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BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

BMR RECORD 1980/41

GROUNDWATER POLLUTION BY PETROL AT THE NRMA BUILDING, BRADDON, ACT

by

G. Jacobson

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CONTENTS

ABSTRACT

Groundwater is polluted by petrol at the NRMA Building in Braddon, ACT. Petrol floats on the water-table about 5 m below the ground surface and has been found in the drainage sump of the building after heavy rain. This is attributed to the entry of petrol into the foundation drains of the building as the water-table rises. The pollution plume extends over about 300 m^2 and is up to 0.5 m thick in monitoring bores. The source of the petrol is associated with the location of an underground tank in the car park of the building; spillage as a result of overfilling is the most likely cause of the pollution. The conditions which led to the entry of petrol into the drainage sump of the building could recur at any time. The petrol floating on the water-table is expected to remain in place for a long time unless some action is taken to remove it, and its extent should be monitored regularly. The petrol plume represents a potential hazard to the safety of the NRMA Building, and the safety precautions, including ventilation, that have been established should be maintained continuously.

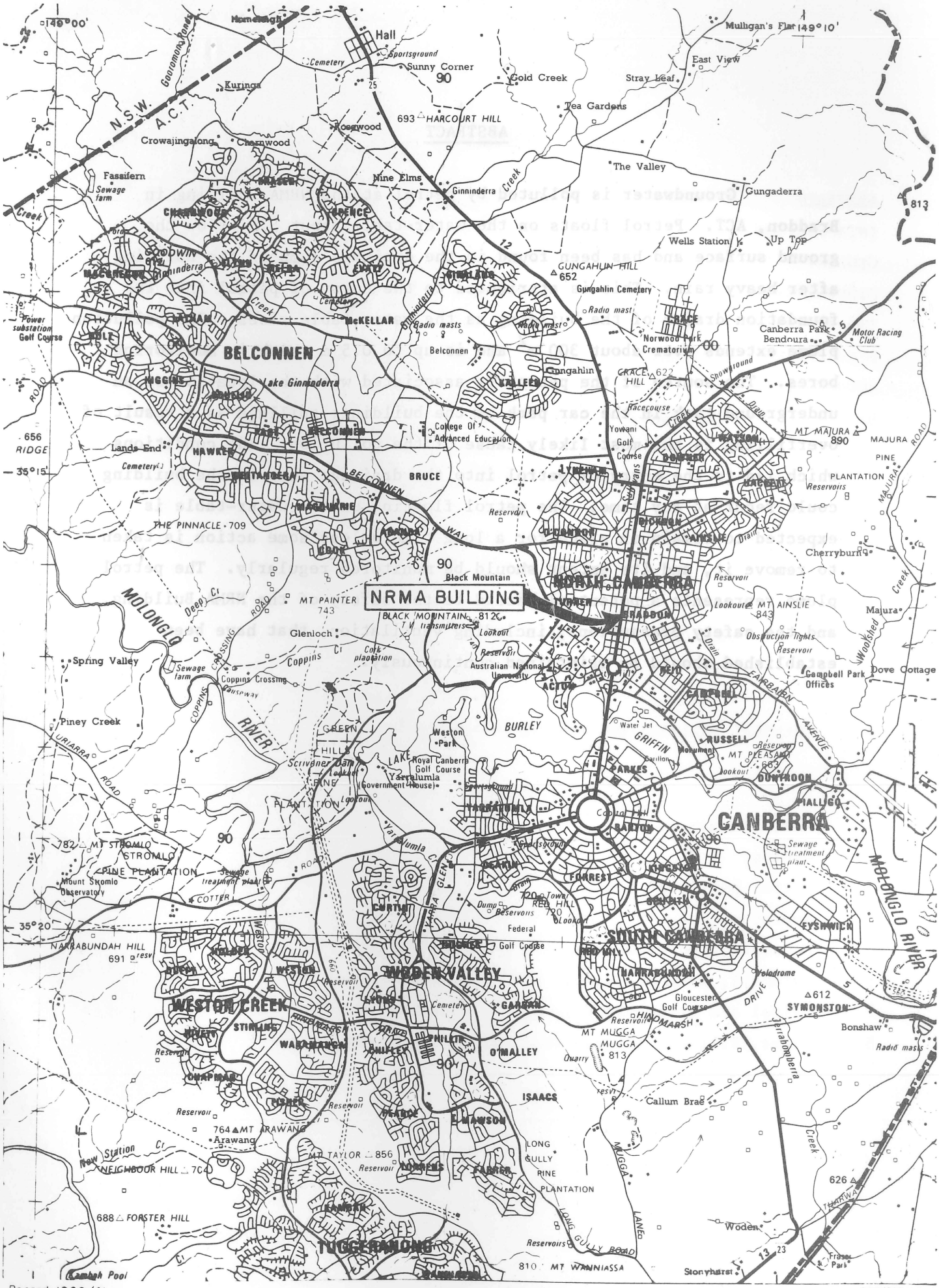

Fig. 1 LOCATION MAP

INTRODUCTION

The NRMA Building in Braddon, ACT (Fig. 1), has a sump which collects groundwater inflow to the foundation drains of the building. The sump was installed when the building was constructed in 1969, after groundwater had flowed into the excavation. On 8 September 1978, petrol entered the sump after heavy rain; explosive vapours were present. Petrol again entered the sump on 18 and 22 September 1978 after heavy rain, and explosive vapours were again detected. An investigation of groundwater conditions at the site was undertaken at the request of the Department of the Capital Territory, in order to identify the source of the petrol and assess the likelihood of its recurrence.

Six drillholes were drilled by a contractor in January 1979, and were equipped with slotted plastic casing to serve as monitoring bores. The drilling contract was funded by the National Capital Development Commission. Cores from the investigation were logged by J.R. Kellett (Appendix 1) and stored at the BMR Core and Cuttings Laboratory, Fyshwick. Petrol and water-levels in the bores have been monitored at roughly weekly intervals.

A preliminary report on the results of the drilling was made available to the Department of the Capital Territory and to the building's owners in October 1979. Subsequently, in November 1979, an underground petrol tank in the building's car park was excavated and replaced; observations were made in the tank excavation at that time.

GEOLOGY

The geology of the Canberra City-Braddon area is known from records of building excavations and site investigations. Limestone was recorded in the foundation of the NRMA Building, and the geological map of the area (Fig. 2), shows that the building is founded on Silurian limestone, the boundaries of which are known only roughly.

The locations of the six drillholes put down during this investigation are shown in Figure 3, and detailed logs are given in Appendix 1. The holes were drilled to depths of 12-17 m and five of

them, numbered 1, 3, 4, 5, and 6, encountered irregularly weathered, cavernous limestone with clay and gravel cavity fillings. Drillhole 2 intersected alluvium to a depth of 12 m without reaching bedrock. Calcareous mudstone was intersected beneath the limestone in drillhole 1. Water losses occurred during the drilling of holes 3, 4, 5, and 6 in cavernous limestone.

GROUNDWATER

The hydrology of the area is shown in Figure 4. The area is urban, and stormwater in the vicinity of the NRMA Building is drained westwards towards Sullivans Creek, which is 500 m away. The neighbouring catchment to the southeast covers much of Canberra city, and is drained by stormwater drains flowing southwards to Lake Burley Griffin. There are insufficient data to delineate groundwater catchments in the area, but it is likely that the groundwater catchments generally coincide with the surface water catchments. Groundwater is recharged by stormwater leaking through the drains, and by infiltration of rainwater in gardens and nature strips. Groundwater is contained in ephemeral alluvial aquifers and in a basal fractured rock aquifer which probably extends throughout the area.

About 20 service stations and motor vehicle workshops in the city-Braddon area have underground petrol tanks. There are consequently about 60 underground petrol tanks in the area, and these have their bases 3–4 m below the surface. Several buildings have been constructed with basements below the water-table, which is commonly 4-5 m below the surface. The combination of underground petrol tanks and groundwater seepage into basements led to a fatal accident in February 1977 at the Center Cinema in Canberra City (Wilson , 1978; Jacobson, Hohnen, & Evans, 1978).

At the NRMA Building, groundwater was encountered in all six drillholes. The water-table is 4-5 m below ground surface and slopes gently to the west. Water-table fluctuations in monitoring bores have ranged up to about 1 m during one year of measurement to the end of February 1980, and have generally declined during this year (Figs. 6 and 7).

A system of drains in the foundation of the building connects to a sump within the building; the sump inlet is at an elevation of about 562 m (Fig. 5). Inflow to the sump declined from 300-500 l/hour in March 1979 to 100 l/hour in November 1979 (Fig. 6). At the present time (March 1980) it is less than 100 l/hour.

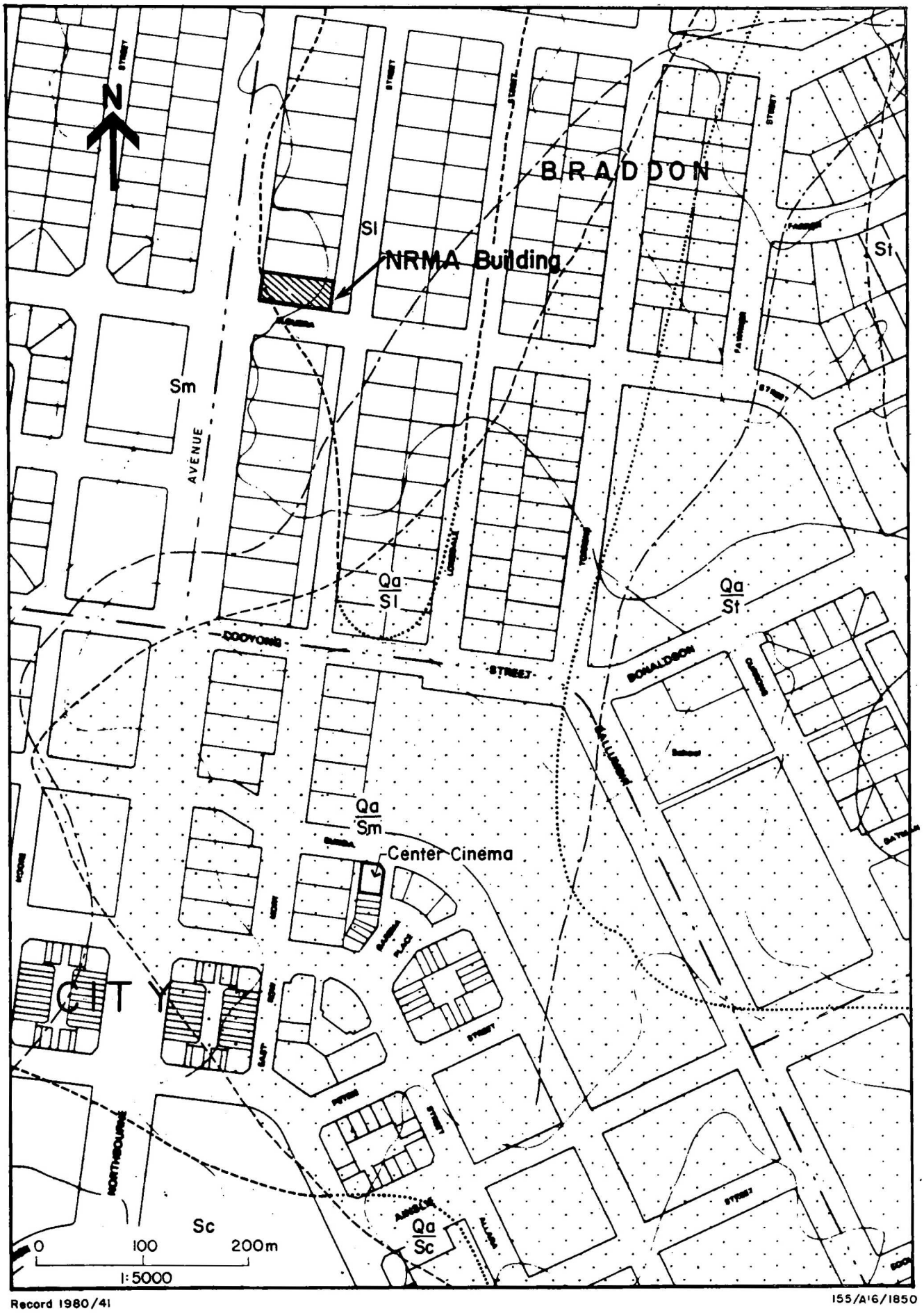

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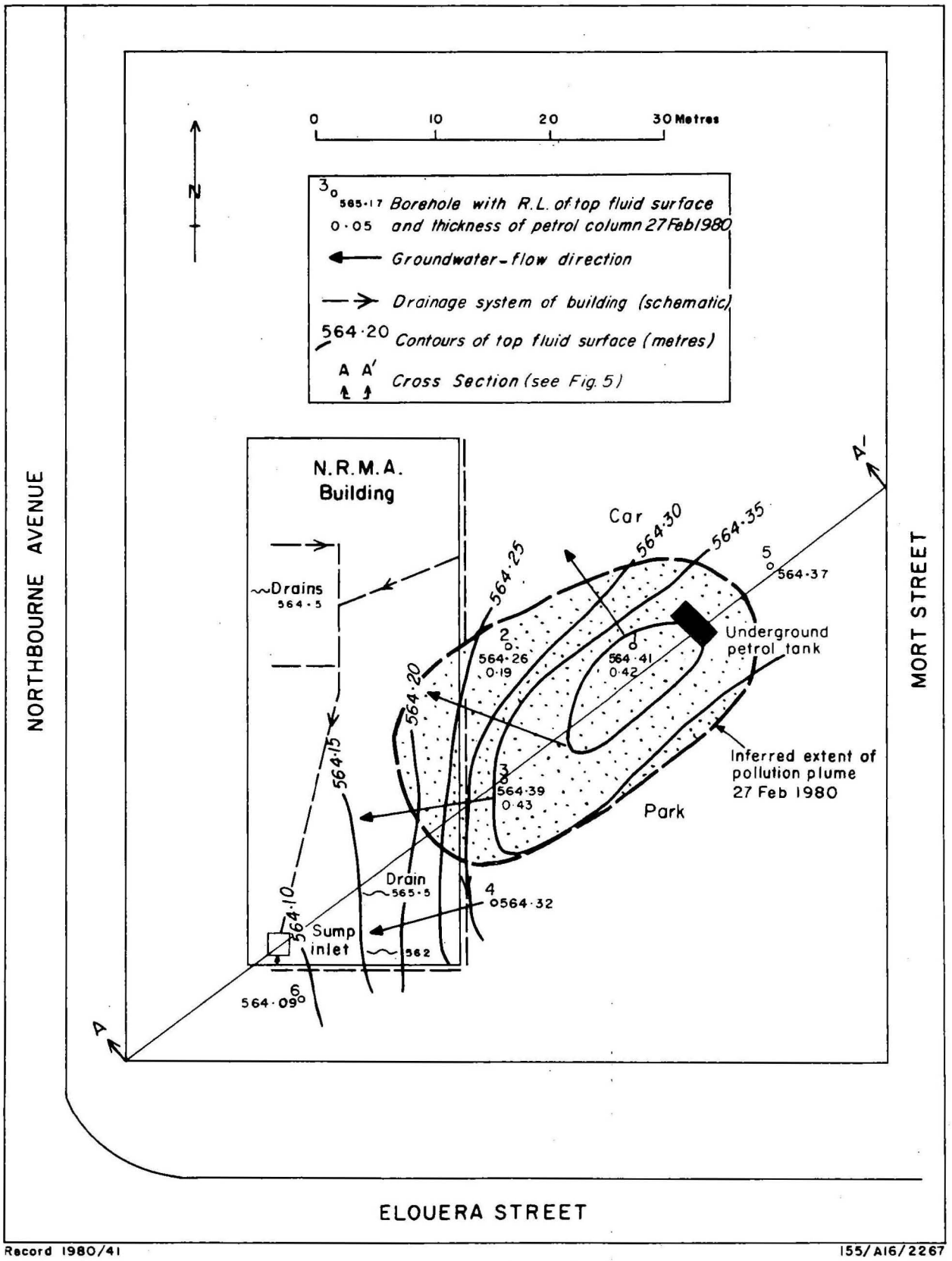
Fig 2 Geology

- Geological boundary, approximate
- Geological boundary, concealed
- Catchment boundary
- Qa — Alluvium: clay, sand, gravel; Quaternary

Silurian:

- Sm — Mudstone: deeply weathered
- Sc — Calcareous mudstone: shallow weathered
- St — Tuffaceous sandstone: deeply weathered
- Sl — Limestone



Record 1980/41

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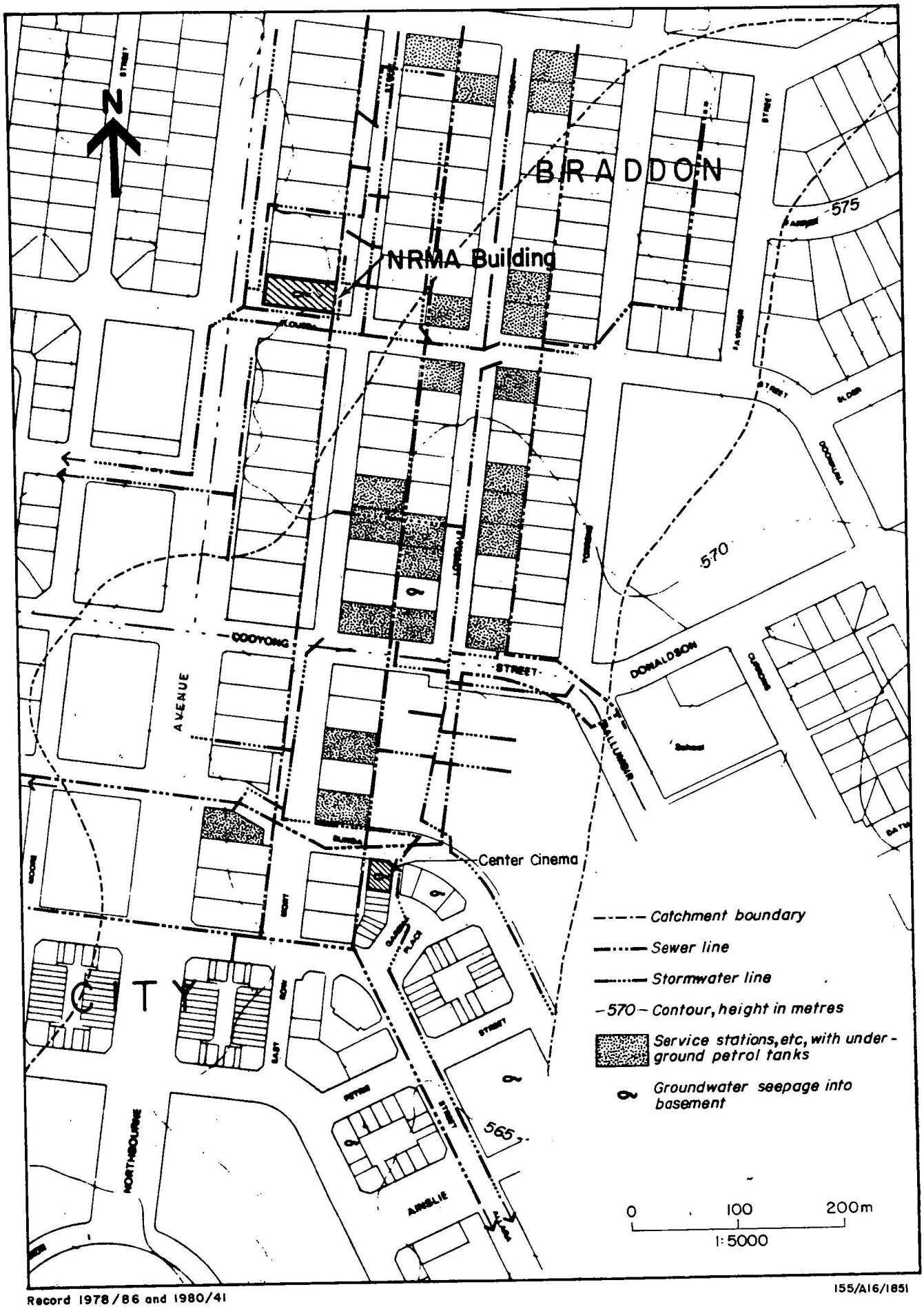
Figure 3 PETROL POLLUTION PLUME at the N.R.M.A. Building, Braddon, A.C.T., 27 February 1980



Record 1978/86 and 1980/41

FIG. 4 Hydrology

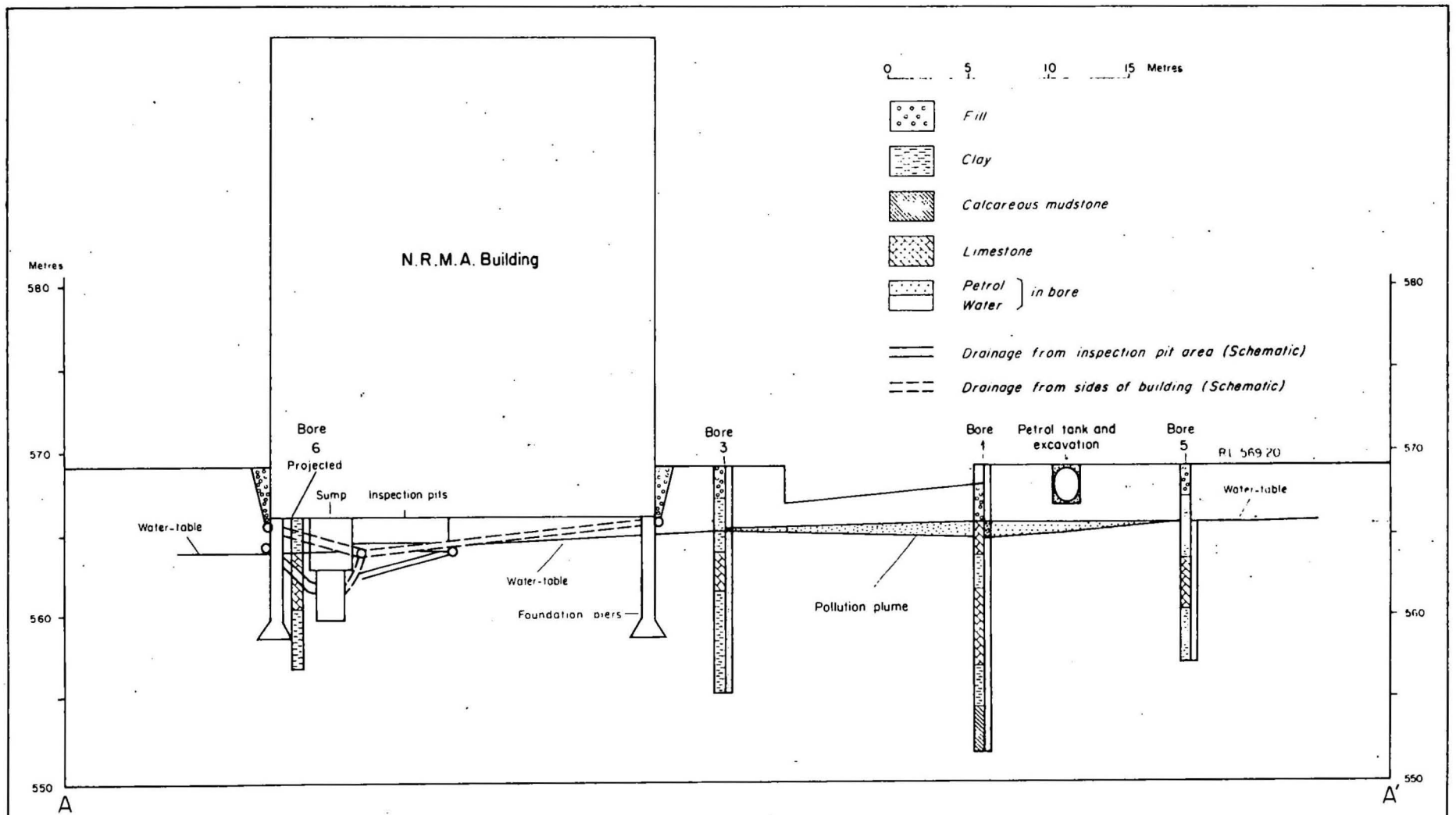


Figure 5 N.R.M.A. Building, Braddon: Cross-Section showing PETROL POLLUTION PLUME, 2 March 1979
(for location of cross-section see Fig. 3)

Record 1980/41

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A cross-section through the building (Fig. 5) shows that the water-table is, at times of high rainfall and considerable groundwater recharge, close to the level of the foundation drains which surround the building and drain into the sump.

THE POLLUTION PLUME

Petrol has been observed on top of the water-table in three of the observation bores; petrol and water-levels in these three bores are shown in Figure 7. Petrol was first observed in bore 1 soon after drilling, and since then the column of petrol has ranged in thickness from 0.42 m to o.84 m. In Bore 2, petrol vapours were observed during drilling, but petrol was not measured in the bore until June 1979; the thickness of the column of petrol has since ranged from 0.19 m to 0.53 m. Bore 3 contained only a few centimetres of petrol until June 1979, when the column thickened; it has since ranged from 0.36 m to 0.49 m thick.

The pollution plume is believed to be continuous between the bores that contain measurable quantities of petrol, and probably extends for some distance laterally beyond these. The inferred extent of the pollution plume in February 1980 was about 300 m^2 (Fig. 3). The total volume of petrol-saturated rock was estimated as about 200 m^3. On the assumption that one percent of the rock is voids - pores, fractures, and solution cavities - which contain petrol, then the total amount of petrol in the plume was about 2000 litres. However, as limestone is present the porosity could be greater than one percent, and the volume of petrol could be considerably greater.

Figure 5 shows that on 2 March 1979 the water-table and the petrol floating on top of it were just below the level of the foundation drains along the east side of the NRMA building. It is likely that a rise in the water-table brought petrol into the drains and thence into the sump on three occasions in September 1978. It is not known to have occurred since, possibly because 1979 was a dry year and groundwater-levels have remained low; however, the ventilation installed in the sump in September 1978 to remove petrol fumes may also mean that the entry of petrol may not be detected. The entry of petrol into the sump is likely to recur

whenever groundwater recharge after heavy rain raises the water-table along the east side of the building so that water, and in some places petrol, enters the drain. The hazard will remain, and continuous ventilation must be maintained in those areas of the building likely to be affected by petrol vapour.

The decline in petrol thickness in bores 1 and 2 (Fig. 7) probably indicates that the plume is spreading out from a source that is no longer active; however, traces of petrol have not yet been detected in bores 4, 5 and 6.

DYE-TRACING EXPERIMENT

A dye-tracing experiment was carried out in collaboration with Mr D. Ingle Smith of the Centre for Resource and Environmental Studies, ANU. On 19 March 1979, rhodomine WT was put into bore 1, which - together with the other drillholes and the sump - was monitored; however, rhodomine was not detected in any locations other than bore 1. The dye left the input bore rapidly - the concentration decreased from 11.3 g/l to 0.8 g/l after 3 days and 0.01 g/l after 35 days.

The result of the dye test is inconclusive. The fall in dye concentration in the input bore indicates that groundwater moved from that hole. However, the failure to detect dye in the other bores probably means that they are not located along the flow lines through bore 1; the direction of the flow lines in limestone with solution cavities is not predictable.

SOURCE OF PETROL

The inferred extent of the pollution plume includes the site of the underground petrol tank in the NRMA car park (Fig. 3), and this tank and its fittings were considered the most likely source of petrol. In-situ tests by the Inspector of Flammable Liquids, Department of the Capital Territory, did not show any leakage. The tank was excavated on 9 November 1979, and petrol was observed in the sand surrounding it.

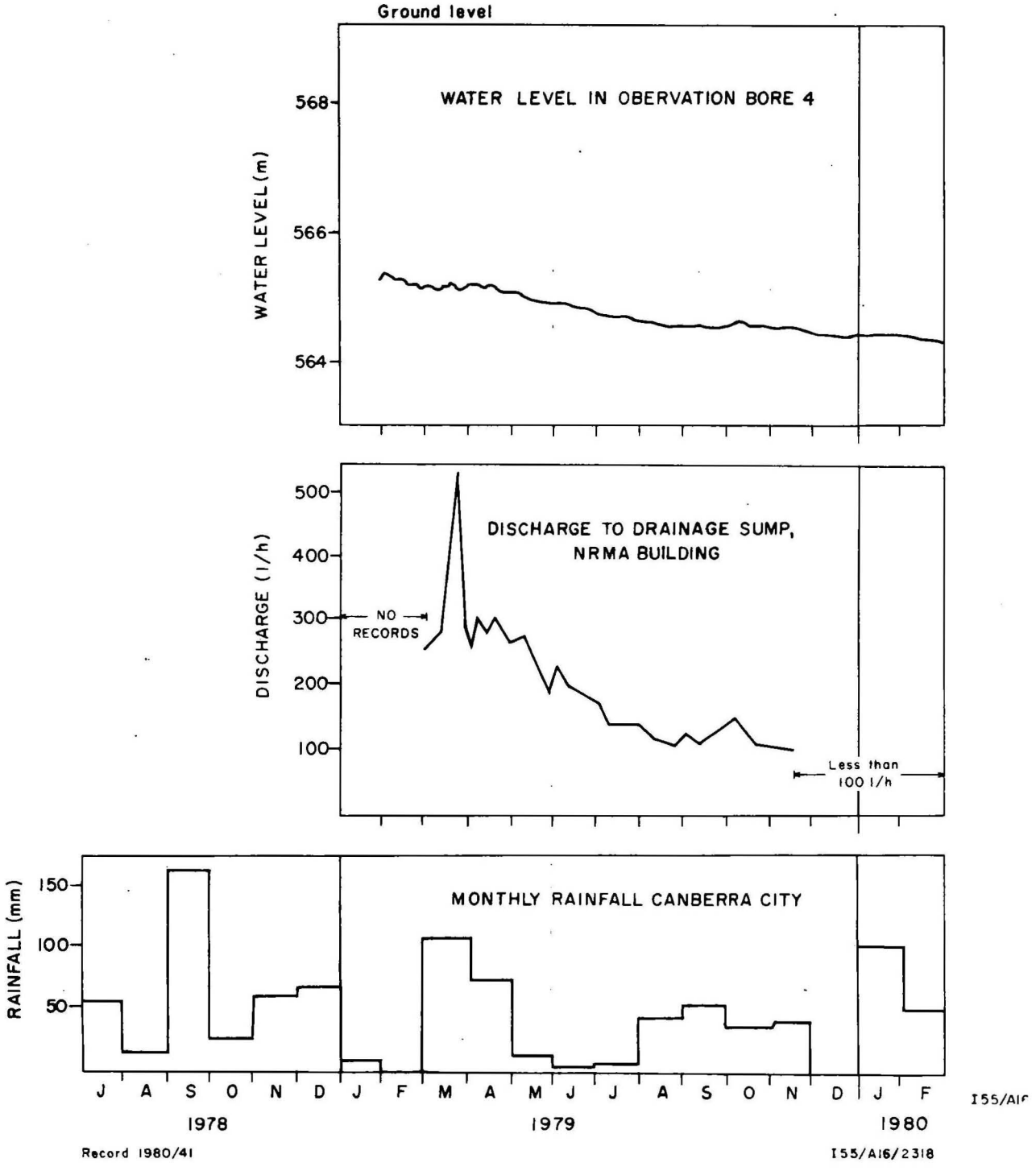
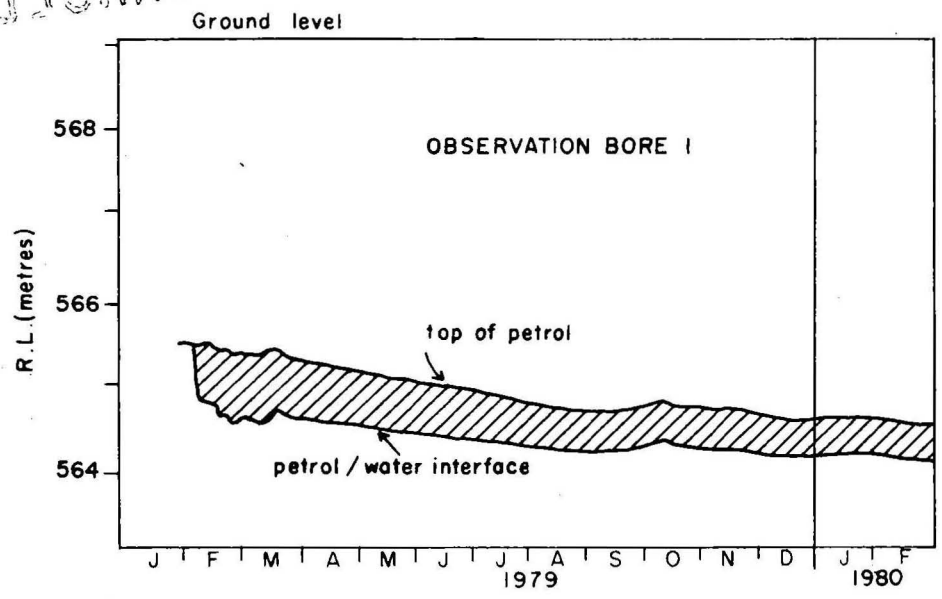
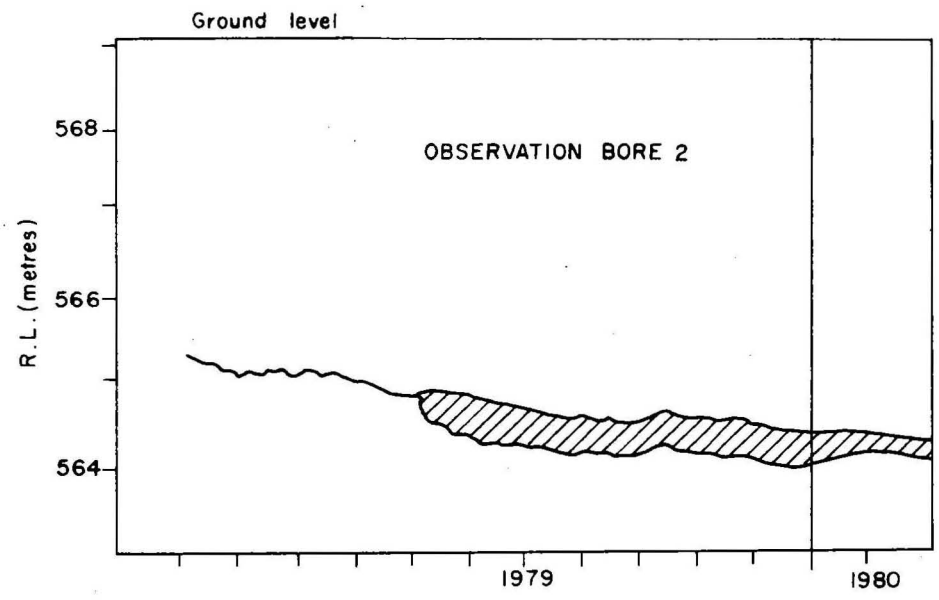


Figure 6 Rainfall, sump discharge, and groundwater-level





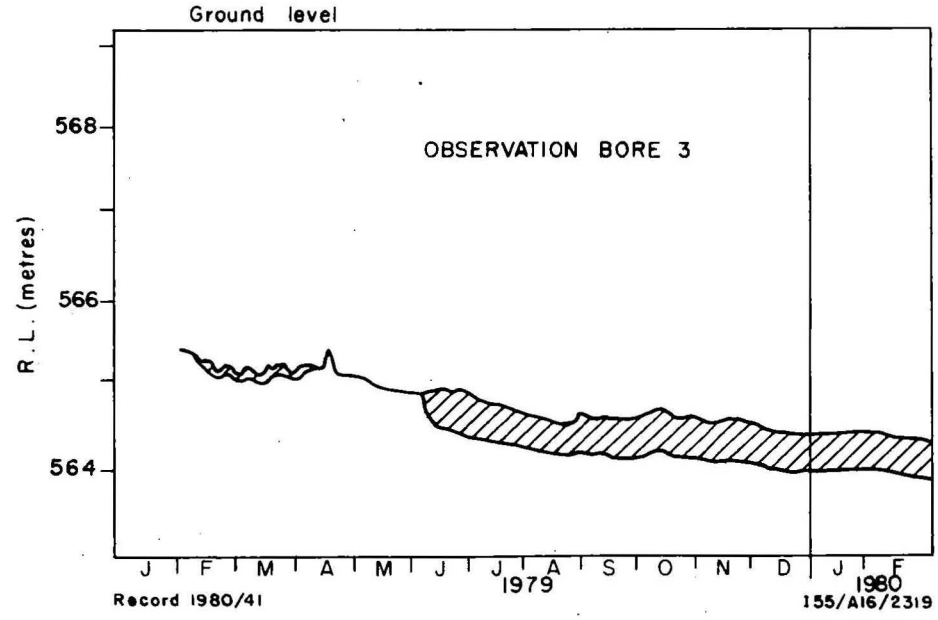


Figure 7 Petrol and groundwater-levels in observation bores N.R.M.A. building

The tank was then hydrostatically tested at the Mobil depot, Queanbeyan, but no leakage was found. The possibility of petrol having leaked from the tank does not seem likely when these tests are considered.

The excavation was enlarged on 13 November 1979 for the installation of a new tank. The excavation, to a depth of 3 m, was in yellowish brown sandy clay with limestone boulders up to 1 m in diameter; the base of the excavation was above the water-table. There was a strong petrol odour in the excavation. The clay in the base of the excavation was saturated with petrol, and it was observed that a piece of limestone, chipped off along a joint plane by the backhoe, smelt of petrol.

The petrol in the sand surrounding the old tank, and in the clay in the excavation, is considered to be petrol that was either spilled at the surface by overfilling during the delivery of bulk petrol to the tank, or leaked from the bowser or associated service lines. The most likely source of the petrol is spillage caused by overfilling; the petrol probably infiltrated readily through backfill around the tank, and eventually down to the water-table, where it floated and spread laterally to form a lens on top of the water-table.

Bore 5 has not at any time contained petrol, and probably indicates the limit of the plume to the northeast. The possibility of the plume extending to the north or east, and being derived from another source, cannot be excluded but is considered unlikely.

HAZARD TO THE BUILDING

The hazard to the building will remain until such time as there is no free petrol floating on the groundwater. Whenever rain causes groundwater and its floating layer of petrol to rise and enter the drainage system of the building, fumes will build up in the sump. If the fumes are not quickly evacuated, they could also spill over into the basement. There is also a possibility of fumes entering the basement from the open sections of the drains.

REMEDIAL ACTION

Remedial action should ensure that the pollution plume is being reduced either by recovery of petrol or by the movement of groundwater out of the immediate area. Adequate precautions should be taken in the building, and in any other building likely to be affected by the pollution plume.

In order to prevent any addition to the pollution plume by spillage, deliveries of petrol to the tank should be carefully monitored. The need to retain the tank and bowser should be reviewed, and its removal considered.

The size of the plume can be reduced by establishing a drawdown pumping well with a petrol skimming device similar to that currently operating near the Center Cinema (Jacobson & Hohnen, 1979). Recovery operations would continue for a number of years and the reduction in the size of the plume would be monitored by observation bores.

If no recovery action is taken, the pollution plume should be monitored by observation bores. Over several years some slow migration of the plume is to be expected, probably to the southwest following the groundwater gradient towards Sullivans Creek. Migration of the petrol plume would constitute a potential threat to buildings in its path, especially those whose foundations are within 1 m of the water-table. The risk is considered low for any building with foundations set 2 m or more above the water-table.

An appropriate ventilation system should operate in the sump of the NRMA Building whenever petrol is likely to enter it. However, as it is doubtful that such events can be reliably predicted, consideration should be given to a continuous ventilation system that could be monitored for serviceability at all times. A review of the ventilation of the basement should be made to assess its effectiveness whenever petrol as well as water is present in the open parts of the drains.

IMPLICATIONS FOR URBAN PLANNING

The NRMA Building is the second building in central Canberra to be affected by petrol which has polluted groundwater. At the other location, the Center Cinema, the source of the petrol is considered to be a service station 30-50 m away (Jacobson & others, 1978), and the cause is probably leakage from underground pipelines.

The NRMA Building and the Center Cinema are in different surface water catchments, and probably in different groundwater catchments. Chemical analyses of some central Canberra groundwaters are shown in Table 1, and the ionic components have been plotted in Figure 8. The NRMA Building groundwater is a bicarbonate water with calcium the dominant cation; whereas the Center Cinema groundwater is a bicarbonate/chloride water with sodium the dominant cation.

The problems at these two sites do not appear to be connected. At both sites the extent and variations in thickness of the pollution plumes suggest pollution derived from a local source, within 50 m. At both sites, buildings with basements below the water-table have been affected; and the basements are dewatered by pumping from inside the building. At both sites, remedial works are expected to be long-term and costly.

The large number of underground petrol tanks in Canberra city and Braddon (Fig. 4) raises the probability of other, as yet undetected, plumes of petrol in the area. Petrol plumes and deep basements can be a lethal combination; the removal of service stations may remove sources of future pollution, but would not remove the petrol that is already underground. In this area, the foundations of buildings that penetrate the water-table are likely to encounter hydrocarbons as well as water and should be designed to exclude both; alternatively the buildings should be founded about 2 m above the water-table.

Consideration should be given to an ordinance governing the filling of fuel storage tanks in order to reduce spillage.

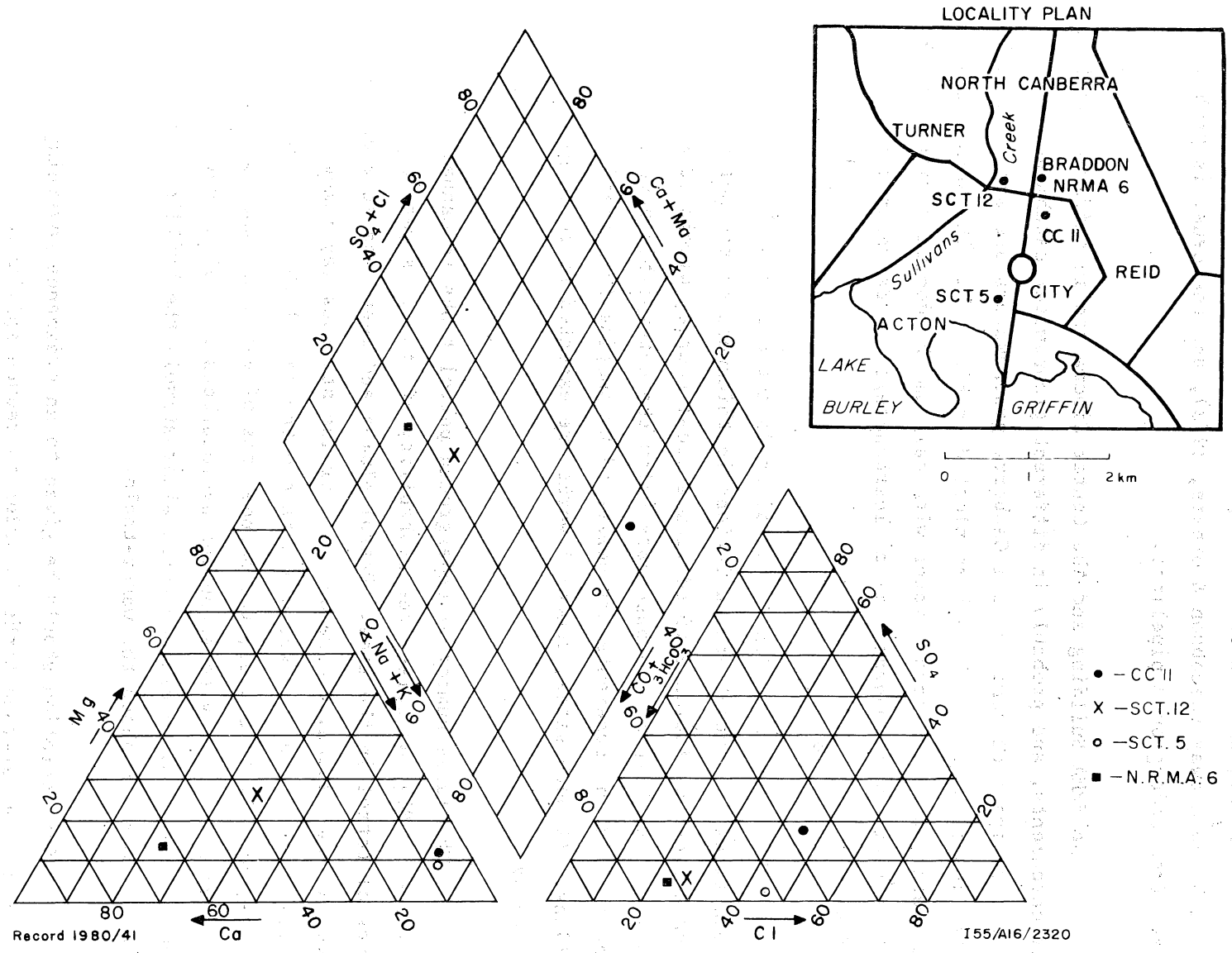


Figure 8 Piper trilinear diagram for Canberra groundwaters. Reacting values for main ionic constituents plotted as percentages.

TABLE 1

CHEMICAL ANALYSES OF GROUNDWATER SAMPLES

	NRMA Building Bore 6 Sept.1979	Sullivans Creek Tunnel 5 Sept. 1979	Sullivans Creek Tunnel 12 Sept. 1979	Center Cinema Bore 11 Feb. 1979
Calcium	84	13	66	5
Magnesium	10	10	31	6
Sodium	32	152	76	69
Potassium	1	1	5	7
Bicarbonate	266	243	370	72
Sulphate	22	6	30	28
Chloride	48	128	84	54
Nitrate	7	4	8	3
Conductivity	586	838	866	371
Total dissolved solids	335	433	482	205
Total hardness	251	74	292	37
Carbonate hardness	218	74	292	37
Non-carbonate hardness	33	0	0	0
Total alkalinity	218	199	303	59
pH	7.4	7.2	7.3	7.0

Analyses by AMDEL, Adelaide.

Chemical composition and derived data in mg/l; conductivity in μS/cm at 25°C

CONCLUSIONS

1. The flows of petrol into the NRMA Building after rain in September 1978 were derived from a pollution plume of petrol located on top of the water-table near the NRMA Building and its surrounds.

2. The pollution plume of petrol is at present (March 1980) up to 0.43 m thick, extends over about 300 m^2, and is estimated to contain at least 2000 litres of petrol.

3. The most likely source of the petrol is the underground tank and pump installation at the rear of the NRMA Building, although it is not possible to positively exclude other petrol storages in the vicinity without establishing additional monitoring bores.

4. The petrol probably infiltrated to the water-table after the tank had been overfilled.

5. The pollution plume constitutes a threat to the safety of the NRMA Building and its occupants. It may, in time, be a potential threat to buildings that lie in the path of the drift of the pollution plume to the southwest, and that have foundations below or within one metre of the water-table.

6. There is no apparent connection between the petrol pollution plume at the NRMA Building and that at the Center Cinema. However, there is potential for further incidents of this kind in Canberra city and Braddon because of the combination of a large number of undergouund tanks and several buildings with basements below or close to the water-table.

RECOMMENDATIONS

1. The necessity for maintaining the underground petrol tank at the rear of the NRMA Building should be considered. Removal of the tank would eliminate a possible source of further pollution.

2. Monitoring of the location and thickness of the pollution plume should continue for as long as it exists.

3. Measures for recovery of the pollution plume should be considered.

4. Permanent ventilation should be installed in those parts of the NRMA Building considered to be at risk from flows of petrol into the drains and the sump.

5. Consideration should be given to reducing the high concentration of underground petrol tanks in Canberra city and Braddon; to the watertight design of basements in the area; and to regulating procedures for the filling of fuel storage tanks.

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APPENDIX 1

LOGS OF DRILLHOLES, NRMA BUILDING, JANUARY 1979

by

J.R. KELLETT

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 1
ANGLE FROM HORIZONTAL (θ) 90 DIRECTION
COORDINATES 141437 Canberra 1:50 000 R.L. OF COLLAR 569.08

HOLE No. 278
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log	Drilling water	Structures	Water level
					0 6 12 18+				
FILL				Auger	1 2 3				petrol level 9.2.79
LIMESTONE Fresh stained	Boulder. Mottled light & dark grey. Fe stained. Numerous healed fractures filled with lime-mud.			100	4			Open Fe stained fractures at 3.3, 3.55, 3.73, 4.15 & 4.45m	
MARL Highly weathered	Pale yellowish brown; some fresh limestone clasts in calcareous cement.			87	5			Rock fabric still apparent. Dip 45	water level 9.2.79
ALLUVIUM	Yellowish brown clayey gravel. Clasts are fresh limestone, shale and calcareous nodules.				6 7				
LIMESTONE Fresh	Limestone boulder. Dark grey with minor light grey mottling. Minor Fe staining 7.5-8.0m. Fine-grained, very hard. Mostly massive but micrite bands dip 43 .			93 100 100	8 9 10 11 12		No significant water loss throughout drilling	Open coated fractures at 7.6, 8.65, 8.8, 8.95, 9.3, 10.05, 10.2, 10.4, 10.8, 11.35, 11.55 & 11.8m.	
ALLUVIUM	Yellowish brown grading to greyish brown. Clayey fine gravel. Clay content decreases with depth. Clasts are mostly non-calcareous shales. Some limestone and calc. nodules down to 14m.			100	13 14 15			Bedding varies between 0 and 5°. Minor slump structures.	
CALCAREOUS MUDSTONE Moderately weathered	Light brownish grey Fossiliferous. Slaty cleavage moderately developed.			100 100	16 17			Bedding 45°, cleavage 65 ; minor parasitic folds. Rock very closely jointed.	
	End of hole 17.35m. Cased to 12m with 50mm perforated pvc pipe: gravel pack below 12m.								

Drill type Mobile Explorer
Feed Hydraulic
Core barrel type Treilus N L M C
Driller Earth Boring Services
Commenced 17.1.79
Completed 19.1.79
Logged by J. Kellett
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole clear to 13.04m after flushing out 25.1.79
Trace of petrol in bore 30.1.79 Column of petrol 0.59m thick on 9.2.79

Checked by

I55/A16/2311

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 2
ANGLE FROM HORIZONTAL (Θ) 90 DIRECTION
COORDINATES 141437 Canberra 1:50 000 R.L. OF COLLAR 569.10

HOLE No. 279
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log	Drilling water	Structures	Water level
					0	6 12 18+			
FILL				Auger	1				
CLAY	Mottled black and greyish yellow. Very dense, structureless - probably from compression during coring. Derived from complete weathering of shale clasts.			38	2 3 4 5 6		No significant water loss throughout drilling	PETROLEUM VAPOURS	petrol level ▼ water level ▼ 8.6.79
ALLUVIUM (CLAY)	Yellowish brown sandy clay. Minor organic material and calcareous nodules.			92	7 8			Bedding 0° to 5°	
ALLUVIUM (GRAVEL)	Pale grey indurated clayey gravel. Calcareous cement. Clasts are mostly subang. quartz.				9			Massive, porous	
ALLUVIUM (CLAY)	Mottled pale grey and yellowish brown gravelly clay. Clasts are mostly shale frags. up to 15mm.			82	10			Bedding 0° to 5° Minor slump structures	
ALLUVIUM (GRAVEL)	Greyish brown silty gravel. Clasts are mostly weath. shale frags ≤ 30mm.			100	11			Bedding highly variable from 0° to 30°. Poor sorting but better than the upper alluvial gravel (7.95-8.8m)	
	End of hole 12.1 m. Cased to 12m with 50mm perforated pvc pipe.				12				

Drill type Mobile Explorer
Feed Hydraulic
Core barrel type Treitus N L M C
Driller Earth Boring Services
Commenced 19.1.79
Completed 19.1.79
Logged by J. Kellett
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole clear to 11.33m after flushing out 25.1.79
PETROL VAPOURS IN CORE FROM 2 TO 4m Trace of petrol in bore 15.5.79
Column of petrol 0.37m thick on 8.6.79

Checked by

155/A16/2312

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 3
ANGLE FROM HORIZONTAL (O) 90 DIRECTION
COORDINATES 141437 Canberra 1:50 000 R.L. OF COLLAR 569.21

HOLE No. 280
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log (0 6 12 18+)	Drilling water	Structures	Water level
FILL									
ALLUVIUM	Pale greyish brown gravelly clay. Clasts are mostly subrounded non-calc. shale up to 30mm. Minor quartz.			5				Core loss in this section due to flushing	petrol level
LIMESTONE Fresh	Limestone boulder. Mottled very dark grey (organic) and pale grey, stylolites in places.			85			90% water loss as soon as limestone was intersected. Partial recovery after 30 mins.	Bedding well defined by 12mm micritic laminae, dip 42°	water level 14.6.79
ALLUVIUM	Yellowish brown gravelly clay. Clasts are dominantly shale ~ 10mm.			Av 36			Complete water loss throughout this section for the duration of drilling	No core recovered in this section. Either megavoid or extremely open structure in alluvium	
	50mm feldspathic sand layer at 11.8m.			62					
	End of hole 13.97m. Cased to 12m with 50mm perforated pvc pipe; gravel pack 12-13.5m								

Drill type *Mobile Explorer*
Feed *Hydraulic*
Core barrel type *Treifus N L M C*
Driller *Earth Boring Services*
Commenced *20.1.79*
Completed *20.1.79*
Logged by *J. Kellett*
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole clear to 10.97m after flushing out 25.1.79
Trace of petrol in bore 30.1.79 *Complete water loss from 7.9m*
Column of petrol 0.44m thick 14.6.79

Checked by

155/A16/2316

CANCELLED

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 4
ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
COORDINATES 141437 Canberra 1:50,000 R.L. OF COLLAR 589.20

HOLE No. 281
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log	Drilling water	Structures	Water level
FILL					0 1	0 6 12 18+	No significant water loss		water level 30.1.79
LIMESTONE Fresh stained	Boulder. Mottled dark & light grey. Massive, Fe stained. Deeply etched at base.			64	2 3				
CLAY	Mottled grey & yellowish brown, some red pigmentation above 3m. Derived from complete weathering of shale clasts.			80	4 5				
				33	6			Core loss in this section all in clay flushed out at surface.	
LIMESTONE Fresh stained	Boulder. Mottled dark & light grey. Massive, Fe stained				7				
ALLUVIUM	Yellowish brown sandy clay. Shale clasts ≤ 3mm, minor organic content.			60	8				
LIMESTONE Fresh	Limestone boulder. Very finely crystalline, dark grey. Abundant stylolites. Occasional micritic bands dip 45°.			90	9 10		Complete water loss in this section	Open stained joints in limestone at 8.8, 9.0, 9.1, 9.25 & 9.95m. 10mm clay seam or open void at 9.6m	
ALLUVIUM	Brown clayey fine grav. Clasts are subrounded shale & Fe pisolites.			83	11				
	End of hole 12.0m. Cased to 12m with 50mm perforated pvc pipe.				12				

Drill type *Mobile Explorer*
Feed *Hydraulic*
Core barrel type *Treilus N L M C*
Driller *Earth Boring Services*
Commenced *20.1.79*
Completed *21.1.79*
Logged by *J. Kellett*
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole clear to 10.24m after flushing out 25.1.79
Complete water loss from 8m

Checked by

155/A18/2315

CANCELLED

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 5

ANGLE FROM HORIZONTAL (θ) 90° DIRECTION
COORDINATES 141437 Canberra 1:50 000 R.L. OF COLLAR 569.12

HOLE No. 282
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log	Drilling water	Structures	Water level
FILL				Auger	1				
LIMESTONE — Mod. weath —	Boulder. Pale grey with brown mottles. Strongly etched.							Bedding 32°	
ALLUVIUM (Indurated)	Mottled white & brown cemented clayey gravel. Clasts are 10mm quartz & soft calcareous nodules.			35	2 3		No significant water loss	Massive, porous	water level 30.1.79
ALLUVIUM (CLAY)	Yellowish brown gravelly clay grading to clayey sand. Clasts mostly shale with minor calc. nodules.			81	4 5				
LIMESTONE Highly weathered	Pale grey Heavily Fe stained on joint faces. 12cm clay seam. No recovery in this section. Sudden drop in drill stem.			89 Av 69 Av 68	6 7 8		est. 50% water loss. Complete water loss throughout this section	Rock very closely fractured. Probable cavern. Assumed to be responsible for total water loss. No open fractures in this section.	
CLAY	Yellowish brown gravelly clay. Clasts mostly 20mm shale and calcareous mudstone.			70	9 10 11			Low angle relict bedding	
	End of hole 12.0m. Cased to 12m with 50mm perforated pvc pipe.				12				

Drill type Mobile Explorer
Feed Hydraulic
Core barrel type Treitus N L M C
Driller Earth Boring Services
Commenced 21.1.79
Completed 22.1.79
Logged by J. Kellett
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole open to 5.65m only after flushing 25.1.79 — obstruction (rock ?)
Complete water loss from 6.7m

Checked by

155/A16/2313

BUREAU OF MINERAL RESOURCES,
GEOLOGY & GEOPHYSICS

GEOLOGICAL LOG OF DRILL HOLE

PROJECT N.R.M.A. building
LOCATION Braddon D.H. 6
ANGLE FROM HORIZONTAL (θ) 90 DIRECTION
COORDINATES 141437 Canberra 1:50 000 R.L. OF COLLAR 569.34

HOLE No. 283
Canberra
SHEET 1 OF 1

Rock Type and Degree of Weathering	Description Lithology, colour, strength, etc.	Casing	Graphic Log	Lift and % core recovery	Depth and size of core	Fracture Log	Drilling water	Structures	Water level
FILL				Auger	0–1	0 6 12 18+			
ALLUVIUM (LATERITIZED)	Mottled strong red & yellow clay with sand lenses ~ 20mm			39	1–3		No significant water loss	Abundant sesquioxides. Sand layers dip 10° to 30°	
	Pale grey silicified fine sand.				3–4			Pallid zone	
LIMESTONE Fresh stained	Mottled light grey and very dark grey with dark micritic laminae to 3mm.			85	4–6		est. 30% water loss	Bedding 52 Open coated joints at 4.35, 4.6, 6.4, 6.65 & 6.95m. All etched.	water level ▼ 30.1.79
	Bordering joints in limestone deeply etched. Cavity ? Little resistance to core barrel.			82	6–8		Complete water loss throughout this section. (assumed to be all lost in cavity 6.4-7.0m).		
(CLAY) ALLUVIUM (GRAVEL)	Yellowish brown gravelly clay grading to silty gravel. Clasts are mostly subrounded non-calc. shale up to 30mm ; some limestone clasts in top 1m			76	8–10			Low angle bedding. Numerous slump structures.	
				100	10–11				
	End of hole 12.0m. Cased to 12m with 50mm perforated pvc pipe.				11–12				

Drill type Mobile Explorer
Feed Hydraulic
Core barrel type Treifus N L M C
Driller Earth Boring Services
Commenced 23.1.79
Completed 23.1.79
Logged by J. Kellett
Record 1980/41

Notes

Fracture Log-Number of fractures per 25cm of core. Zones of core loss blacked in.
Bedding & Joint Planes - Angles are measured relative to a plane normal to the core axis
No mud used in drilling (diamond cored with water only)
Hole clear to 11.36m after flushing out 25.1.79
Complete water loss from 6.4m

Checked by

155/A16/2314