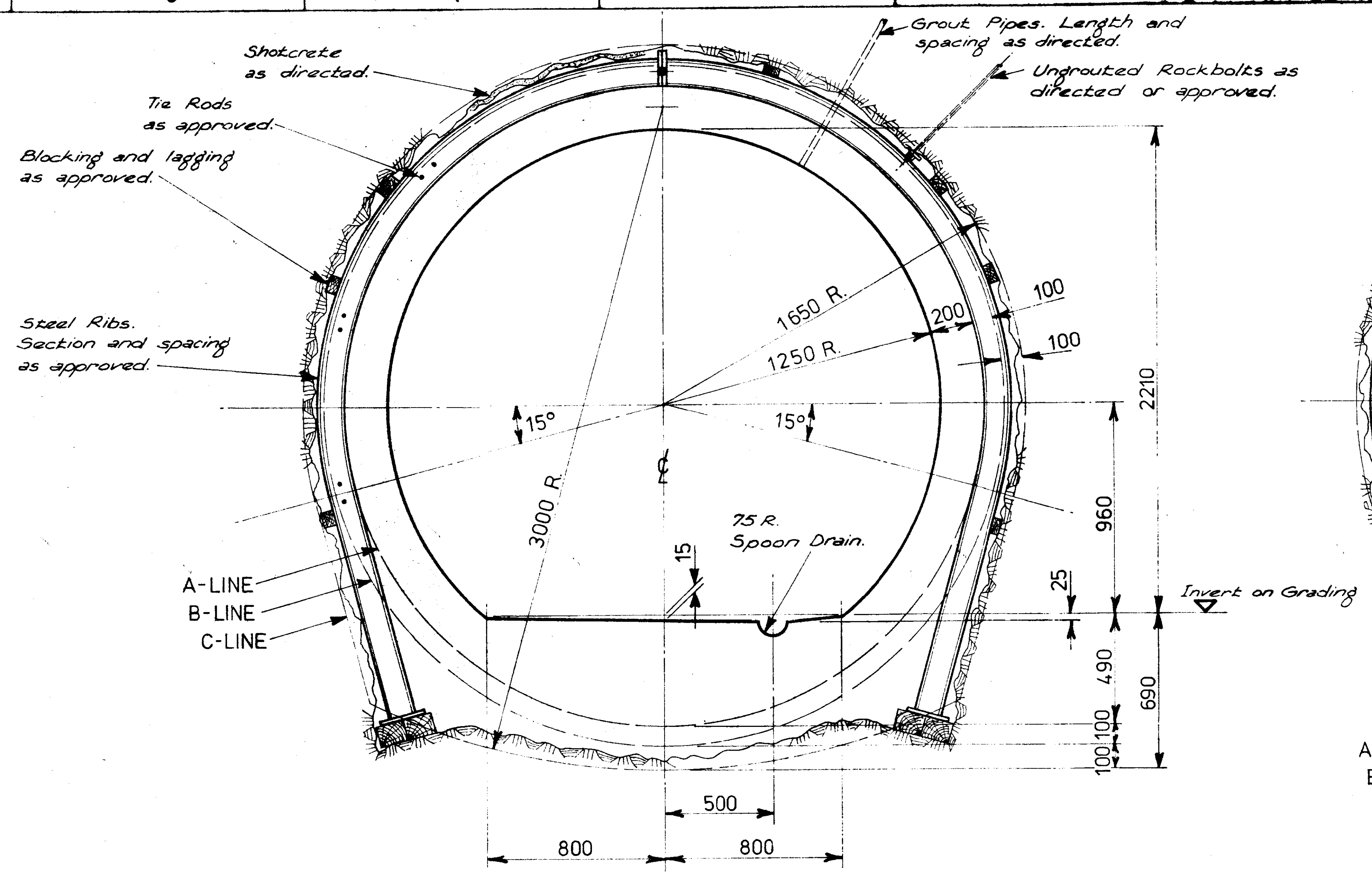
PROPOSED TELECOM CABLE TUNNEL

TUNNEL LAYOUT & INTERPRETED SURFACE GEOLOGY

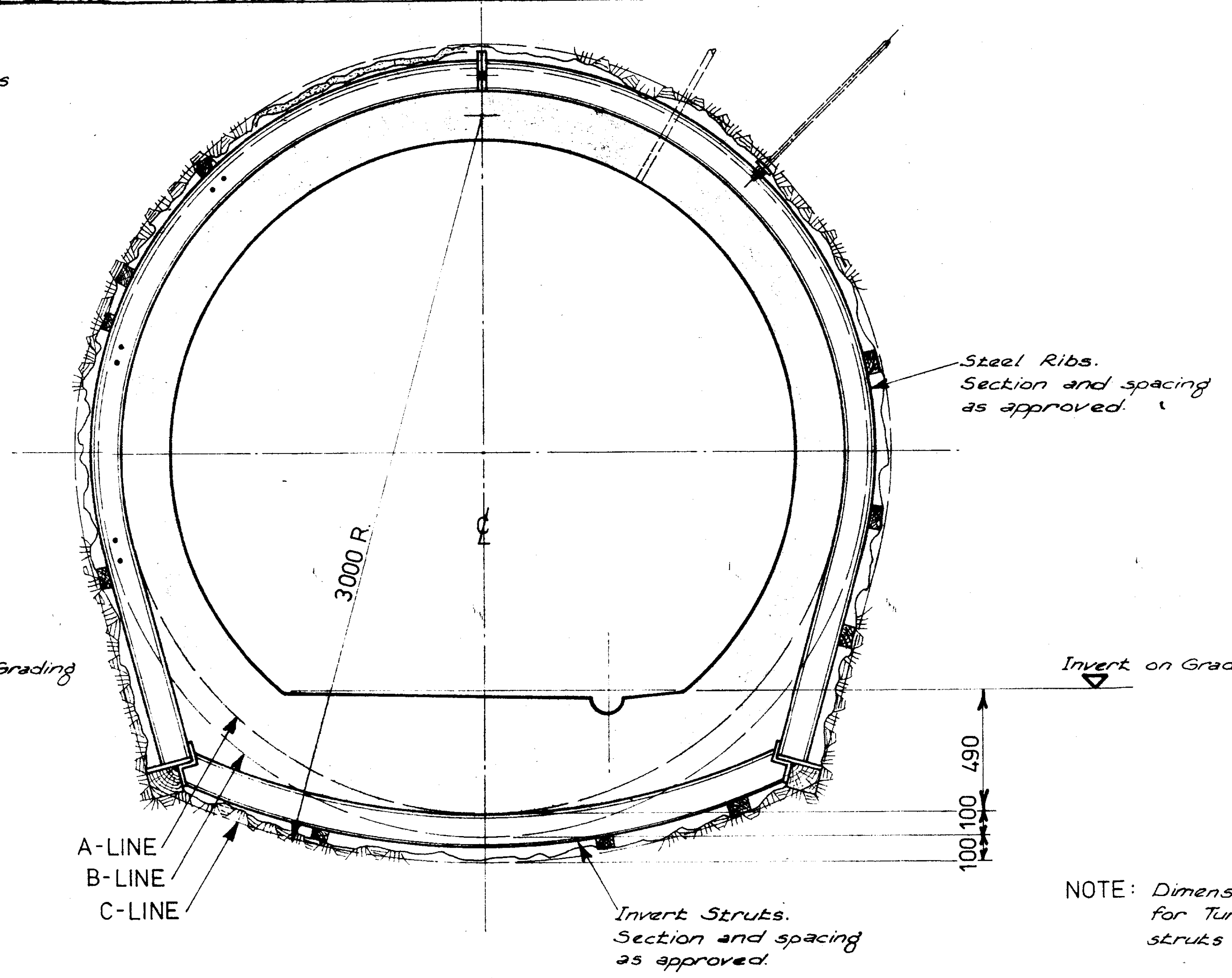
SCALE. 1:5000 Approx.

PLATE 1

Record No. 1978/90

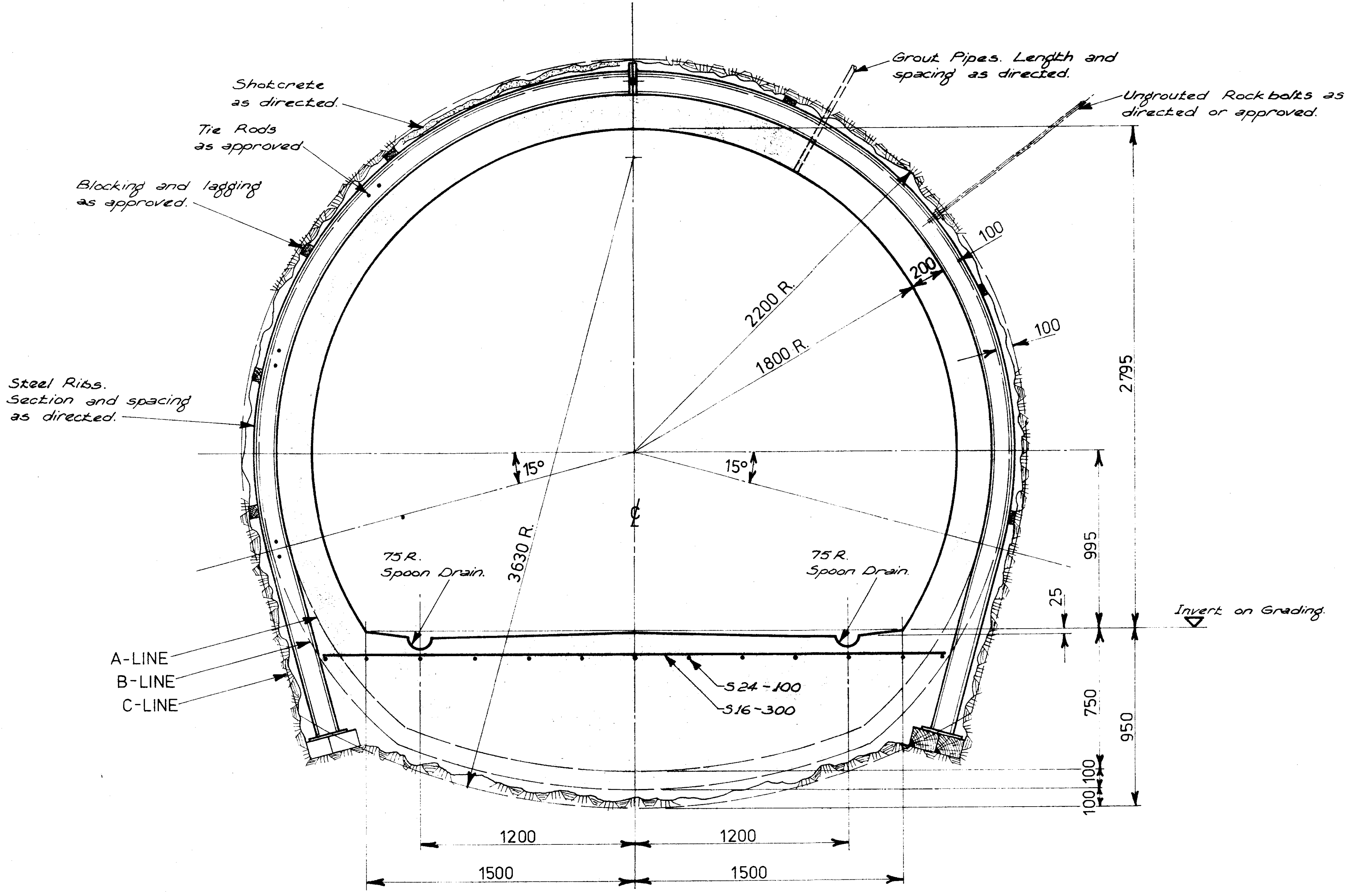


SINGLE TUNNEL
WITHOUT INVERT STRUT



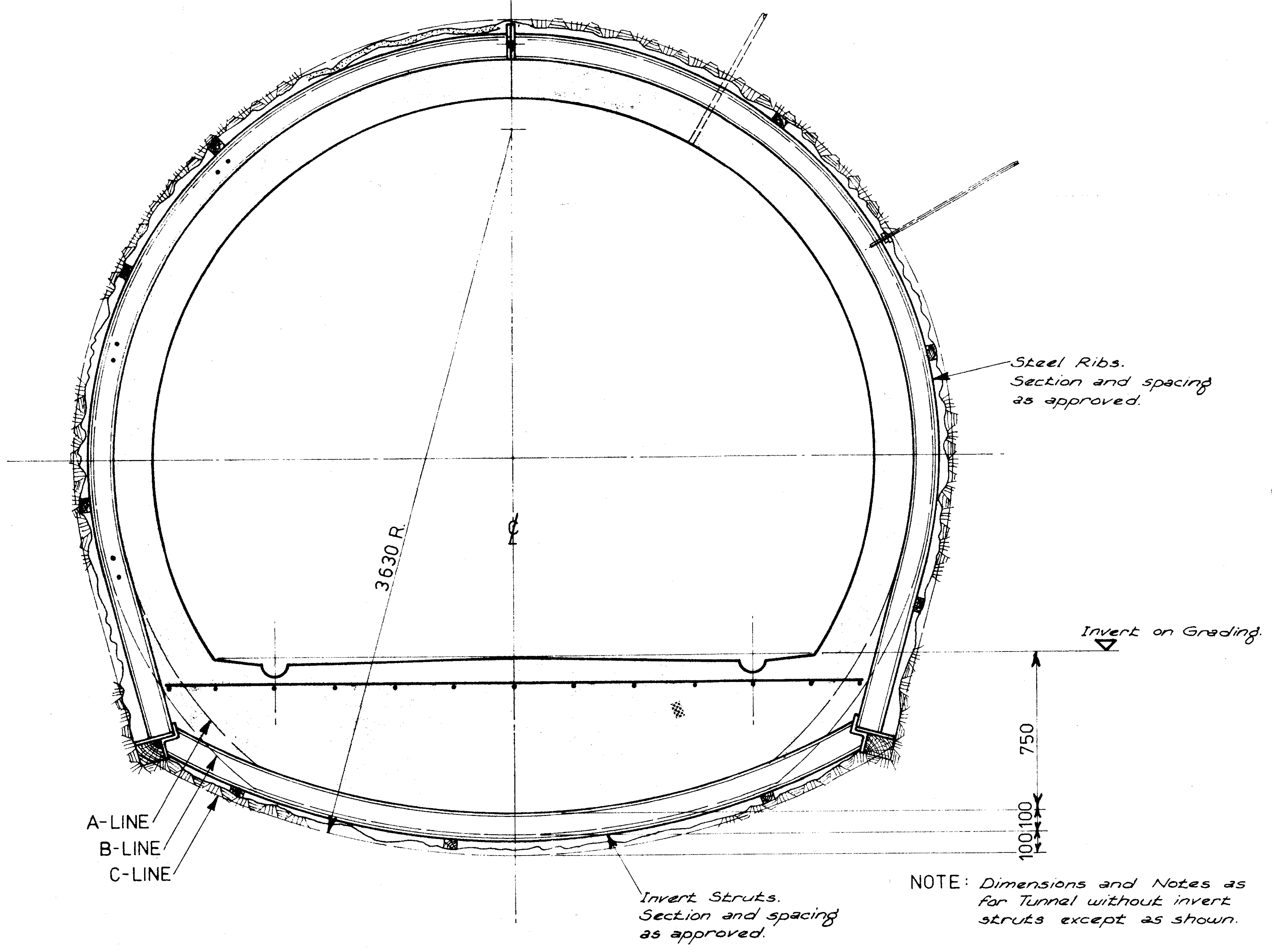
NOTE: Dimensions and Notes as for Tunnel without invert struts except as shown.

SINGLE TUNNEL
WITH INVERT STRUT



DOUBLE TUNNEL
WITHOUT INVERT STRUT

0 1 2 3
SCALE OF METRES



NOTE: Dimensions and Notes as for Tunnel without invert struts except as shown.

DOUBLE TUNNEL
WITH INVERT STRUT

J 55/A5/10(A) PLATE 2A

DEPARTMENT OF CONSTRUCTION
VICTORIA & TASMANIA REGION

DESIGNED R. DEVLIN
DESIGN PROJECT LEADER
DRAWN M. SCHARLEY
PROJECT MANAGER
CHECKED
DIRECTOR J.C.WISKEN

TITLE MELBOURNE 3000
LONSDALE ST. TUNNELS

TYPE CROSS SECTIONS

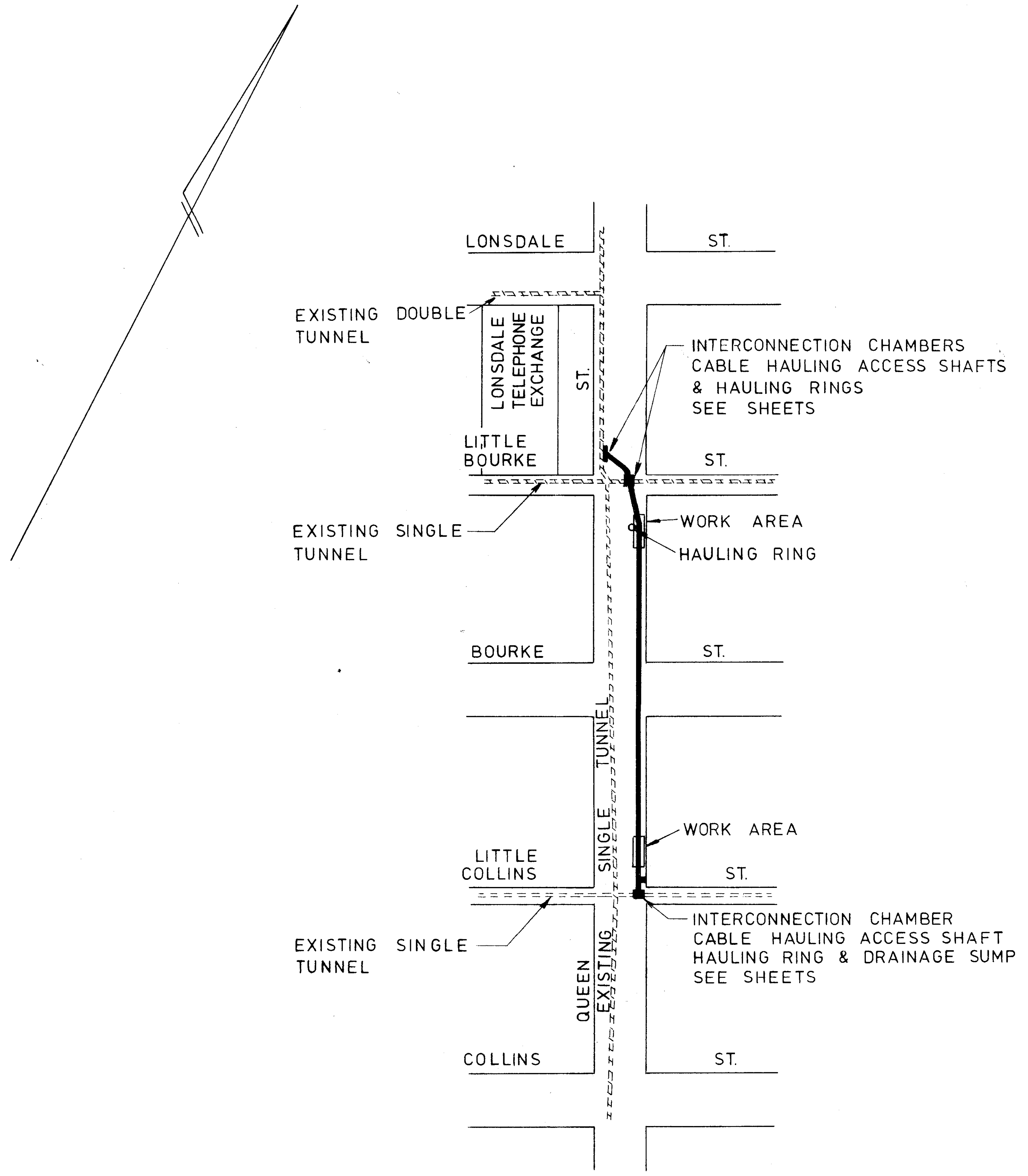
FOR TELECOM

R	'85	A		C	
		E		S	●
D		M			
SPEC.	●	BILL			

SCALE AS SHOWN
DATE AUGUST '78
FILE 53503
D. I. F. S.

PROJECT No. SHEET AMDT
V 78 / 192 - /

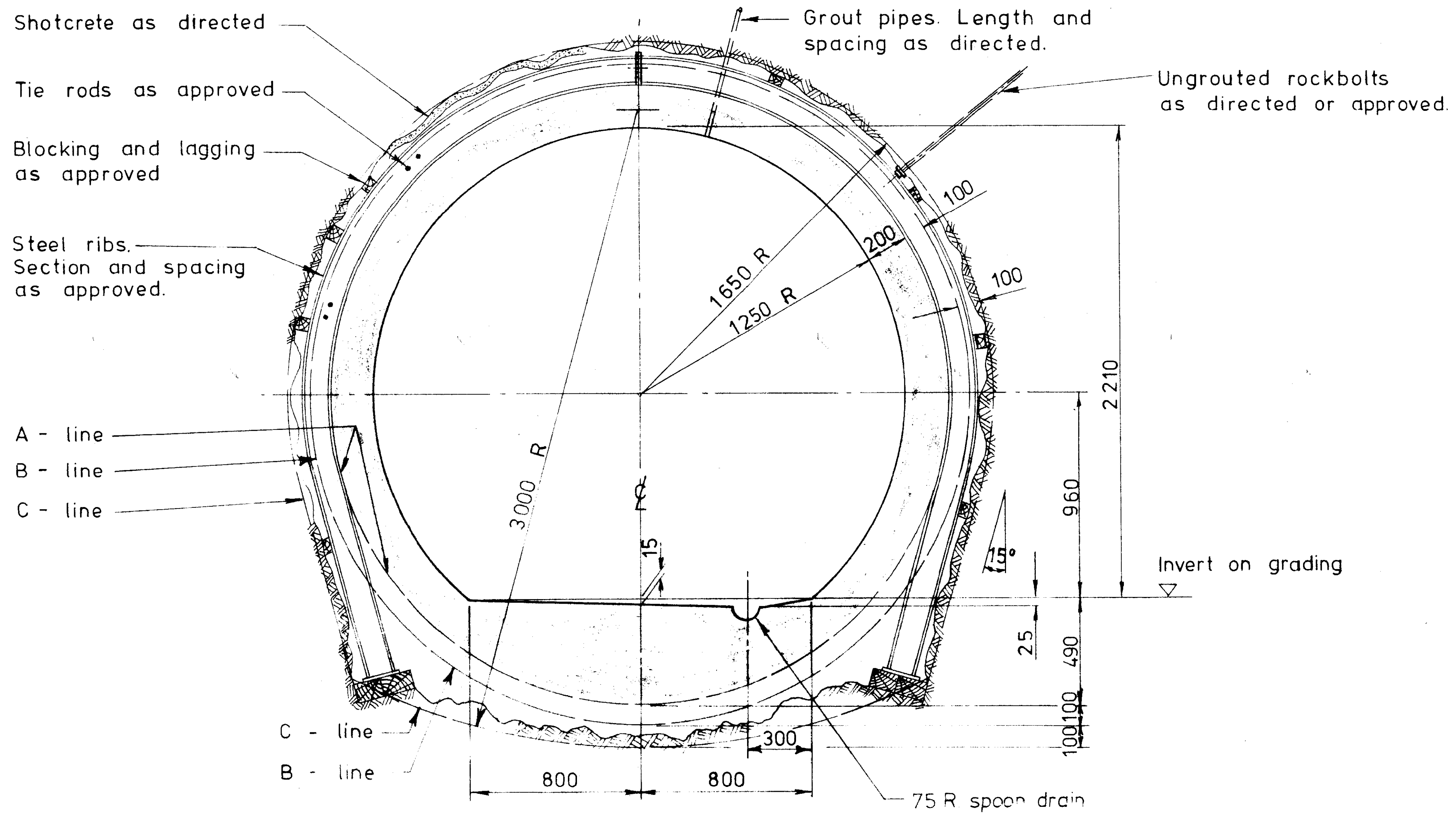
A1



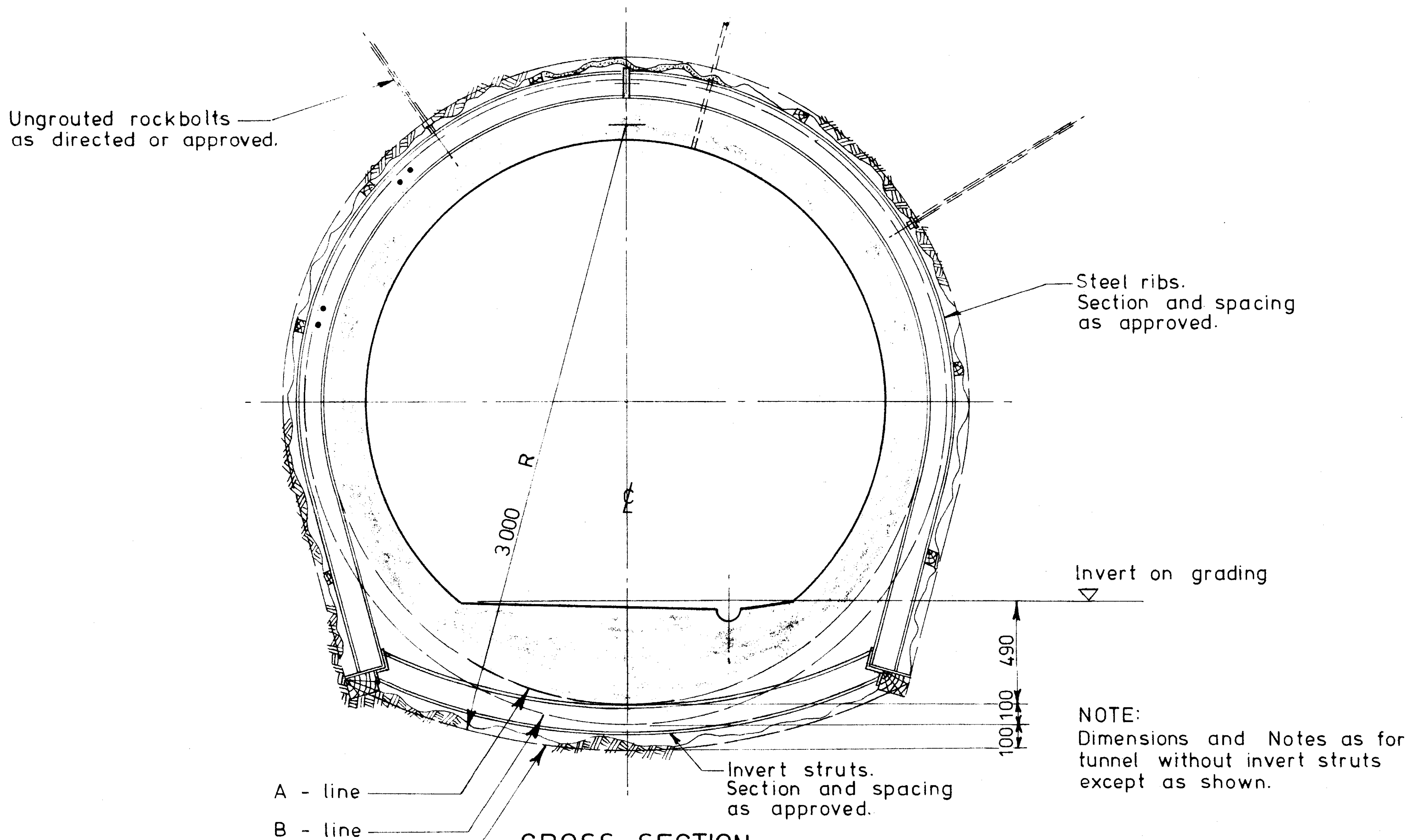
LOCALITY PLAN

0 50 100 150 200

Scale of Metres



CROSS SECTION WITHOUT INVERT STRUT



NOTE:
Dimensions and Notes as for tunnel without invert struts except as shown.

CROSS SECTION WITH INVERT STRUT

0 5 1 15 2

Scale of Metres

J55/A5/10 (b)

PLATE 2B

DEPARTMENT OF CONSTRUCTION
VICTORIA & TASMANIA REGION

DESIGNED R. Devlin	DESIGN PROJECT LEADER
DRAWN L. Lange	PROJECT MANAGER
CHECKED	DIRECTOR

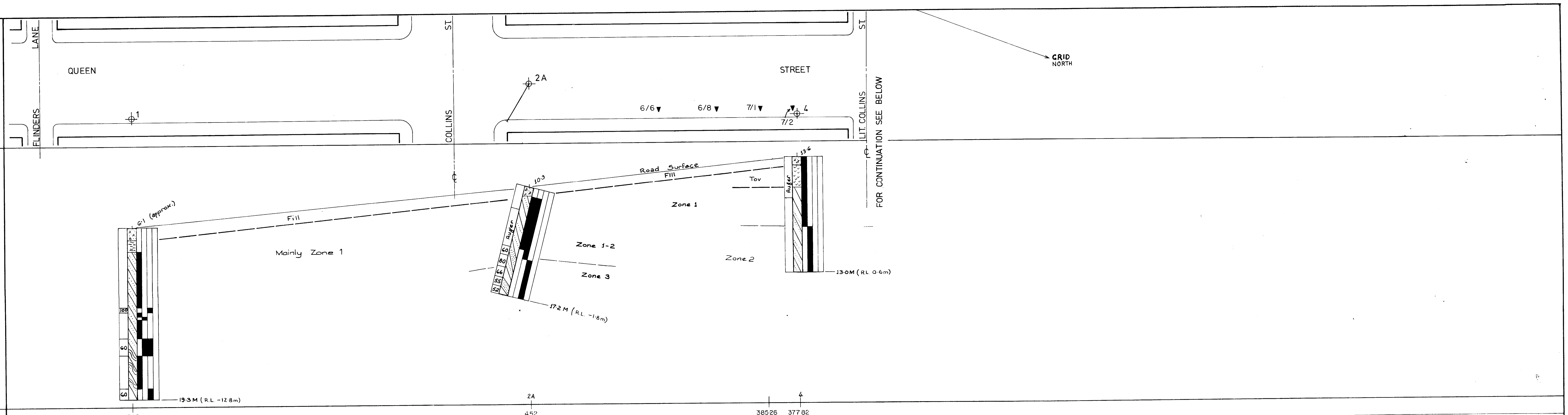
TITLE
MELBOURNE 3000
QUEEN ST. TUNNEL
LOCALITY PLAN AND
TYPE CROSS SECTIONS
FOR TELECOM

R	85	A		C	
		E		S	■
D		M			
SPEC.	■	BILL			

SCALE As shown
DATE July '78
FILE 53503
D. I. F. S.

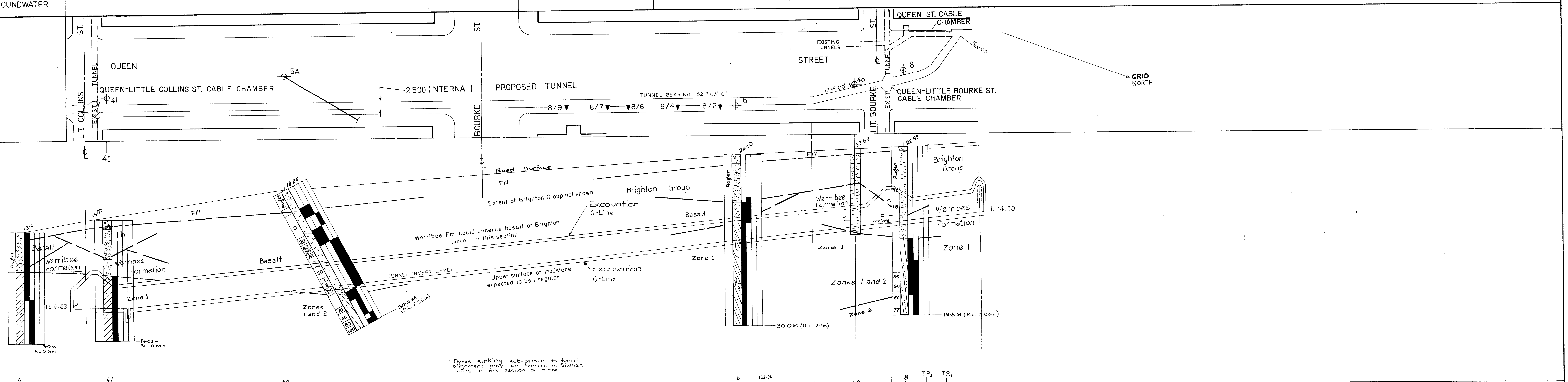
PROJECT No. SHEET AMDT
V78 /193 - /

A1



DATUM -14·000

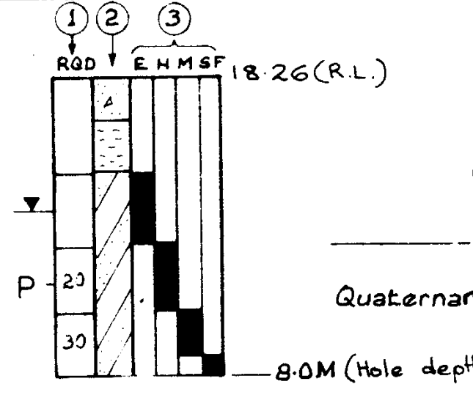
TRAVERSE CHAINAGE	565	452 (2A)	38526 · 377 82 (4)	
MATERIAL HARDNESS AND STRENGTH			Is(50) 0·71 (10·4m), 0·11 (10·7m) s 127 (7·6 m) Is(50) 0·15 (11·1m) σ1 1·25 (10·7m)	
ROCK MASS DEFECTS				
PREDICTED TUNNELLING CONDITIONS				
PREDICTED OVERBREAK				
PREDICTED SUPPORT				
PREDICTED GROUNDWATER INFLOWS				



DATUM -5·000

TUNNEL CHAINAGE	4 377·82 · 41 366·38 359·88 355·88 349·88 321·0	5A 305·00 · 6 171·00	163·00 · 149·59 · 40 137·00 · 126·50 · 8 122·50 · T.P.2 116·42 · T.P.1 110·44 · 100·00	
MATERIAL HARDNESS AND STRENGTH	Hardness and strength variable.	Hardness and strength may be MOST variable σ1 2·02 (11·7m), 5·26 (13·8m) Is (50) 0·26 (11·7m), 0·51 (12·1m), 0·82 (13·8m), 0·10 (6·05m)	Hole 40 SPT (6.4) 49/300; (8.0) 59/300 (7.0) 54/300; (8.7) 52/300 (7.3) 49/300; (9.2) 61/300	HOLE 8 Is(50) 0·21 (5·5m), 0·43 (6·8m), 0·72 (7·0m)
ROCK MASS DEFECTS	Werribee Fm. in chamber roof and near tunnel crown; irregular boundary between Zone 1 mudstone and Werribee Fm. Zone 1 mudstone incompetent; Werribee Fm. soft and loose if wet. Stability depends on water present,and whether steeply dipping defects dip into tunnel.	Basalt overlying Zone 1 mudstone is likely; however,possibility exists of sections with Werribee Fm overlying Zone 1 mudstone,and with basalt or Brighton Group above the Werribee Formation. Irregular surface at top of Z 1 mudstone; most irregular surface at top of Werribee Fm. (if present). Basalt is EW at its lower contact; otherwise generally highly fractured/closely jointed,some limonitic cement on joints. Dykes may intersect tunnel at a very acute angle. Bedding in mudstone 45-90° and closely jointed/fractured adjacent to dykes (if present).	Soft and loose in Werribee Fm. and Brighton Group if wet; some hard bands in Brighton Group with limonitic cement. Zone 1 mudstone is incompetent.	
PREDICTED TUNNELLING CONDITIONS	Poor in Werribee Fm and Zone 1 mudstone	Generally poor in Zone 1 mudstone,and in Werribee Fm. and Brighton Group (if present); conditions fair in basalt; short sections of basalt may require blasting. Tunnelling generally slow due probability of mixed rock at face over most of this section. Estimated stand-up times; basalt (hole 5a), 1 day; mudstone (hole 6), 1 hour; stand-up time at mixed face generally minimal.	Generally poor in Brighton Group,Werribee Formation and Zone 1 mudstone. Brighton Group and Werribee Fm will be fairly stable if drained.	
PREDICTED OVERBREAK	Potentially large where Zone 1/Werribee Fm. or Zone 1/basalt boundaries are close to or at tunnel crown.	Potentially large where any formation boundaries are at or close to tunnel crown. Overbreak can be kept to a minimum with care in tunnelling; potentially large for Werribee Fm. and Brighton Group (if present) if wet and uncemented,more stable if dry. Larger overbreak may occur adjacent to dyke rock.	Potentially large if wet and uncemented; more stable if dry.	
PREDICTED SUPPORT	Steel sets at 1 m spacing with full timber lagging in crown - concrete sub-invert may be required.	Steel sets and timber lagging generally; probably reduced lagging in basalt; possibility of face boards if Werribee Fm. and Brighton Group (if present) are wet, more stable if dry. Concrete sub-invert may be required.	Steel sets at 1 m and timber lagging,possibly face boards if wet; sub-invert concrete may be required.	
PREDICTED GROUNDWATER INFLOWS	Groundwater level may be between invert and crown initially. Inflows potentially high initially,but minor inflows only expected mainly from top of mudstone. Seepages should dry out within weeks,but some may recur. See piezometers,hole 40.	Minor inflows expected from top of mudstone; initial groundwater levels probably close to tunnel level; seepages expected to dry out within weeks, but some may recur after rain.	Potentially high initially,but only minor inflows expected; seepage expected to dry out within weeks; some seepage will recur after rain; see Piezometers in holes 8 and 40.	

DRILL HOLE SUMMARY LOG



① R.Q.D.(Rock Quality Designation)

Percentages not given for extremely weathered rock.

② GRAPHIC LOG

Quaternary	▨	Concrete, bitumen and fill
	▨	Colluvium and/or clay (Qco)
	▨	Elizabeth Street Formation (Qe)

GRAPHIC LOG (CONT.)

Tertiary	▨	Brighton Group (Tb)	
	▨	Basalt	Tertiary Older Volcanics (Tov)
	▨	Tuff	
	▨	Werribee Formation (Tw)	
Devonian	▨	Dyke	
Silurian	▨	Mudstone	Dargile Formation (S)
	▨	Mudstone with minor sandstone	
	▨	Mainly sandstone	

③ ROCK WEATHERING

E Extremely weathered
H Highly weathered
M Moderately weathered
SF Slightly weathered or fresh
When dealing with mudstone:
E Zone 1
H Zone 2
M Zone 3
SF Zone 4 or 5
▼ Water level in drill hole
P— Location of piezometer

GEOLOGICAL BOUNDARY

— — Position approximate

WEATHERING BOUNDARY

— — Position approximate

Sheared rock

▼6/6 Location and no. of penetration resistance test (static cone).

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification — CL, CH, SC,etc.
2) Direct Shear Stress — s, kPa, (depth)
3) Unconfined Compressive Strength - Soil — σ_1, kPa.(depth)
4) Unconfined Compressive Strength - Rock — σ_1, MPa (depth)
5) Point Load Index — Is(50), MPa. (depth)
6) Penetration Resistance — SPT (depth in m) N° of blows/length of hole (mm)

STAND-UP TIME: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

TUNNEL BEARING: Add 6° 39' 40" to bring to AMG ZONE 55 approximate plane bearing.

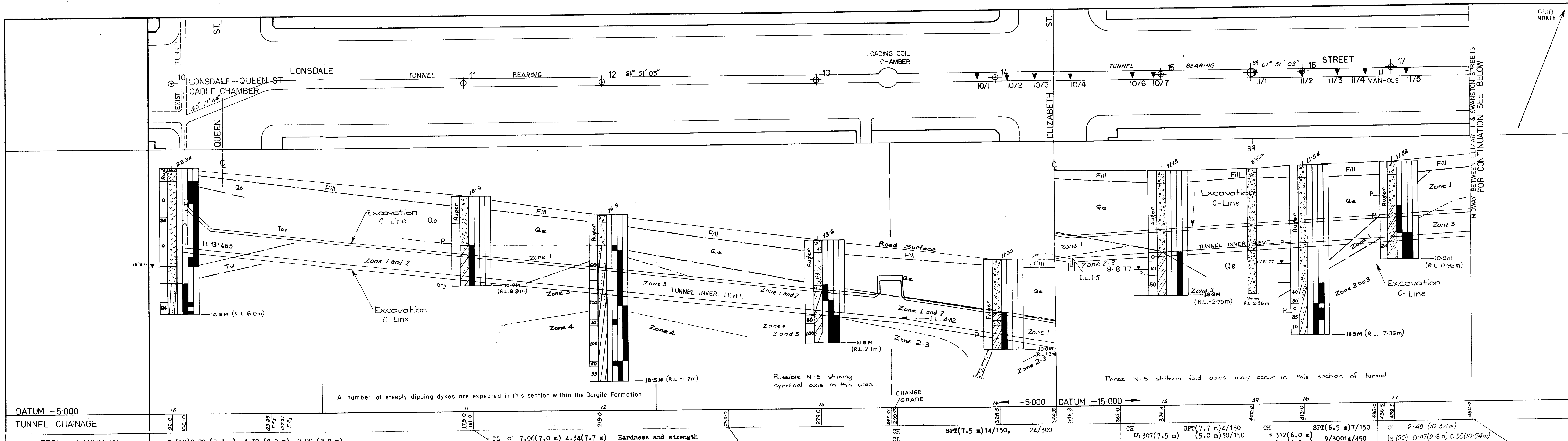
AMENDMENTS
28-6-78
18-8-78
3-10-78

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, ACT

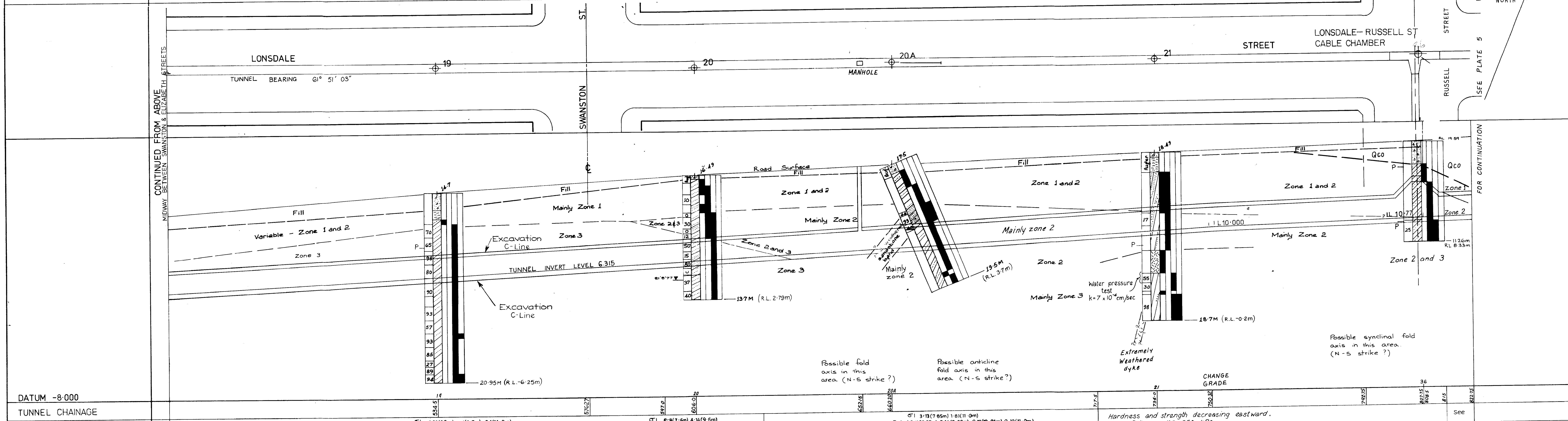
GEOLOGIST G. Trand D.C. Purcell
CHECKED D.C. Purcell
DATE 1 SEPTEMBER 1978
DRAWING NUMBER J55/A5/11

TITLE
PROPOSED TELECOM CABLE TUNNEL
GEOLOGICAL SECTIONS
QUEEN STREET
CHAINAGE 100 TO 366
SCALE: Hor. 1:500 Vert. 1:200
PLATE 3

Record No 1978/90

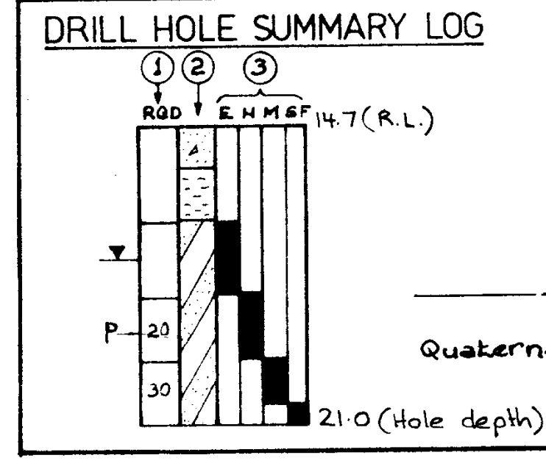


MATERIAL HARDNESS AND STRENGTH	Is(50)0.22 (8.3 m), 1.30 (8.9 m), 0.90 (9.0 m) Is(50)1.36 (1.05 m), 0.95(10.2 m),0.11(11.0 m). Hardness and strength most variable	CL σ1 7.06(7.0 m) 4.34(7.7 m) Is(50)0.23(7.0 m) 0.32(7.7 m) Hardness and strength variable	CH CL s 249(9.0 m) SPT(7.5 m)14/150, 24/300	CH σ1 307(7.5 m) SPT(7.7 m)4/150 (9.0 m)30/150 CH s 312(6.0 m) σ1 344(6.0 m) SPT(6.5 m)7/150 9/30014/450	σ1 6·48 (10·54m) Is (50) 0·47(9·6m) 0·99(10·54m)
ROCK MASS DEFECTS	Werribee Fm. likely along section of invert; less likely to continue to crown. Base of Elizabeth Street Formation may be at or close to tunnel crown. Basalt is closely jointed with defects rarely spaced >10 cm. Mudstone below the basalt and Elizabeth St. Fm. is extremely weathered; some dykes expected in mudstone	Zone 1 to Zone 3 mudstone; some dykes expected to intercept tunnel; mudstone adjacent to dykes likely to be closely jointed/fractured. Zone 3 mudstone may extend about 1 m above crown in places. Bedding steep. Some hard sandstone bands.	Elizabeth Street Fm - mudstone contact at or near tunnel crown; elsewhere Z1 and 2 mudstone; one or more dykes intercept tunnel, possibly with closely jointed/fractured mudstone adjacent to dykes.	Poorly consolidated Elizabeth St. Fm.	Zone 1 mudstone grading east to Zone 3. Bedding 45° (east) joints 45° and 90°
PREDICTED TUNNELLING CONDITIONS	Good in the basalt, but some sections may require blasting; poor in the mudstone and Werribee Fm., the latter will be fairly stable if drained; poor in Elizabeth St. Fm. (if present). Stand-up times basalt (hole 10)<5 hrs, mudstone (hole 11)<10 min (see text)	Variable, but fair to poor depending on support requirements. Stand-up time Z3 mudstone (hole 12) 1 day.	Poor. Potential settlement greater if Elizabeth St. Fm. is wet and drained by tunnel. Direction of tunnel advance upslope would facilitate drainage. Stand-up time for mudstone (hole 13)<10 min.	Poor especially if wet; tunnel face stand-up time would be short; tunnel face likely to vary from silty sand to clayey sand. If tunnelling proceeds upgradient Elizabeth St. F. would drain and become more stable. Surface water inflows may take place during heavy rain.	Conditions improving towards Swanston St. Estimated stand-up time mudstone (hole 17) less than 10 mins (c.f. hole 19)
PREDICTED OVERBREAK	Main overbreak probably confined to sections where basalt-mudstone and Elizabeth St. Fm. - mudstone boundaries are at or close to tunnel crown. Large overbreak possible if Werribee Fm. extends to tunnel crown	Potentially large where Zone 1 rock is at or close to tunnel crown.	Potentially large if not mined carefully with proper methods and support	Potentially moderate initially as water table is likely to be at tunnel level or higher.	Slabbing from crown or face possible if bedding planes poorly oriented to direction of tunnel drive
PREDICTED SUPPORT	Steel sets and timber lagging in basalt and mudstone; increased lagging in crown where more overbreak is expected, or wherever Werribee or Elizabeth St. Formations are at or near tunnel crown. Concrete subinvert may be required in Werribee Fm. and Zone 1 mudstone.	Steel sets and timber lagging. Rock bolts plus mesh reinforced shotcrete may be preferred in Zone 2 and 3 mudstone.	Steel sets and timber lagging; full lagging in crown, reduced lagging below spring line if in mudstone.	Steel sets and full timber lagging. Concrete sub-invert may be required. Some settlement to be expected.	Steel sets and timber lagging or rockbolts plus mesh reinforced shotcrete
PREDICTE GROUNDWATER INFLOWS	Probably small flows only coming from rock contacts and Werribee Fm., but should dry up rapidly. Groundwater level expected to be below tunnel invert.	Probably small flows only; will not persist; groundwater level probably at or near invert.	Small inflows initially, mainly from upper surface of mudstone; should not persist but may recur following rainfall. Groundwater level within mudstone expected above invert level.	Moderate inflows should decrease fairly rapidly as excavation proceeds from hole 15 towards hole 17 (upgrade).	Initially small; some seepages may recur with rain.



MATERIAL HARDNESS AND STRENGTH	σ1 6·38(8·3m), 0·08(9·7m), 9·1(11·0m) Is(50) 0·55(8·3m), 0 61(9·7m), 0·50(11·0m)	σ1 6·8(7·6m) 4·14(9·6m) Is(50) 0·38(7·6m) 0·63(9·6m) 1·76(11·0m) σ1 3·13(7·85m) 1·81(11·0m) Is(50)0·19(7·85m) 0·14(9·39m) 0·18(10·01m) 0·19(11·0m)	Hardness and strength decreasing eastward. Dyke pp 100-350 kPa.	See plate 5 for detail of this section
ROCK MASS DEFECTS	Bedding generally tight, probably dips eastward at about 35°. Joints generally tight with some limonite cement. Rock mass generally competent. The few closely jointed or fractured zones are expected to be tight. Rock becomes a little less competent at each end of this section. Dargile Formation, mainly mudstone with thin sandstone bands at tunnel level.	Bedding probably dips west at 20°-30° (increases to about 55° near tunnel invert in hole 20A). Jointing close and rough with some limonite cement. Weathering is main defect. Some moderately weathered sandstone beds. Fold axes in this section may align with closely jointed zones.	Weathering main defect; mostly Zone 1 and 2 mudstone. Frequency of dykes may increase east of hole 21. Bedding dips at 80° in hole 21 adjacent to dyke, but is variable elsewhere. Joints open with some clay seams. Some closely jointed and fractured zones.	
PREDICTED TUNNELLING CONDITIONS	Good tunnelling conditions; little variation in rock quality expected. Estimated stand-up time Zone 3 mudstone (hole 19) about 1 week.	Fair tunnelling conditions; some instability, particularly near tunnel crown, due to shallow dipping beds and possibly from the hanging wall of thick hard sandstone beds. Estimated stand-up time (hole 20A) about 8 hours; slabbing may occur from main tunnel face if driven eastward.	Poor in Zone 1 and 2 mudstone. Blocks of loose rock likely, especially in region of dykes and in tunnel crown. Estimated stand-up time Hole 21 = less than 1 Hr.	
PREDICTED OVERBREAK	Should be negligible if rock quality remains uniform, particularly if a tunnel excavating machine is used.	Potentially moderate; slabbing from crown and beneath hard sandstone beds is possible in places.	Potentially high, particularly in zone 1 mudstone and extremely weathered dykes.	
PREDICTED SUPPORT	Ranging from no support (with random rockbolts), to rockbolts, untensioned and grouted at 1 m centres, mesh reinforced (plus shotcrete in more fractured sections).	Rockbolts, tensioned and grouted, 1 m centres plus mesh reinforced shotcrete (5 cm). Alternatives steel sets and lagging or mesh reinforced shotcrete (10 cm).	Rockbolts tensioned and grouted, 1m centres plus mesh reinforced shotcrete (5cm). Alternatives mesh reinforced shotcrete 10cm thick, or steel and timber lagging, with addition of shotcrete in places.	
PREDICTED GROUNDWATER INFLOWS	Negligible; some seepage initially; some seepage recurrent.	Some seepage initially; some seepage recurrent.	Seepage only. No significant flows	

DRILL HOLE SUMMARY LOG



① R.Q.D. (Rock Quality Designation)

Percentages not given for extremely weathered rock.

② GRAPHIC LOG

Quaternary
- Concrete, bitumen and fill
- Colluvium and/or clay (Qco)
- Elizabeth Street Formation (Qe)

GRAPHIC LOG (CONT.)

Tertiary
- Brighton Group (Tb)
- Basalt } Tertiary Older Volcanics (Tov)
- Tuff } Tertiary Older Volcanics (Tov)
- Werribee Formation (Tw)

Devonian
- Dyke

Silurian
- Mudstone } Dargile Formation (S)
- Mudstone with minor sandstone } Dargile Formation (S)
- Mainly sandstone } Dargile Formation (S)

③ ROCK WEATHERING

E Extremely weathered
H Highly weathered
M Moderately weathered
SF Slightly weathered or fresh
When dealing with mudstone:
E Zone 1
H Zone 2
M Zone 3
SF Zone 4 or 5
▼ Water level in drill hole
P— Location of piezometer

GEOLOGICAL BOUNDARY

— — — Position approximate

WEATHERING BOUNDARY

— — — Position approximate

Sheared rock

▼6/6 Location and no. of penetration resistance test (static cone)

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification ____ CL., CH., SC. etc.
2) Direct Shear Stress ____ s , kPa., (depth)
3) Unconfined Compressive Strength - Soil ____ σ_1 , kPa., (depth.)
4) Unconfined Compressive Strength - Rock ____ σ_1 , MPa., (depth)
5) Point Load Index ____ Is(50), MPa., (depth)
6) Penetration resistance ____ SPT (depth in metres) N° of blows/ length of hole(mm)

STAND-UP TIMES: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

TUNNEL BEARING: Add 6° 39' 40" to bring to AMG ZONE 55 approximate plane bearing.

AMENDMENTS
28-6-78
18-8-78
9-10-78

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, A.C.T.

GEOLOGIST G. Trand D.C. Purcell
CHECKED E.G. Wilson
DATE 1 SEPT. 1978
DRAWING NO. J55/A5/12

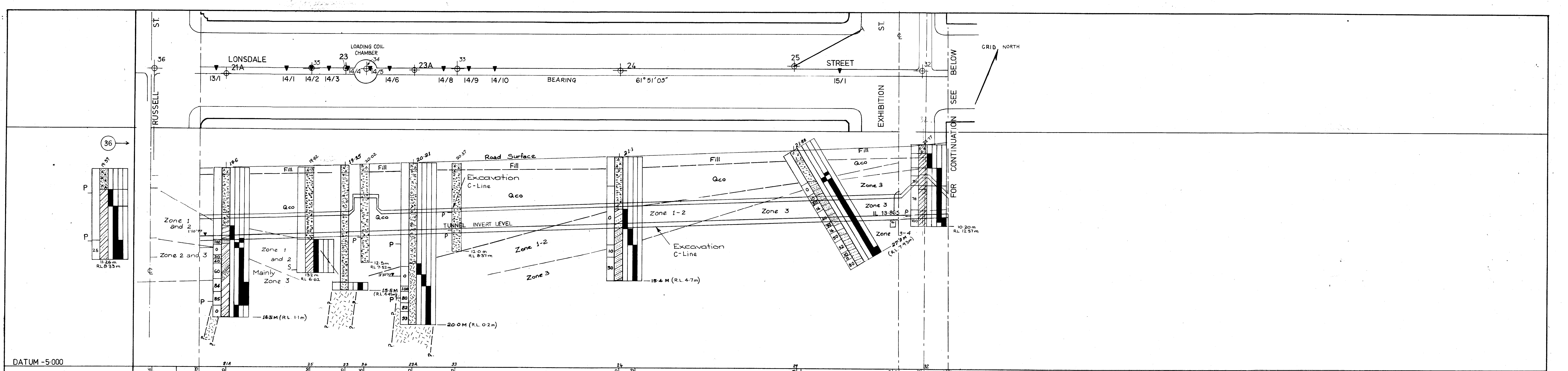
TITLE
PROPOSED TELECOM CABLE TUNNEL

GEOLOGICAL SECTIONS

LONSDALE ST. CH. 100 TO 460 m
LONSDALE ST. CH 460 TO 807 m

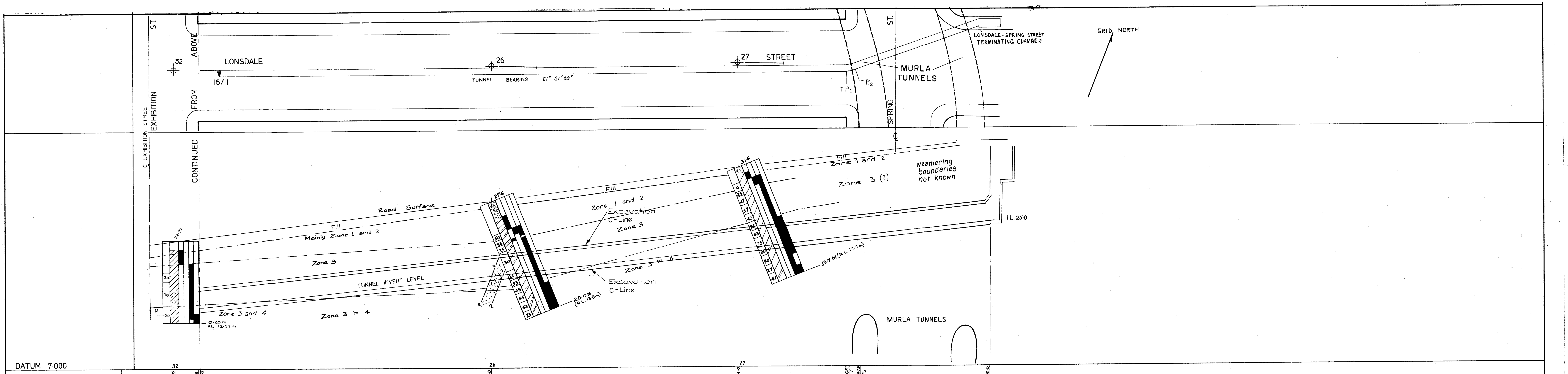
SCALE: Hor. 1:500 Vert. 1:200

PLATE 4



DATUM -5·000

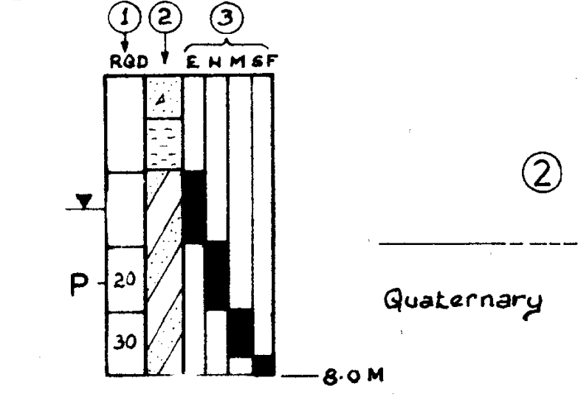
TUNNEL CHAINAGE	808·5 815 822·75 21A 831·0 35 857·0 23 870·0 34 874·5 23A 890·0 33 903·0 24 954·0 959·0	29 1007·8 1009	1037·9 1039·9 32 1047·05 1047·9 1054·9 1055·55
MATERIAL HARDNESS AND STRENGTH	Hole 35 SPT (5·3) 35/300,(6·3) 41/300,(7·3) 25/140, (8·2) 5/10, (9·2) 12/150 σ1 C.L. S.C. - 156 kPa (5·5m) SPT (7·0m) 50/380 (8·0m) 36/450 (9·0m) 50/200 SPT (4·3) 20/300,(5·3) 22/300,(6·1) 33/300 (7·3) 30/300,(8·3) 21/300,(9·0) N/300		Is(50) 0·39 (4) 0·481 (6·5) 0·481 (7·5 - 9·0)
ROCK MASS DEFECTS	**Colluvium consisting of clayey silts and sands, and sandy clays; some clean sands with 13-15 percent fines mainly clay; some pebbles near base of colluvium. Stiff silty clay, thickness 5-6 m overlies the silty and clayey sand present at tunnel level. Main defect will be presence of water in sands.**	Weathered Dargile Formation with zones 1 and 2 mudstone, colluvium at or near tunnel crown. Bedding horizontal to 35° west; joints open with some clay seams.	See next section below for text
PREDICTED TUNNELLING CONDITIONS	**Poor tunnelling conditions; possibly the most difficult material to be tunnelled if wet. Low permeability sands not readily stabilized by grouting (Williams, 1978). Surface water inflows may take place during heavy rain.**	Poor in zones 1 and 2 mudstone; blocks of loose rock likely in zones 1 and 2, but improving eastward in zone 3 mudstone with some MW sandstone.	
PREDICTED OVERBREAK	**Potentially large if sands are wet; overlying silty clays would probably limit initial overbreak. Some settlement is to be expected; careful mining required to control settlement.**	Potentially high particularly in zone 1 mudstone	
PREDICTED SUPPORT	**Sheet piles and timber for open cut. Steel sets 1 m centres with full timber lagging for tunnelling; if full face stability cannot be maintained, shield or hand mining would be required.**	Rockbolts, tensioned and grouted 1m centres plus mesh reinforced shotcrete 5cm thick; alternative mesh reinforced shotcrete 10cm thick or steel sets with timber lagging	
PREDICTED GROUNDWATER INFLOWS	**Potentially low but persistent inflows from sands of low permeability, particularly during rainy periods; groundwater levels below the tunnel are expected to rise, see standpipe and piezometer levels for groundwater monitoring. Direct dewatering of sands not considered feasible; dewatering by pumping from deep bores in fractured MW to SW Dargile Fm. should improve invert conditions in the colluvium.**	Seepage only, will subside but may recur after rain	



DATUM 7·000

TUNNEL CHAINAGE	FROM CHAINAGE 1009·00	32 1047·05 1054·9 1055·55 26 1146·0 27 1224·0 1256·51 T.P.1 1259·79 T.P.2 1300·5
MATERIAL HARDNESS AND STRENGTH		**Material strength and hardness broken by dykes, generally improving to the east.** Is(50), 0·8, 1·2 (8m) Is(50) 1·2 (8m)
ROCK MASS DEFECTS		**Bedding generally tight and close and surfaces often rough; probably dips west at 20-35°. Joints frequently normal to bedding, generally tight but vary from strongly to weakly cemented; some are weathered and clay coated. Thin clay on bedding plane surfaces not common. Fracture zones likely in mudstone adjacent to dykes, some of which may be 1 m wide. No drillholes near the Lonsdale-Spring St. Terminating Chamber; Zone 3 mudstone is expected to continue through to Spring St.** Stand-up times: Hole 26 about 3 hours; Hole 27 about 1 day.
PREDICTED TUNNELLING CONDITIONS		**Tunnelling conditions generally very good; rock weathering decreases east of hole 26 to Zones 3 and 4. Some minor instability may arise from slabbing from tunnel crown where joints and/or bedding planes are open and clay coated.**
PREDICTED OVERBREAK		**Very small. Minor amount associated with slabbing from tunnel crown or face (if driven against dip direction, i.e. east). Little overbreak expected from a tunnel excavation machine. Blasted sections will have greater overbreak.**
PREDICTED SUPPORT		**Ranging from no support with random rockbolts to pattern rockbolts, untensioned and grouted at 1 m centres, mesh reinforced (plus shotcrete in more fractured sections).**
PREDICTED GROUNDWATER INFLOWS		**Mainly dry or partly damp; some seepages initially and some seepage recurrent after rain.**

DRILL HOLE SUMMARY LOG



① R.Q.D.(Rock Quality Designation)

Percentages not given for extremely weathered rock.
▼ - water
P → Piezometer

② GRAPHIC LOG

Quaternary	▨	Concrete, bitumen and fill
	▨	Colluvium and/or clay (Qco)
	▨	Elizabeth Street Formation (Qe)

GRAPHIC LOG (CONT)

Tertiary	▨	Brighton Group (Tb)	
	▨	Basalt	Tertiary Older Volcanics (Tov)
	▨	Tuff	
	▨	Werribee Formation (Tw)	
Devonian	▨	Dyke	
Silurian	▨	Mudstone	Dargile Formation (S)
	▨	Mudstone with minor sandstone	
	▨	Mainly sandstone	

③ ROCK WEATHERING

E Extremely weathered
H Highly weathered
M Moderately weathered
SF Slightly weathered or fresh

When dealing with mudstone:

E Zone 1
H Zone 2
M Zone 3
SF Zone 4 or 5

▼ Water level in drill hole
P — Location of piezometer

GEOLOGICAL BOUNDARY

——— Position Approximate

WEATHERING BOUNDARY

——— Position Approximate
≀ Sheared Rock

▼6/6 Location and no. of penetration resistance test (static cone).

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification ——— CL, CH, SC, etc
2) Direct Shear ——— s, kPa (depth)
3) Unconfined Compressive Strength - Soil ——— σ1, kPa (depth)
4) Unconfined Compressive Strength - Rock ——— σ1, MPa (depth)
5) Point Load Index ——— Is(50), MPa. (depth)
6) Penetration Resistance ——— SPT (depth in m) N° of blows/length of hole (mm)

STAND-UP TIMES: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

TUNNEL BEARINGS: Add 6° 39' 40" to bring to AMG ZONE 55 approximate plane bearing.

AMENDMENTS
28-6-78
18-8-78
3-10-78

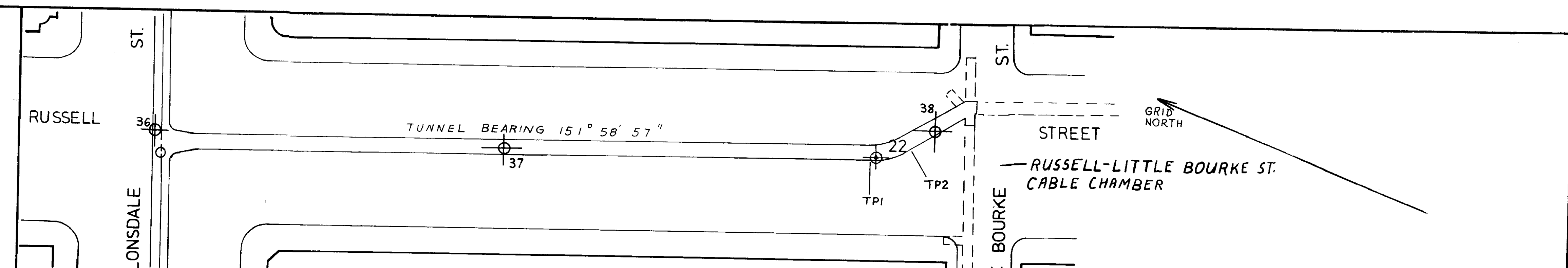
BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, A.C.T.

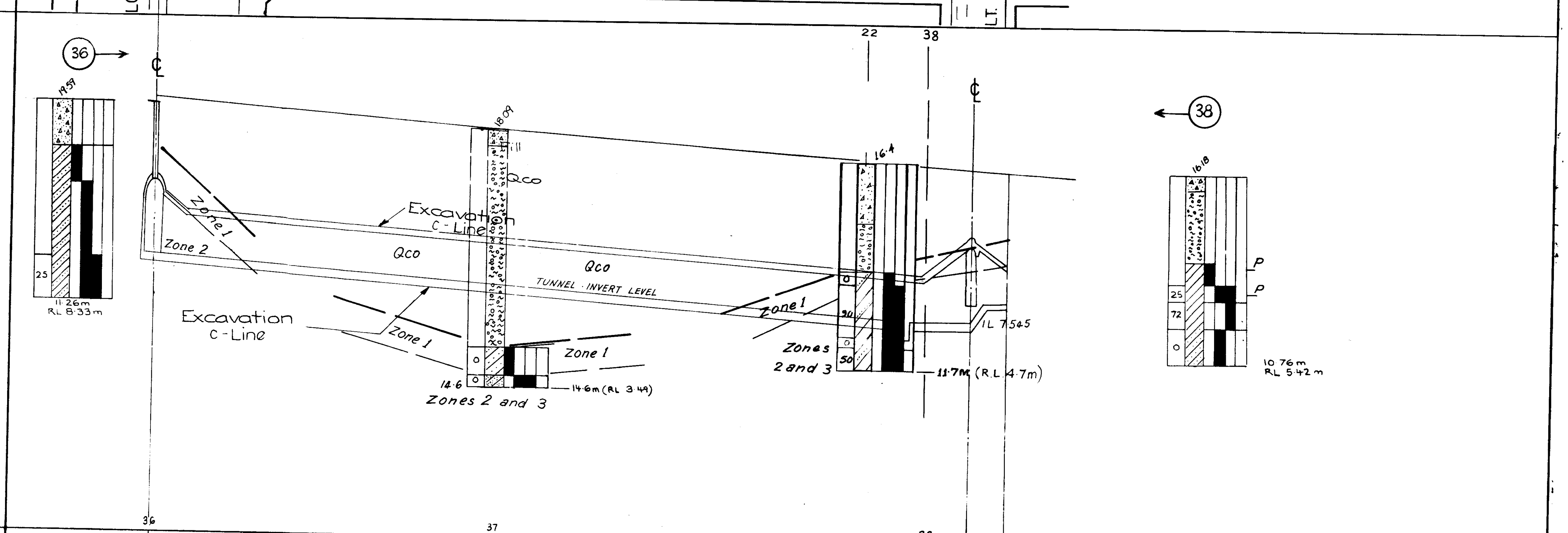
GEOLOGIST G. Trand, D.C. Purcell
CHECKED E. G. Wilson
DATE 1 SEPT. 1978
DRAWING NUMBER J55/A5/13

TITLE
PROPOSED TELECOM CABLE TUNNEL
GEOLOGICAL SECTIONS
LONSDALE ST. CH. 807 TO 1054m
LONSDALE ST CH. 1054 TO 1300m

SCALE: Hor. 1:500 Vert. 1:200

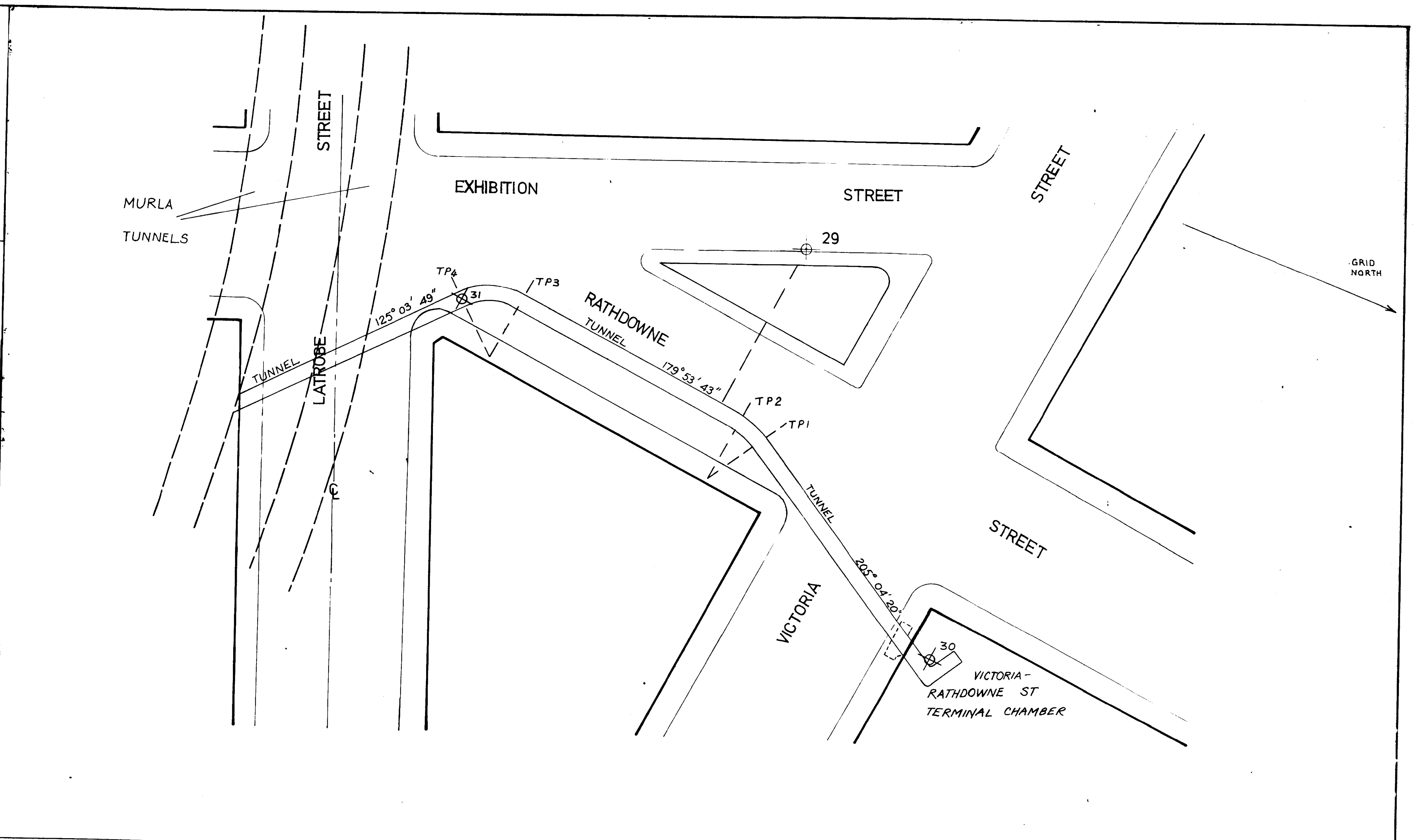
PLATE 5

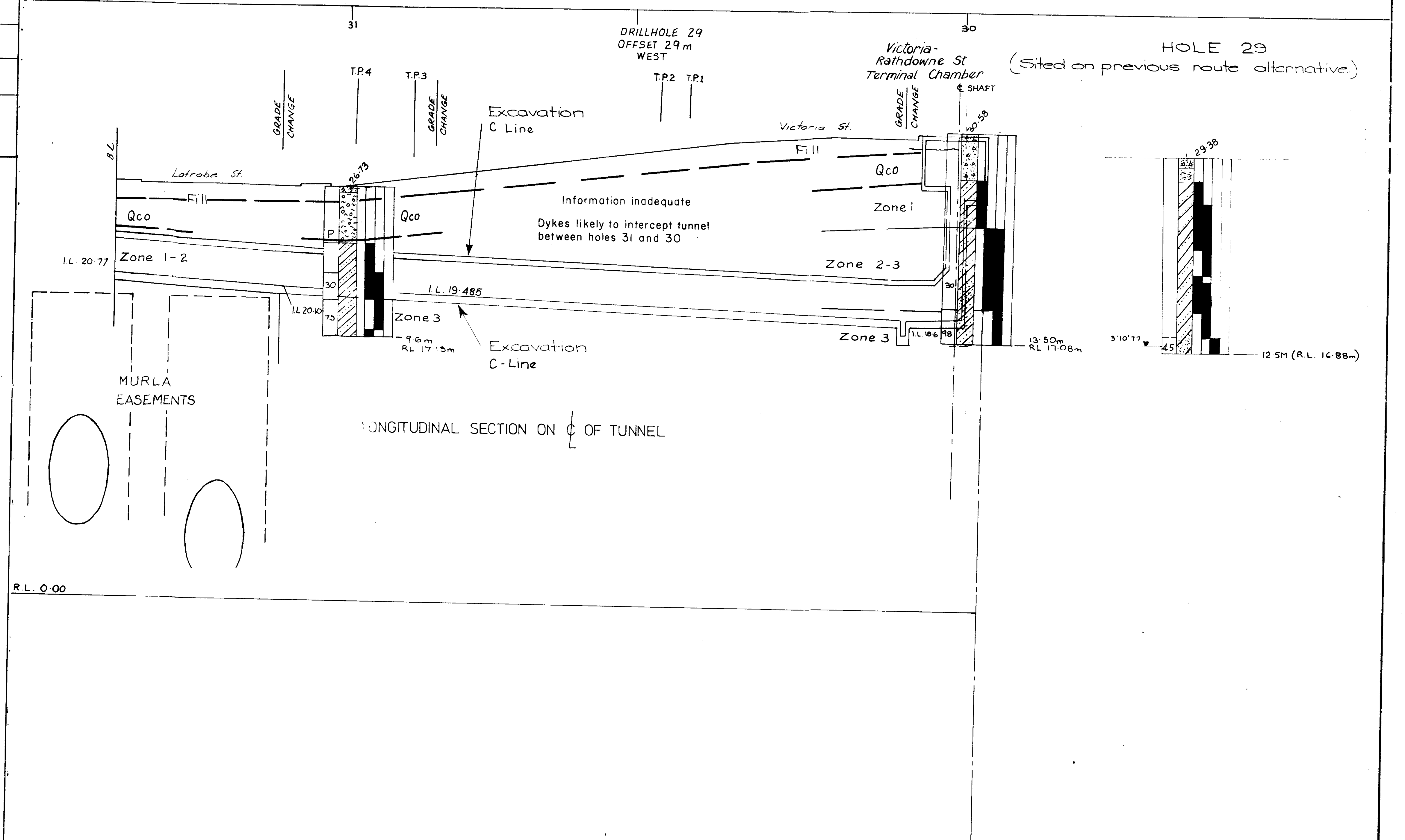


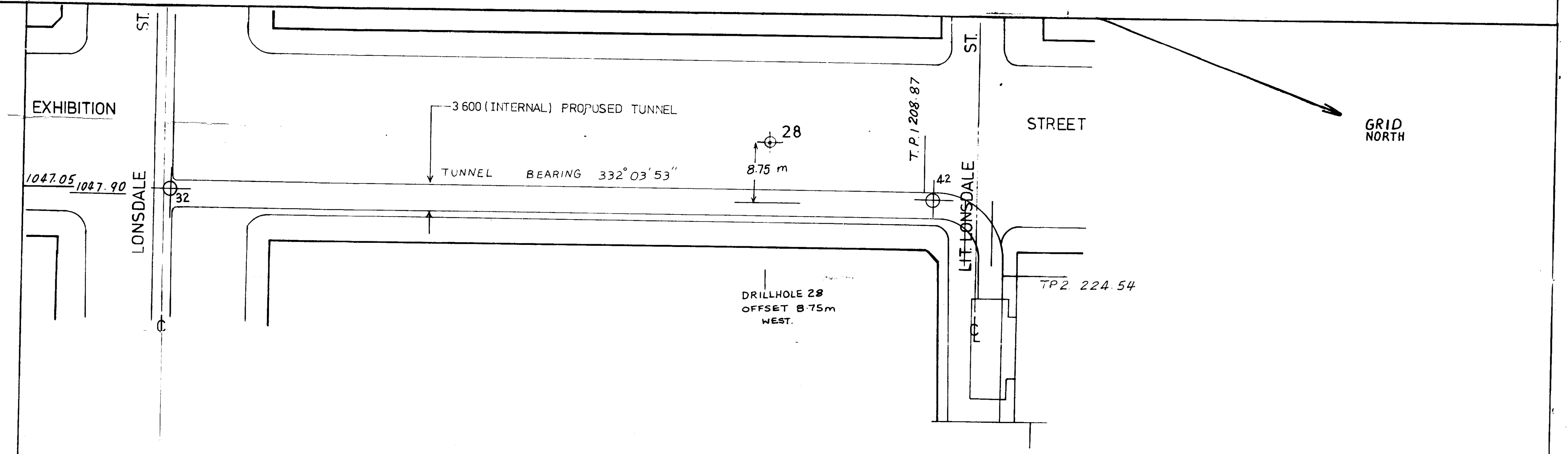


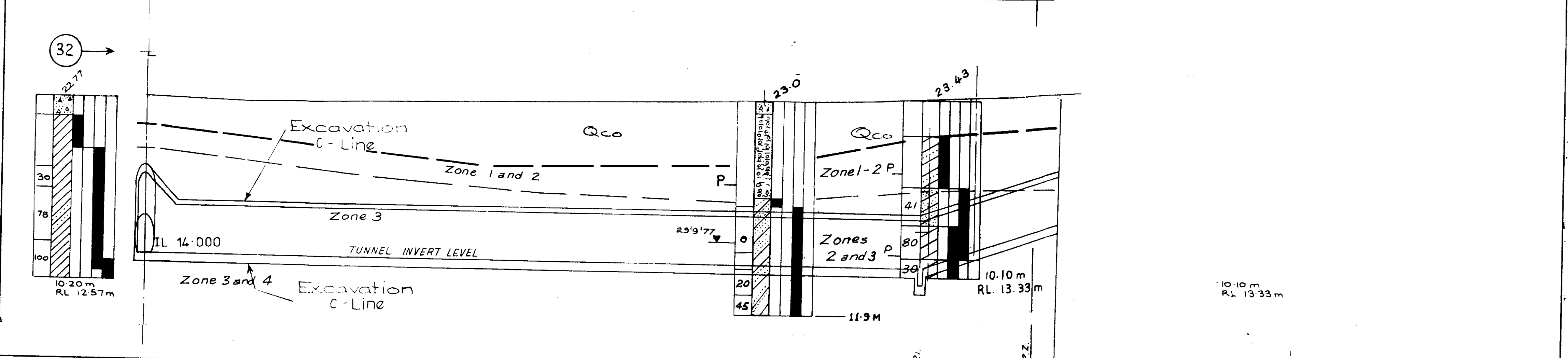
DATUM -5.000

TUNNEL CHAINAGE	100.00 148.7 200.22 200.75 205.45 T.P.2 207.00 210.00 215.68 221.0
MATERIAL HARDNESS AND STRENGTH	SPT 3 m - 17/300; 5 m - 20/300; 7 m - 47/300; 9 m - 2-/150 4 m - 19/300; 6 m - 25/300; 8 m - 30/160; 10 m - 25/120
ROCK MASS DEFECTS	**Colluvium:** mottled dark brown,orange,firm to stiff silty clay from surface to about 5m. Clayey silts and sands at tunnel levels. Zones 1 and 2 mudstone at each end of this section,bedding 25-45° clay lined. Main defect will be presence of water.
PREDICTED TUNNELLING CONDITIONS	Poor tunnelling conditions in colluvium,possibly the most difficult material of the project if wet. Low permeability sands not readily stabilized by grouting (Williams, 1978). Zones 1 and 2 mudstone will provide poor tunnelling conditions.
PREDICTED OVERBREAK	Potentially about 1 m extending up to base of firm silty clay if the sandy clay at tunnel crown is wet. Some settlement to be expected,careful mining required to control settlement. Blocky overbreak from crown in mudstone,particularly in Zone 2.
PREDICTED SUPPORT	Steel sets at 1 m spacing with full timber lagging; if full face stability cannot be maintained,shield or hand mining would be required. Sheet piles and timber if open cut.
PREDICTED GROUNDWATER INFLOWS	Potentially low but persistent inflows from sands of low permeability,particularly during rainy periods; groundwater levels below the tunnel are expected to rise; see standpipe and piezometer levels for groundwater monitoring. Direct dewatering of sands not considered feasible; dewatering by pumping from deep bores in fractured MW to SW Dargile Fm. should improve invert conditions in the colluvium.





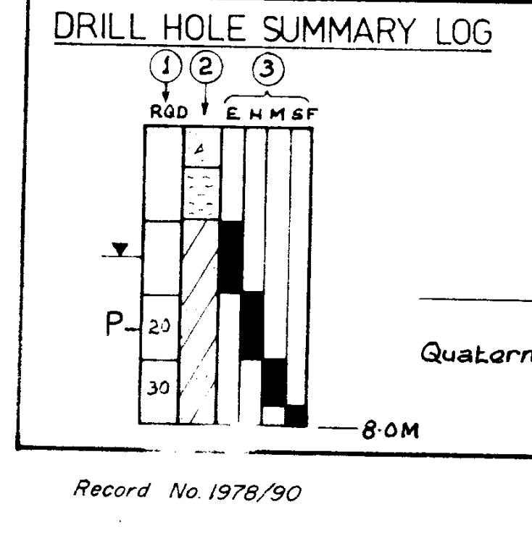




DATUM 8.000

TUNNEL CHAINAGE	100.00 186.37 207.4 208.87 T.P.1 210.0 224.56 T.P.2 227.84	234.18 207.68 196.0 195.56 185.99 T.P.3 183.18 151.00 147.03 T.P.2 142.63 T.P.1 108.0 100.0 99.2 95.5
MATERIAL HARDNESS AND STRENGTH	Hardness and strength controlled by weathering and intensity of jointing Is(50) 5-7 m-0.711 7-9 m-0.230 9-10 m-0.140	Variable from Zone 3 mudstone to EW dykes (probably present).
ROCK MASS DEFECTS	Dargile Fm. Zone 3 mudstone becoming Zone 2-3 mudstone at Little Lonsdale St.; MW interbedded sandstone. Zone 1 mudstone likely within 1 m above crown opposite hole 28. Bedding ranges from subhorizontal at Lonsdale St. to 35° west at Little Lonsdale St. Bedding tight and close to wide and open with clay fill or limonite staining; joints generally normal to bedding dip 45 to 70°,ranging from close uncemented to weakly cemented or open. Dykes may intercept tunnel at a very acute angle.	Dargile Fm Zone 1 to 2 mudstone at Latrobe St. ranging to Zone 2-3 at Victoria St.; some MW sandstone interbeds. Known 10 m dyke nearby; dykes likely to intercept tunnel at very acute angle, particularly between holes 30 and 31; EW dyke rock and closely jointed/fractured Dargile Fm adjacent to dykes. Bedding strike subparallel to mid-section of tunnel and dips 35-45° west. Joints and bedding partially cemented with limonite. Stand-up times generally > 8 hours in Zone 2 to 3, reduced where colluvium is within 2m of crown, about 10mins at hole 31
PREDICTED TUNNELLING CONDITIONS	Tunnelling conditions good; some minor instability may arise from slabbing from tunnel crown where joints/bedding planes are open or clay lined. Possible closely jointed/fractured rock adjacent to dykes (if present). Estimated stand-up times from hole 32, > 10 hours; hole 42, about 10 hours.	Variable from good to poor,depending on incidence of fracture zones and dykes,proximity of colluvium to tunnel crown at hole 31,and the tendency for slabbing from the crown. Stand-up times expected to vary widely.
PREDICTED OVERBREAK	Small,may be associated with slabbing from tunnel crown above eastern spring line. Little overbreak from a tunnel excavation machine. Any blasted sections will have greater overbreak. Overbreak from east wall and crown will increase greatly adjacent to dykes (if present).	Small to large depending on combined effect of rock defects. Most overbreak expected from above east wall spring line.
PREDICTED SUPPORT	Rockbolts,untensioned and grouted at 1 m centres, mesh reinforced (plus shotcrete in more fractured sections).	Steel sets in centres and timber lagging; alternatively rockbolts,tensioned and grouted at 1 m centres and mesh reinforced; shotcrete up to 10 cm added as required for stability. Steel piles with full lagging for open cut.
PREDICTED GROUNDWATER INFLOWS	Mainly dry or partly damp.	Small inflows initially; mainly dry.

DRILL HOLE SUMMARY LOG



① R.Q.D.(Rock Quality Designation)

Percentages not given for extremely weathered rock.

② GRAPHIC LOG

Quaternary	▨	Concrete, bitumen and fill
	▨	Colluvium and/or clay (Qco)
	▨	Elizabeth Street Formation (Qe)

GRAPHIC LOG (CONT.)

Tertiary	▨	Brighton Group (Tb)	
	▨	Basalt	Tertiary Older Volcanics (Tov)
	▨	Tuff	
	▨	Werribee Formation (Tw)	
Devonian	▨	Dyke	
Silurian	▨	Mudstone	Dargile Formation (S)
	▨	Mudstone with minor sandstone	
	▨	Mainly sandstone	

③ ROCK WEATHERING

E Extremely weathered
H Highly weathered
M Moderately weathered
SF Slightly weathered or fresh

When dealing with mudstone:

E Zone 1
H Zone 2
M Zone 3
SF Zone 4 or 5

▼ Water level in drill hole
P— Location of piezometer

GEOLOGICAL BOUNDARY

——— Position approximate

WEATHERING BOUNDARY

——— Position approximate

⟋⟋ Sheared rock

▼6/6 Location and no. of penetration resistance test (static cone).

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification ——— CL, CH, SC, etc
2) Direct Shear Stress ——— s , kPa.,(depth)
3) Unconfined Compressive Strength - Soil ——— σ_1 , kPa., (depth)
4) Unconfined Compressive Strength - Rock ——— σ_1 , MPa., (depth)
5) Point Load Index ——— Is(50),MPa., (depth)
6) Penetration resistance ——— SPT (depth in m) N° of blows / length of hole (mm)

STAND-UP TIMES: Most figures given are considered to be conservative (see text).

NOTE: These sections must be read in conjunction with the appropriate parts of the written report.

TUNNEL BEARING: Add 6° 39' 40" to bring to AMG ZONE 55 approximate plane bearing.

AMENDMENTS
28-6-78
18-8-78
3-10-78

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, A.C.T.

GEOLOGIST
G. Trand
D.C. Purcell

CHECKED
E.G. Wilson

DATE
1 SEPTEMBER 1978

J55/A5/14

TITLE
PROPOSED TELECOM CABLE TUNNEL

GEOLOGICAL SECTIONS

RUSSELL ST. &
EXHIBITION ST.

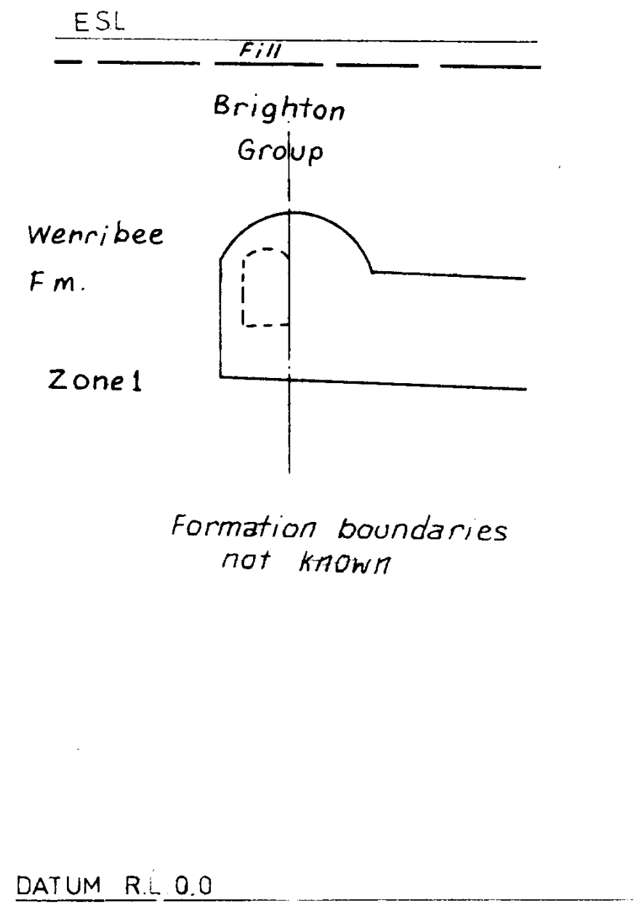
SCALE: Hor. 1:500 Vert. 1:200

PLATE 6

Record No. 1978/90

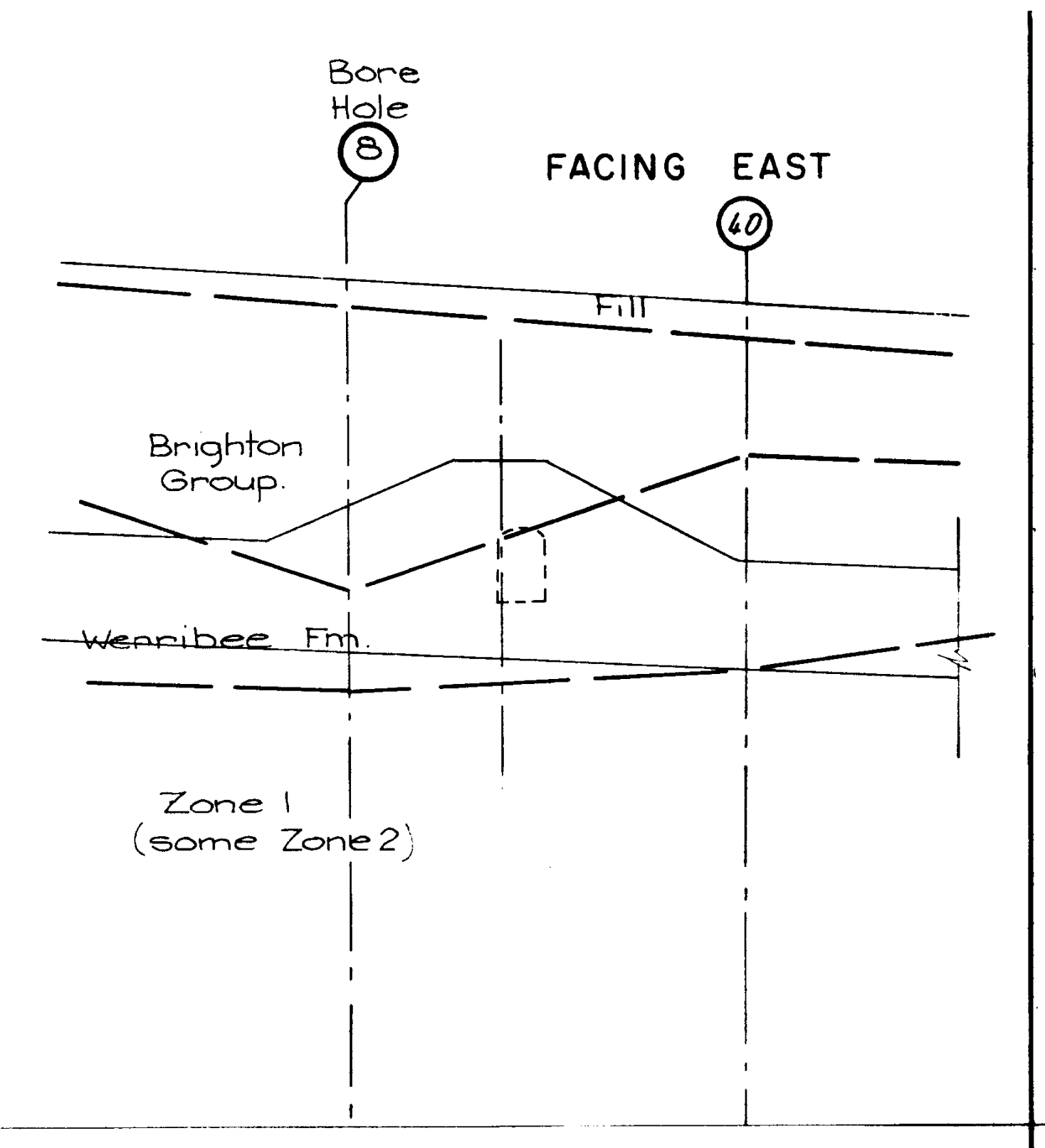
QUEEN STREET

FACING NORTH



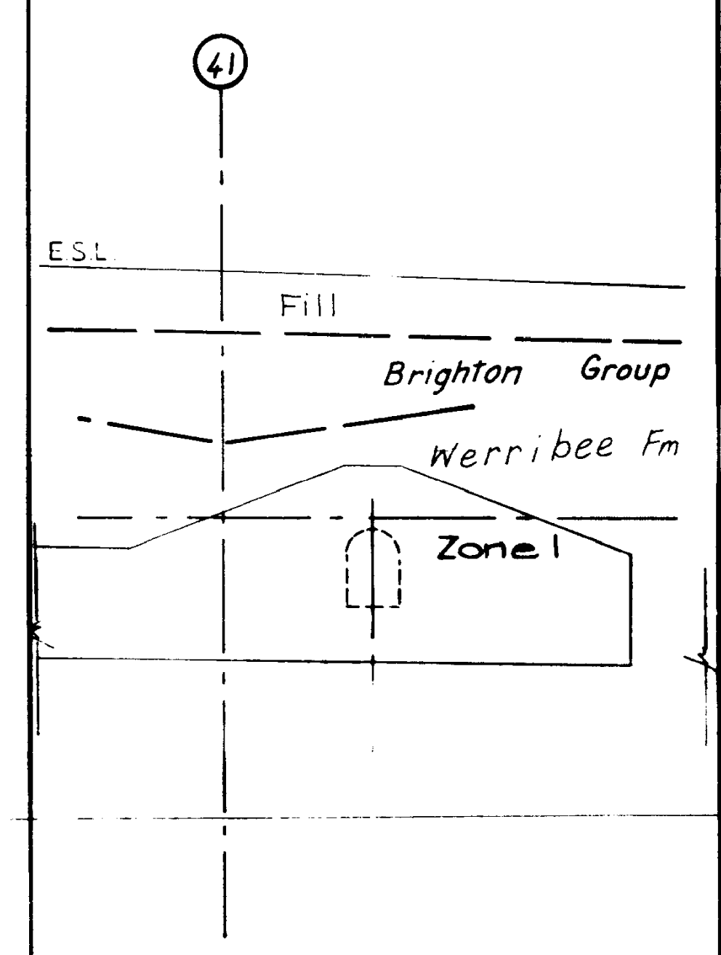
QUEEN ST.
CABLE CHAMBER

FACING EAST



QUEEN - LT. BOURKE ST.
CABLE CHAMBER

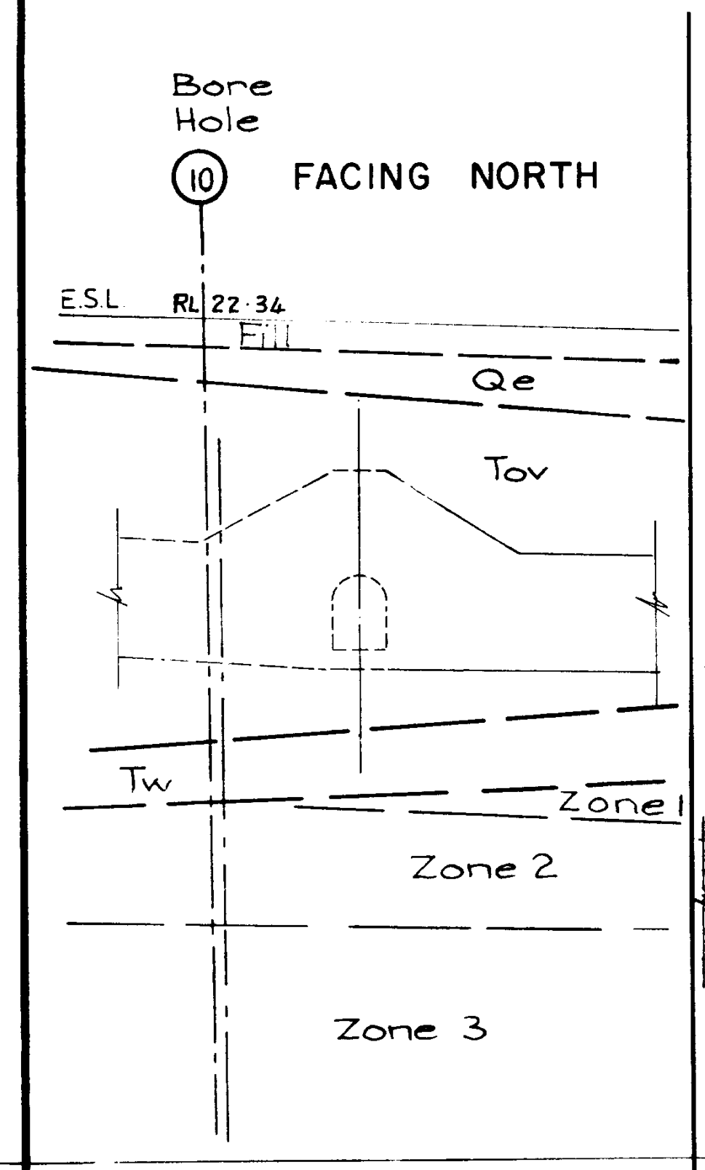
FACING EAST



QUEEN - LT. COLLINS ST.
CABLE CHAMBER

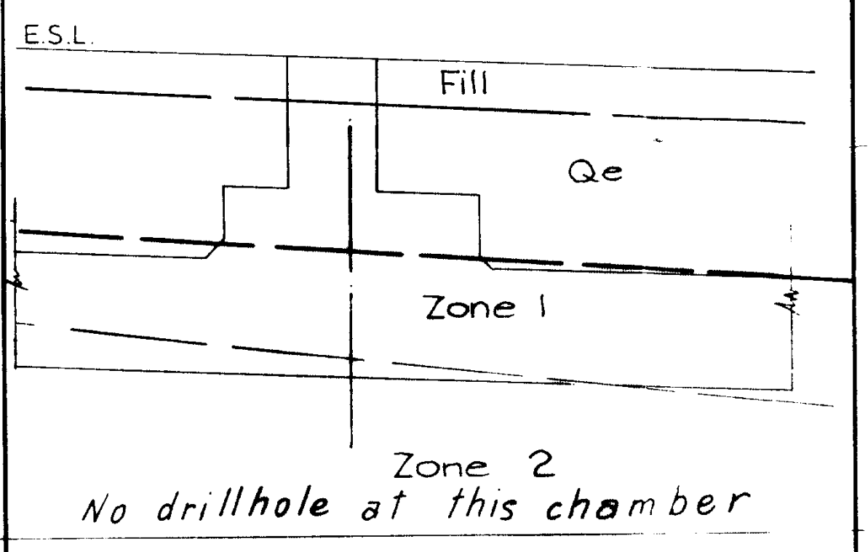
LONSDALE STREET

FACING NORTH



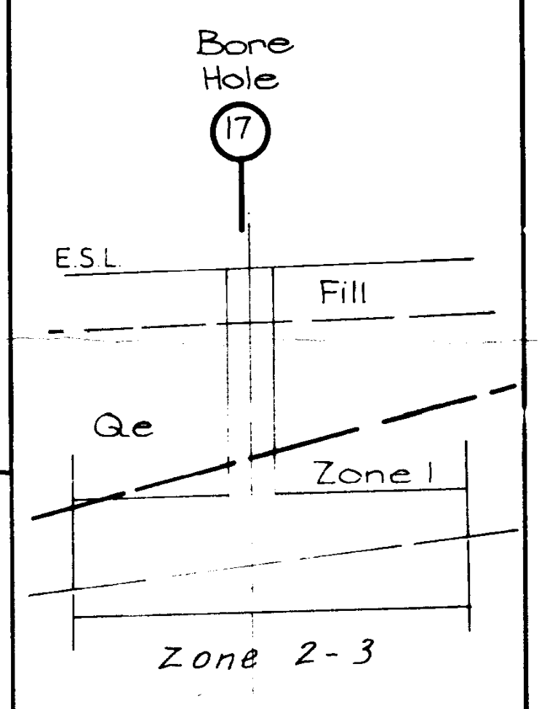
LONSDALE - QUEEN ST.
CABLE CHAMBER

FACING NORTH



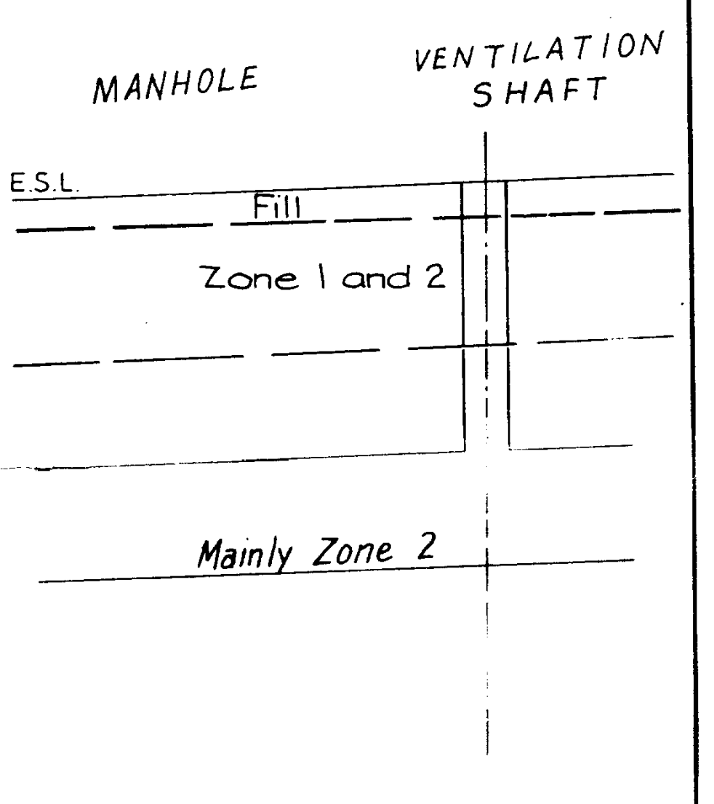
LONSDALE - WEST OF ELIZABETH ST
LOADING COIL CHAMBER

FACING NORTH



LONSDALE - EAST OF ELIZABETH ST
MANHOLE

FACING WEST

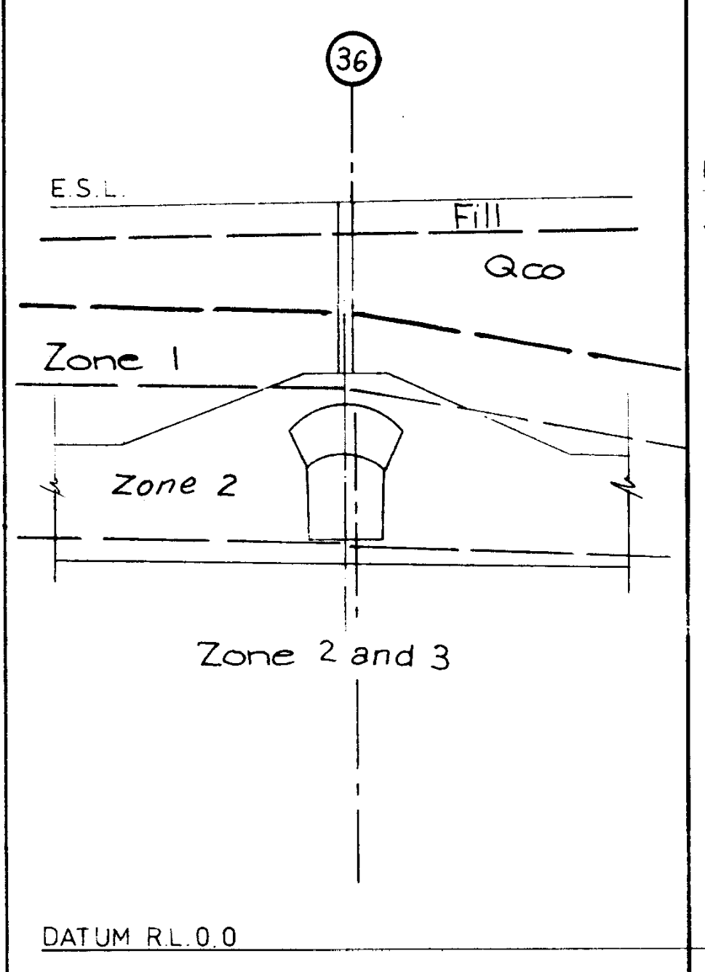


LONSDALE - WEST OF RUSSELL ST.
MANHOLE & VENTILATION SHAFT
(NEAR HOLE 20 A)

	QUEEN ST. CABLE CHAMBER	QUEEN - LT. BOURKE ST. CABLE CHAMBER	QUEEN - LT. COLLINS ST. CABLE CHAMBER	LONSDALE - QUEEN ST. CABLE CHAMBER	LONSDALE - WEST OF ELIZABETH ST LOADING COIL CHAMBER	LONSDALE - EAST OF ELIZABETH ST MANHOLE	LONSDALE - WEST OF RUSSELL ST. MANHOLE & VENTILATION SHAFT
TUNNEL CHAINAGE	100	8 40 122.50 126.50 137.0	355.88 359.88	HOLE 10 96.0 100	297.91	436.5	652.15
MATERIAL HARDNESS AND STRENGTH	Hardness and strength variable	SC Is(50) 0.21 (5.5m) 0.43 (6.8m) 0.72 (7.0m).		Is(50) 0.22 (8.35m) 1.3/0.4 (8.90m) 1.36/0.95 (10.05m) 0.11 (11.0m)		σ1 6.48 (10.6 m) Is(50) 0.47 (9.6 m) 0.99 (10.6 m)	
ROCK MASS DEFECTS	Soft and loose in Werribee Fm and Brighton Group if wet; some hard bands in Brighton Group with limonite cement Zone 1 mudstone is incompetent.		Werribee Formation in chamber roof; irregular boundaries between Werribee Fm and Zone 1 mudstone and Werribee Fm and Brighton Group. Zone 1 mudstone incompetent, Werribee Fm soft and loose if wet stability depends mainly on amount of water present and orientation of rock defects or presence of dykes	Located entirely in highly fractured variably weathered basalt. Top of Werribee Fm may be close to invert level. Base of basalt is EW rock	Qe is generally firm in dry condition. Mudstone is extremely weathered and incompetent. Mudstone - Qe boundary very weak; liable to be wet.	Rock mass generally soft and weak	Rock mass fairly soft and weak.
PREDICTED EXCAVATION CONDITIONS	Poor in Brighton Group, Werribee Fm and Zone 1 mudstone, Brighton Group and Werribee Fm will stand up satisfactorily if drained, provided the delay in installation of support is kept to a minimum.		Poor in Werribee Fm and Zone 1 mudstone.	Material strong but rock mass fairly weak due to fractures tunnelling conditions only fair. Estimated stand-up time <5 hrs	Good in Qe material if dry Poor in Mudstone.	Good for drilling and casing.	Good for drilling and casing.
PREDICTED OVERBREAK	Loss of ground potentially high if wet and uncemented Surface settlements potentially large		Potentially high particularly in crown where Werribee Fm could be loose and uncohesive. Zone 1 mudstone overbreak from walls depends on orientation of defects including dykes.	Potentially high, especially above spring line.	Qe - small with careful excavation Mudstone - potentially higher than Qe.		
PREDICTED SUPPORT	Full support - full timber lagging behind sets. Sub invert concrete may be required		Steel sets and full timber lagging required for Werribee Fm and zone 1 mudstone. Concrete sub invert may be required.	Steel sets and timber lagging. Rockbolts with mesh reinforced shotcrete	Steel and timber lagging in tunnel section. Open cut walls supported by soldier piles and lagging only.	Steel casing.	Steel casing.
PREDICTED GROUNDWATER INFLOWS	Initially may be high, decreasing fairly rapidly to seepage Piezometers in holes 8 and 40 for monitoring groundwater		Groundwater level may be between invert and crown initially. Initial inflows potentially high, but will revert to minor seepage only mainly from top of mudstone.	Initially small flows through fract. basalt. Reducing to seepage.	Small initially - seepage to dry after excavation.	Not relevant if manhole drilled and cased.	Not relevant if manhole and shaft drilled and cased.

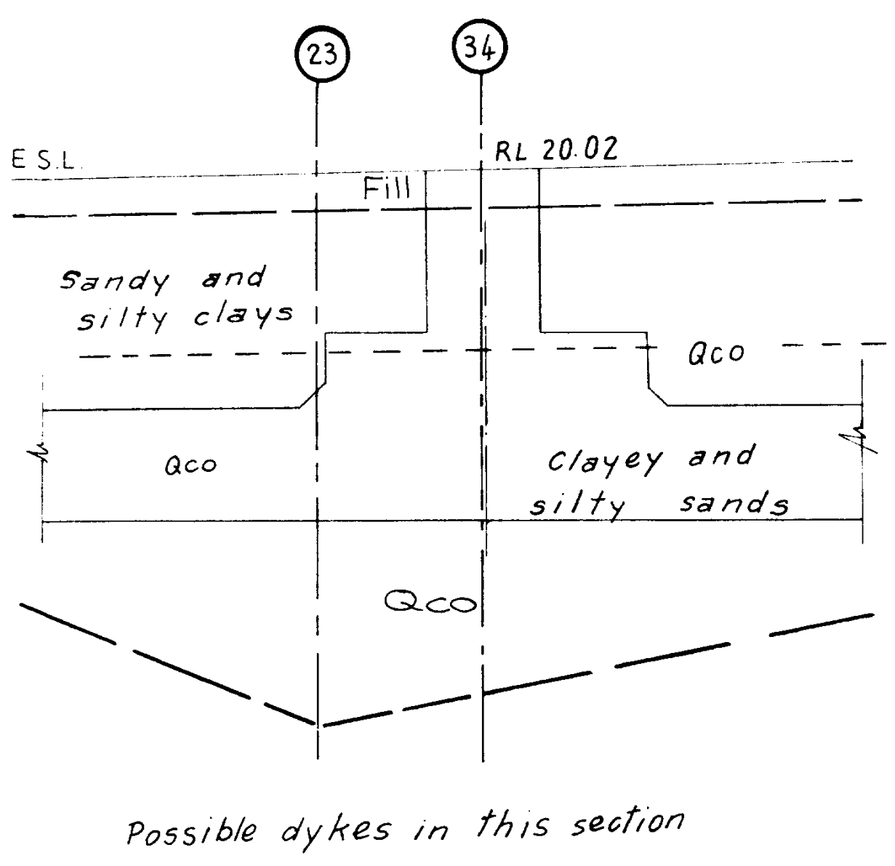
LONSDALE STREET

FACING NORTH



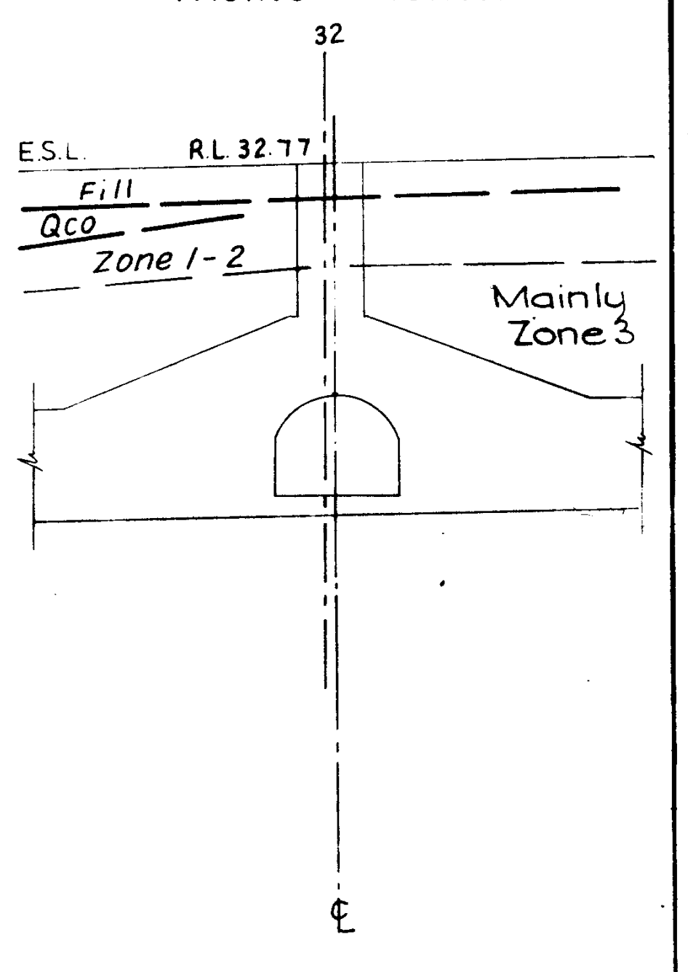
LONSDALE - RUSSELL ST.
CABLE CHAMBER

FACING NORTH



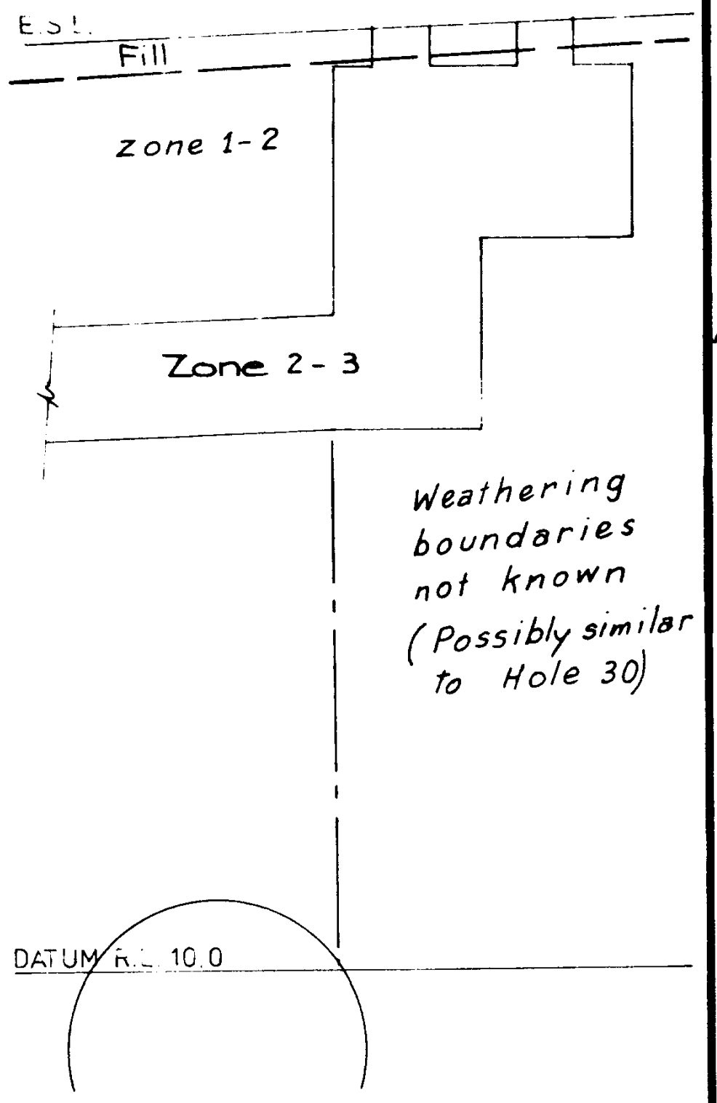
LONSDALE - EAST OF RUSSELL ST.
LOADING COIL CHAMBER

FACING NORTH



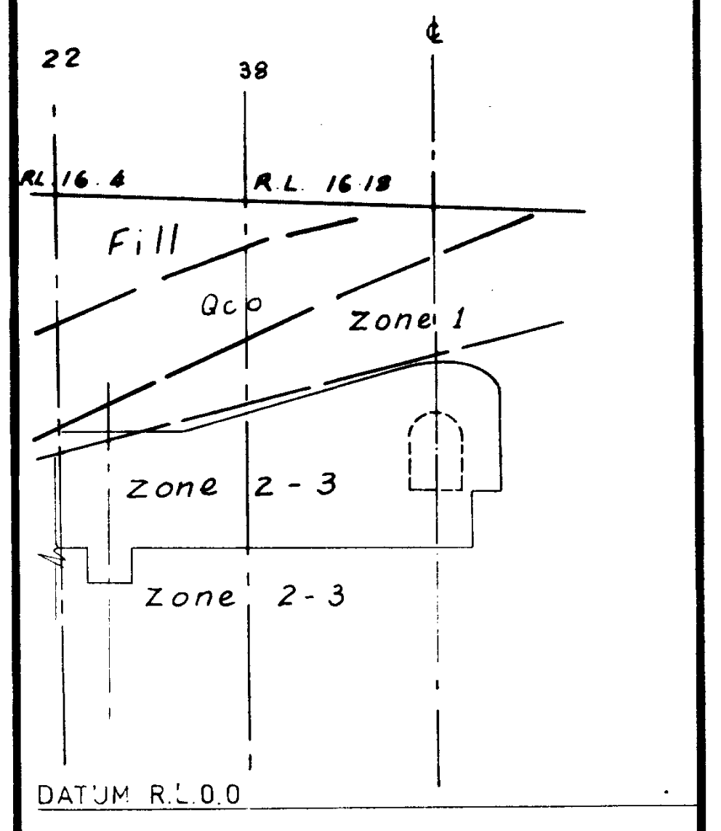
LONSDALE - EXHIBITION ST.
CABLE CHAMBER

FACING NORTH



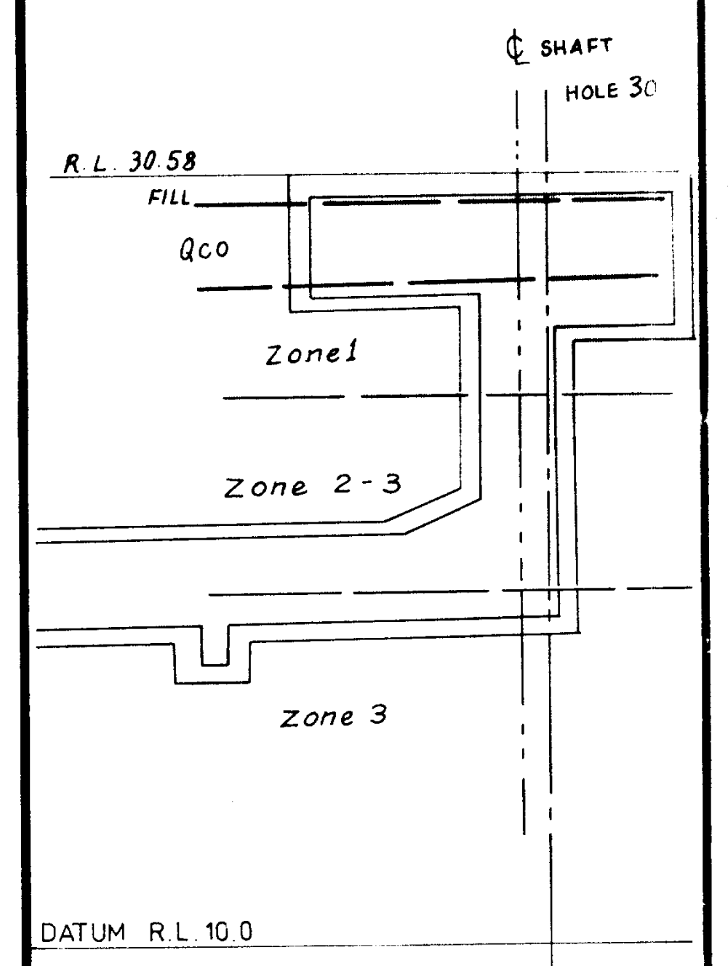
LONSDALE - SPRING ST.
TERMINATING CHAMBER

FACING NORTHEAST



RUSSELL - LT. BOURKE ST.
CABLE CHAMBER

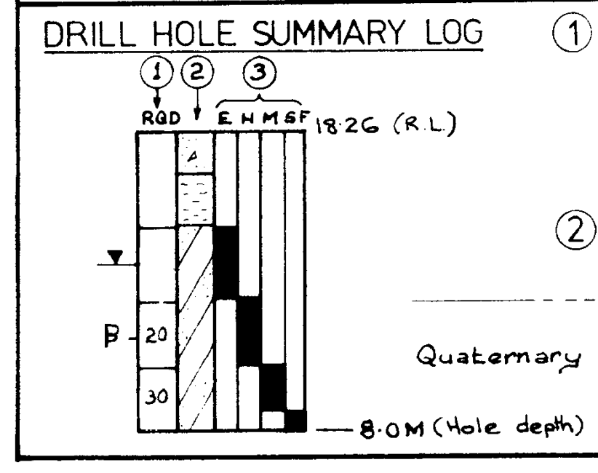
FACING WEST



VICTORIA - RATHDOWNE ST
TERMINAL CHAMBER

	LONSDALE - RUSSELL ST. CABLE CHAMBER	LONSDALE - EAST OF RUSSELL ST. LOADING COIL CHAMBER	LONSDALE - EXHIBITION ST. CABLE CHAMBER	LONSDALE - SPRING ST. TERMINATING CHAMBER	RUSSELL - LT. BOURKE ST. CABLE CHAMBER	VICTORIA - RATHDOWNE ST TERMINAL CHAMBER
TUNNEL CHAINAGE	807.75 807.0	HOLE 23 HOLE 34 870.0 874.0 874.5	HOLE 32 ℄ 1047.05 1047.9	1300.5	HOLE 22 HOLE 38 200.75 207.0 210.0 215.68	HOLE 30 108.0 100.0 99.2
MATERIAL HARDNESS AND STRENGTH		CH (1.0m) CL (3.0m)				
ROCK MASS DEFECTS	Zone 1 mudstone in chamber roof incompetent. Zone 2 mudstone with clay filled to open joints Colluvium about 1.4 m above chamber roof	Colluvium mostly soft with little strength. Sandy clays to about 5.5m and clayey and silty sands below. Low permeability in sands.	Main defects will be joints and bedding planes; bedding 15-35° probably to west; some slabbing from crown	Main defects will be joints and bedding planes (35°) Boundary between Zone 1-2 and Zone 2-3 is not known. No drillhole data.	Zone 1 mudstone at or close to crown of chamber; Zone 2-3 elsewhere	Chamber located in zone 1 soft incompetent mudstone; shaft traverses zone 1 to zone 2-3 mudstone, rock conditions improving with depth.
PREDICTED EXCAVATION CONDITIONS	Poor. Stand-up times probably less than 10 minutes. (assuming full face excavation). Possibility of inflow of surface water runoff	Poor if excavated without adequate support. If colluvium has been dewatered, excavation conditions will be improved. Possibility of inflow of surface runoff	Generally good stand up times; greater than 10 hours	Generally fair-good. Moderately hard and strong Mudstone. Dykes may be present. Stand-up time probably > 8 hours in Zone 2 to 3	Poor standup times about 10 minutes	Fair for open cut poor to fair for shaft and fair to good for tunnel Stand-up time > 8 hours in Zone 2 to 3
PREDICTED OVERBREAK	Potentially high, especially in crown.	Potentially high: base of clays may limit overbreak.	Potentially high in central part of the chamber crown.	Potentially small; no factual data	Potentially high in crown of chamber	Potentially high in chamber and top of shaft
PREDICTED SUPPORT	Steel and timber lagging. Shotcrete in parts.	Soldier piles and lagging.	Steel and timber lagging (especially in crown) and shot crete.	Bolts, mesh and shotcrete below about 6 m Soldier piles and timber lagging for open cut.	Steel and timber lagging particular in the crown; also shotcrete.	Steel and timber lagging in chamber and shaft; also shotcrete.
PREDICTED GROUNDWATER INFLOWS	Seepages initially that may persist if groundwater levels are high	Potentially initially high; reducing to small inflows or seepage.	Negligible.	Negligible.	Negligible if chamber is excavated after the tunnel	Seepage only.

DRILL HOLE SUMMARY LOG



① R.Q.D. (Rock Quality Designation)

Percentages not given for extremely weathered rock.

② GRAPHIC LOG

Quaternary
- ▨ Concrete, bitumen and fill
- ▨ Colluvium and/or clay (Qco)
- ▨ Elizabeth Street Formation (Qe)

GRAPHIC LOG (CONT.)

Tertiary
- ▨ Brighton Group (Tb)
- ▨ Basalt } Tertiary Older Volcanics (Tov)
- ▨ Tuff } Tertiary Older Volcanics (Tov)
- ▨ Werribee Formation (Tw)

Devonian
- ▨ Dyke

Silurian
- ▨ Mudstone } Dargile Formation (S)
- ▨ Mudstone with minor sandstone } Dargile Formation (S)
- ▨ Mainly sandstone } Dargile Formation (S)

③ ROCK WEATHERING

E Extremely weathered
H Highly weathered
M Moderately weathered
SF Slightly weathered or fresh
When dealing with mudstone:
E Zone 1
H Zone 2
M Zone 3
SF Zone 4 or 5
▼ Water level in drill hole
B— Location of piezometer

GEOLOGICAL BOUNDARY

—— —— *Position approximate*

WEATHERING BOUNDARY

—— —— *Position approximate*

≀≀ *Sheared rock*

▼6/6 *Location and no. of penetration resistance test (static cone)*

MATERIAL HARDNESS & STRENGTH

1) Unified Soil Classification	CL, CH, Sc, etc.
2) Direct Shear Stress	s, kPa (depth)
3) Unconfined Compressive Strength - Soil	σ_1, kPa (depth)
4) Uncontined Compressive Strength - Rock	σ_1, MPa (depth)
5) Point Load Index	Is (50), MPa (depth)
6) Penetration resistance	SPT (depth in m) Nº of blows / length of hole (mm)

STAND-UP TIME: Most figures given are considered to be conservative (see text).

Note: Outlines shown of Chambers, Shafts and Manholes are excavation outlines only.

NOTE: These sections must be read in conjunction with appropriate parts of the written report.

AMENDMENTS
28-6-78
3-10-78

BUREAU OF MINERAL RESOURCES, GEOLOGY & GEOPHYSICS, CANBERRA, A.C.T.

GEOLOGIST G. Trand D.C. Purcell

CHECKED E.G. Wilson

DATE 1 SEPTEMBER 1978.

DRAWING NO. J55/A5/16

TITLE
PROPOSED TELECOM CABLE TUNNEL
GEOLOGICAL SECTIONS
CHAMBERS,
SHAFTS &
MANHOLES.

SCALE: *Hor. 1:200 Vert. 1:200*

PLATE 8

Record No. 1978/90