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TITLE: HYDROGEOLOGY AND DRILLING RESULTS OF THE 1969-1970 DROUGHT RELIEF PROGRAMME

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HYDROGEOLOGY AND DRILLING RESULTS OF THE 1969-1970 DROUGHT RELIEF PROGRAM

by W.A. Davidson

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HYDROGEOLOGY AND DRILLING RESULTS OF THE 1969-1970 DROUGHT RELIEF PROGRAM

by W.A. Davidson

INTRODUCTION (Plate 1)

During 1969 rainfall for the agricultural areas in the southwest of Western Australia was far below the annual average and drought areas were declared for many Shires. Most farm dams only had natural (unimproved) catchments, there being few roaded or sealed catchments which might concentrate rainfall toward the dams. Consequently most farmers were unprepared for drought and many dams were dry by January, 1970.

A drought relief groundwater exploratory drilling program was established towards the end of 1969 and continued into 1970. The following areas were eligible for drought relief drilling: Mount Marshall-Koorda, Westonia, Burracoppin South, South Yilgarn, Mount Walker, Kulin-Kondinin, Holt Rock, Nyabing-Pingrup, Lake Grace, Ravensthorpe, Ongerup, Chillinup, North Stirling, South Stirling and Fitzgerald.

Because of the severity of the drought many sites asked for by the farmers were drilled, some being geologically not very favourable for groundwater.

A bore yielding more than 4.5 m^3/d (1 000 gallons per day) of groundwater having less than 11 000 mg/l TDS (milligrams per litre, Total Dissolved Solids) was classified as successful, these limits being set by the Department of Agriculture.

Selection of bore sites and supervision of drilling was done by the Geological Survey. The resulting reports have been incorporated, partly verbatim, into this record, as well as being listed in the references.

Between July and September, 1976, a field check was made of how many successful drought relief bores have been equipped and used.

MOUNT MARSHALL - KOORDA

LOCATION AND TOPOGRAPHY

The Mount Marshall-Koorda area is centred about Lake Mollerin, Lake O'Grady, Lake Harvey and the southern end of Lake Moore.

The land surface is flat to gently undulating with Mount Collier, a prominent granite 'rock' between Lake Moore and Lake O'Grady, being the main topographic relief.

GEOLOGY

Most of the area is covered with silty sand which is underlain by granite and allied rocks. West of Lake O'Grady and east of Lake Moore drilling has revealed large areas of deep weathering, exceeding, in a number of cases, 60 m.

Dolerite dykes and quartz veins quite commonly form small narrow ridges.

HYDROGEOLOGY

Rainfall

The annual average rainfall is about 280 mm most of which falls between June and September. However, it is unreliable and spasmodic.

Groundwater

Hydrogeologically the outstanding characteristic of the region is not salinity or shallow bedrock, but the almost total absence of groundwater, where according to

general rules and experience elsewhere, it should be found.

Two examples illustrate this:

1. From Mount Collier, an excellent bare granite catchment, long, sandy slopes fall towards Lake Moore and Lake O'Grady. Seventeen bores were drilled on these slopes at varying elevations, but no, or little, usable groundwater was located until the lakes were approached (where the salinity is very high).

2. West of Lake O'Grady and east of Lake Moore where deep weathering of the granite has been proved by drilling, very little groundwater is available. These weathered zones, although permeable, and favourably located with respect to catchment and infiltration, are dry or near dry.

In both these examples the absence of groundwater appears to be due to (1) the rapid movement of the groundwater down into the centres of internal drainage (lakes), a feature which is probably caused by the absence of concealed granite, or other impermeable barriers, or (2) the groundwater follows preferred more permeable paths with the less permeable inter-areas evapotranspiring all of the rainfall.

As a general rule the salinity of the groundwater increases with increasing distance from high recharge areas and becomes exceedingly salty near the lakes.

DROUGHT RELIEF INVESTIGATIONS 1969-1970
(Table 1)

Number of properties inspected	31
Number of Government Reserves inspected	2
total	33

Number of properties recommended for drilling	..	24
Number of Government Reserves recommended for drilling	..	1
total		25

Number of properties drilled successfully	.. ..	9
Number of Government Reserves drilled successfully	..	0
total		9

Number of properties drilled unsuccessfully	..	15
Number of Government Reserves drilled unsuccessfully	..	1
total		16

Table 1: Summary of drought relief drilling: Mount Marshall-Koorda

	Properties		Reserves	
	No.of bores	Total depth	No.of bores	Total depth
		(m)		(m)
Dry	85	2 492	5	163
Wet-insufficient supply	41	1 448		
Wet-saline supply	5	101		
Wet-suitable supply	10	265		
Abandoned	20	378		
totals	161	4 684	5	163

FOLLOW—UP SURVEY 1976 (Table 2)

During July, 1976, a follow-up survey was conducted to establish how many of the 10 successful 1969-1970 drought relief bore sites had been developed.

Results : 4 successfully developed
2 not successfully developed
4 not developed.

Two attempts were made at each of the unsuccessful sites. The aquifer at site No.2336-ID32 is a quartz vein containing only a thin fresh-water film over a very brackish groundwater body. Both attempts to secure a successful bore failed and the bores were abandoned when the salinity of the groundwater increased to more than 15 000 mg/l TDS.

Poor bore construction may be the cause of the bores failing at site 2336-IA11. Generally, farmers require instruction on the methods available to reduce silting of bores, by using proper methods of developing the supply.

Table 2: Status of drought relief successful bores: Mount Marshall-Koorda, July 1976

Owner	Litho	Loc.	Bore No.	1969-1970			1976		
				Depth m	Supply m^3/d	Salinity TDS mg/l	Success-fully developed	Unsuccess-fully developed	Not developed
L.E. Job	66/80	3736	2436-ID10	24.4	9	2000	x		
R. & R. Caldenwood	66/80	2569	2437-IIIB30	42.7	9	7650			x
P.R.Groves	55/80	2399	2436-IC1	15.2	5	4900			x
"	55/80	2397	2436-IVB9	15.2	5	8000			x
G.J. Colins & Co.	55/80	2355	2436-IC4	33.5	7	6100	x		
J.Ross	65/80	1227	2337-IIC17	18.3	11	3000	x		
L.E. & W.M. Collins	65/80	1308	2437-IIIC1	13.7	13	2000	x		
Wilson Bros	65/80	2408	2336-ID15	27.4	11	4900			x
J.N. Westlund	65/80	1240	2336-ID32	37.5	14	5000		x[1]	
A.E. Chester	65/80	2784	2336-IA11	36.6	23	2900		x[2]	
totals							4	2	4

1. Two bores were drilled and abandoned because the salinity of the groundwater rose to more than 15 000 mg/l.

2. Two bores were drilled and abandoned because of silting problems.

COMMENTS ON FUTURE SITING OF BORES

If rapid outflow from the intake areas (or the presence of preferred groundwater paths) is the reason for the almost total absence of groundwater, then the selection of bore sites becomes speculative, because there is no apparent relationship between topography and groundwater accumulation.

However, large catchments with long drainage slopes are still the most prospective areas for groundwater even though many have proved unsuccessful.

If there is a thick sequence of sand and clay overlying the fractured basement rock, or if groundwater barriers are present to trap the throughflowing groundwater then chances of success are enhanced.

Drilling should continue down into the underlying fresh bedrock and the entire saturated thickness opened to the bore by slotted casing.

WESTONIA

LOCATION AND TOPOGRAPHY

The Westonia drought relief area is between Mukinbudin and Southern Cross and occupied a strip of country which is predominantly gently undulating but does have a few large granitic hills which rise abruptly from the general surface of the land.

GEOLOGY

The hill tops are either granitic outcrop, lateritic caprock or a thin cover of sand over a granitic basement.

The sandy slopes are underlain by kaolinized porphyritic granite and fine- to medium-grained granite which have been intruded by quartz-feldspar pegmatites, quartz-epidote veins and by dolerite dykes.

Lower in the poorly defined drainages the depressions have been infilled with alluvium and colluvium consisting of poorly sorted sand and clay.

The basement rocks may be fractured at depth as indicated by the prominent fractures and fracture lines in the granites exposed at the surface.

HYDROGEOLOGY

Rainfall

The average annual rainfall which is variable and unreliable is about 280 mm. Most of the rain is evaporated or transpired and only a very low percentage reaches the water table.

Groundwater

In this environment groundwater occurs in two ways.

1. Soil mantle: The groundwater which occurs in the soil mantle is often the freshest particularly when fairly high in the drainage. Rainfall enters the ground most easily where there is a sandy or laterite cover. The groundwater tends to move downslope from the higher ground toward the depressions or valleys where it forms salt lakes. Only small yields can be expected from bores within the soil mantle with perhaps the best supplies coming from thick sands adjacent to granite outcrops.

2. Weathered bedrock: Some of the soil water seeps to a deeper level in the underlying weathered bedrock and is stored in joints and fissures.

The salinity of the groundwater varies considerably ranging from less than 1 000 mg/l to more than 10 000 mg/l. During the infiltration process the water increases in salt content, and the farther it moves underground the more brackish it becomes. Generally, the groundwater at low topographic levels is more saline than the water

found higher up the slopes towards the recharge areas.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 3)

Number of properties inspected	24
Number of Government Reserves inspected	7
total	31
Number of properties recommended for drilling ..	22
Number of Government Reserves recommended for drilling ..	6
total	28
Number of properties drilled successfully	9
Number of Government Reserves drilled successfully	2
total	11
Number of properties drilled unsuccessfully	13
Number of Government Reserves drilled unsuccessfully	4
total	17

Table 3: Summary of drought relief drilling: Westonia

	Properties and Reserves	
	No. of bores	Total depths (m)
Dry	159	2482
Wet-insufficient supply	76	1685
Wet-saline supply	22	579
Wet-suitable supply	25	574
Abandoned	4	50
totals	286	5370

FOLLOW-UP SURVEY 1976 (Table 4)

During July, 1976, a follow-up survey was conducted to establish how many of the 25 successful 1969-1970 drought relief bore sites had been developed.

Results : 7 successfully developed
18 not developed.

Twelve of the eighteen sites were not developed because the yields and salinities were not satisfactory for the farmers requirements.

The three sites on Yanneymooning Hill Reserve were not developed because sufficient supplies were found on nearby farms.

Two of the three sites at Geelabin Rock Reserve were not developed because the third provided large enough yields to satisfy the demands.

One site was not developed because the farm changed ownership.

COMMENTS ON FUTURE SITING OF BORES

There are two main sources of groundwater in the Westonia area.

1. Large catchments with long gentle slopes and comparatively large drainages are fairly prospective areas for groundwater drilling particularly if there is a thick sequence of sand and clay overlying fractured basement rock.

2. Thick superficial sands adjacent to large granitic outcrops.

Yanneymooning Hill and Geelabin Rock Reserves are probably the best areas for developing community supplies of groundwater.

In all cases drilling should be continued down into fresh bedrock and the entire saturated thickness opened to the bore by slotted casing or screens.

Table 4: Status of drought relief successful bores: Westonia, July 1976

Owner	Litho	Loc.	Bore No.	1969-1970			1976		
				Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
Govt Res. Yanneymooning Hill	54/80	24406	2636-IVC28	21.3	14-23	370			x
"	"		2636-IVC29	29.6	23	230			x
"	"		2636-IVC23	15.2	68	100			x
Warrachuppin Res.	35/80		2635-IVA41	12.2	5	700			x
"	"		2635-IVA46	25.9	9	1110			x
"	"		2635-IVA47	22.9	14	11100			x
Geelabin Rock Res.	54/80	347	2636-IIIC1	27.4	45	300	x		
"	"		2636-IIIC17	21.3	23	480			x
"	"		2636-IIIC20	33.5	45	590			x
M.Lane	35/80	303	2635-IVB6	13.7	7	7400			x
Palmer (Della Bosca)	24/80	119	2634-IVA1	54.9	7	9000			x
H.M.Poole & Sons	35/80	301	2635-IVB10	40.2	7	6150			x
"	"	309	2635-IVA35	9.1	9	500			x
"	"	306	2635-IVD5	8.8	7	640			x
Max Halbert & Sons	35/80	327	2635-IVA12	9.1	7	1300			x
"	"	339	2635-IVA24	12.5	5	10000			x
"	"	327	2635-IVA30	13.1	18	480	x		
A.R.Priestly	35/80	334	2635-ID46	13.7	14	230			x
W.Duncan	54/80	1444	2636-IID7	48.8	9	3330	x		
A.M. & J.M. Morrison	54/80	363	2636-IIIC26	35.1	14	5770	x		
D.McDowall	35/80		2635-ID11	13.7	7	630	x		
"	"		2635-ID15	18.3	7	10700			x
"	"		2635-ID19	15.2	9	10000			x
"	"		2635-ID20	49.4	9	570	x		
"	"		2635-ID25	9.1	14	210	x		
totals							7	0	18

BURRACOPPIN SOUTH

LOCATION AND TOPOGRAPHY

Burracoppin South is east of Merredin and southwest of Westonia. The country is gently undulating with some of the higher elevations being capped with laterite. Small lateritic breakaways can be seen in these areas.

GEOLOGY

Most of the area is covered with sandy to loamy soils with the higher elevated areas containing abundant loose lateritic gravel and some solid laterite capping. The slopes are covered with loosely consolidated sandy gravel with some clay.

A white, very hard kaolinitic-rich clay representing weathered granitic basement is at fairly shallow depth.

A typical section will be (a) laterite gravel and clayey sands, underlain by (b) kaolinitic-rich clay with some quartz sand, underlain by (c) weathered granitic rock with quartz, some weathered feldspar and kaolinitic clay resting on (d) fresh granitic basement, sometimes fractured.

Dolerite dykes may also be present.

HYDROGEOLOGY

Rainfall

The average annual rainfall is about 300 mm but is unreliable. Most of the rainfall is lost to evapotranspiration and only a very small percentage reaches the water table.

Groundwater

All the successful drought relief (1969) bores for this area were situated on the western side. A much larger proportion of the bores in the east were completely

dry. No mills exist in the east part of the area.

In many cases bores in the east had a washed, iron-stained layer of weathered granite - sometimes with definite sand layers - on top of the bedrock. It is clear that these layers have at one time experienced substantial amounts of groundwater passing through them. It seems that the water moves comparatively quickly through these layers until it reaches the salty groundwater reservoirs in the main drainage depressions.

In the western area groundwater is obtained from the geological zones (a) to (d).

Auld (No.2534-IB9) obtained a supply from lateritic gravel on top of hard lateritic conglomerate - the hard iron-pan often encountered at the base of laterite in this area.

Five bores (Auld Nos.2534-IB10 and 2534-IB14, Crosthwaite No.2534-IB22,J. Liebeck No.2634-IVC23 and Veitch No.2634-IIID21) yielded a supply from sandy kaolinized granite. All except the last-named were on or near drainages from granites although in the cases of Auld No.2534-IB14 and J. Liebeck No.2634-IVC23 they were quite some distance from the outcrops.

Two bores (Crosthwaite No.2534-IB17 and Girando No.2534-IA17) were located very close to large granite outcrops, locating water in fractured granite. One other bore (Ellery No.2634-IVD14) also encountered a supply in fractured granite, but much further from granite outcrops in a sandy depression.

The Mount Cramphorne Reserve test bore No.2634-III A29 was tested by air-blowing for 6 hours with no lowering of the water level. The production bore, however, failed to yield any supply. Therefore either a limited reservoir had been exhausted, or some other explanation must be sought. Other bores close to rocks, with water in fractures, have also failed on occasion, so perhaps another factor is involved. This other factor could be the blocking off of fractures by sand, silt and clay, caused by the violent agitation of air-blowing or test-pumping.

DROUGHT RELIEF INVESTIGATIONS 1969-1970

(Table 5)

Number of Properties inspected	21
Number of Government Reserves inspected	1
total	22
Number of properties recommended for drilling ..	21
Number of Government Reserves recommended for drilling ..	1
total	22
Number of properties drilled successfully	6
Number of Government Reserves drilled successfully ..	1
total	7
Number of properties drilled unsuccessfully	15
Number of Government Reserves drilled unsuccessfully ..	-
total	15

Table 5: Summary of drought relief drilling: Burracoppin South

	Properties		Reserves	
	No.of bores	Total depth m	No.of bores	Total depth m
Dry	93	2570	12	207
Wet-insufficient supply	29	924	3	61
Wet-saline supply	9	325	-	-
Wet-suitable supply	10	301	2	24
Abandoned	16	575	1	23
totals	157	4695	18	315

FOLLOW—UP SURVEY 1976 (Table 6)

During August, 1976, a follow-up survey was conducted to establish how many of the 12 successful 1969-1970 drought relief bore sites had been developed.

Results : 8 successfully developed
3 not developed
1 not successfully developed.

The two Mount Cramphorne Reserve sites were not required and therefore not developed.

Site 2534-IA14 was not developed because 2534-IA17 failed.

After developing and equipping site 2534-IA17 the yield dropped below 5 m^3/d and the bore failed probably due to poor construction and developing techniques.

Table 6: Status of drought relief successful bores: Burracoppin South, August 1976

Owner	Litho	Loc.	Bore No.	1969-70			1976		
				Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
E.Ellery	24/80	25250	2634-IVD14	42.7	14	955	x		
G.D. Crosthwaite	24/80	18059	2534-IB17	29.9	14	3360	x		
"	"	18259	2534-IB22	30.5	9	782	x		
H.C.Auld	24/80	19102	2534-IB9	9.1	5	1992	x		
"	"	18264	2534-IB10	29.3	7	100	x		
"	"	19106	2534-IB14	36.6	14	3500	x		
Mt Cramphorne Res.	5/80	19211	2634-IIIA27	9.1	68	570			x
"	"	"	2634-IIIA28	15.2	23	397			x
G.Girando	24/80	20753	2534-IA14	24.4	5	270			x
"	"	"	2534-IA17	25.0	7	410		x	
J.Liebeck	24/80	18275	2634-IVC23	42.1	9	5356	x		
D.N.Veitch	5/80	18270	2634-IIID21	24.4	14	6672	x		
totals							8	1	3

COMMENTS ON FUTURE SITING OF BORES

Although reasonable chances of finding usable groundwater on the west side of the area exist, the east side appears quite lacking in such chances. Some alternative source of water must therefore be provided on the eastern side, if the results of future droughts are to be avoided.

Key dams - or perhaps an extension of scheme water - would seem to be the answer.

Mount Cramphorne area appears the most prospective area for locating a community groundwater supply providing that the production bore failure was mechanical and not geological.

SOUTH YILGARN

LOCATION AND TOPOGRAPHY

South Yilgarn covers an area southeast of Westonia and is mainly on the western side of the Southern Cross greenstone belt.

The country is gently undulating with long rolling sandy slopes and a few low ridges marking quartz veins and dolerite dykes.

GEOLOGY

Most of the area is covered with silty sand, some with laterite, and is mainly underlain by granite and allied rocks.

A greenstone belt occupies the eastern margin and dolerite dykes and quartz veins are scattered throughout.

HYDROGEOLOGY

Rainfall

The average annual rainfall is about 280 mm but is unreliable. Most of the rainfall is lost to evaporation and transpiration and only a very small percentage reaches the water table.

Groundwater

There are very few mills in the area, and almost all of these are situated towards the base of long sand and gravel slopes. Numerous similar sites were drilled during the 1969-1970 drought relief program, but without success - although many bores exceeded 45 m before reaching bedrock.

Only one success was obtained during the drought relief drilling. This was in shallow yellow sand on the west side of a large north-south quartz ridge. There were already three previously successful bores along this line. Test boring on the east side of the same quartz ridge was unsuccessful.

Most of the farms drilled during the 1969-1970 drought relief had a number of other bores put down over the years, with very little success. One farmer - A. McKenzie - had 52 bores on his property of 1 863 hectares for one success only.

It seems that (1) most of the groundwater moves fairly rapidly down into the main saline drainages, so that there is almost no usable groundwater in the area, or (2) most of the rainfall is lost to evapotranspiration and does not form groundwater.

DROUGHT RELIEF INVESTIGATIONS 1969-1970
(Table 7)

Number of properties inspected	15
Number of Government Reserves inspected	-
total	15
Number of properties recommended for drilling ..	15
Number of Government Reserves recommended for drilling ..	-
total	15
Number of properties drilled successfully	1
Number of Government Reserves drilled successfully ..	-
total	1

Number of properties drilled unsuccessfully	14
Number of Government Reserves drilled unsuccessfully	-
total	14

Table 7: Summary of drought relief drilling: South Yilgarn

	Properties		Government Reserves
	No.of bores	Total depth m	
Dry	74	2 140	
Wet-Insufficient Supply	23	814	
Wet-Saline Supply	3	88	
Wet-Suitable Supply	1	9	Nil
Abandoned	5	109	
totals	106	3 160	

FOLLOW-UP SURVEY 1976 (Table 8)

The original successful site has not been redrilled or developed and is covered with drift sand making its location impossible. Two successful production bores have been drilled within 200 m of this site.

Table 8: Status of drought relief successful bore: South Yilgarn, July 1976

				1969-1970			1976		
Owner	Litho	Loc.	Bore No.	Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
J.H.Panizza	23/80	464	2734-ID5	9.1	5	8800	x		

COMMENTS ON FUTURE SITING OF BORES

Because of the apparent almost total absence of usable groundwater, future drilling cannot be recommended.

An alternative source of supply - key dams or an extension of scheme water - must be sought if the effects of future droughts are to be avoided.

MOUNT WALKER

LOCATION AND TOPOGRAPHY

Mount Walker is a marginal agricultural district in the eastern part of the Shire of Narembeen. The 1969 drought relief drilling area is west of No.1 Rabbit Proof Fence, and is about 48 km north-south and an average of 48 km east-west. Mount Walker is a conspicuous granite hill, in the central part.

The only outstanding relief features are scattered granite hills (like Mount Walker), examples being Mount Anderson, Gibb Rock and Glenelg Rock. Otherwise the country consists of flat to gently undulating featureless sandplain with tracts of heavy clay soils on the lower ground.

GEOLOGY

It appears that there has been some superficial sorting of the soil on the slopes and that wind and water have removed the finer clay and soluble constituents from the slopes and deposited them in the lower areas. The result is a superficially sandy soil on the slopes and the addition of excessive clay to that already in the valleys. These soils are underlain by broken granitic rocks resting on an irregular surface of fresh granite.

HYDROGEOLOGY

Rainfall

The average annual rainfall which mainly falls during the winter months is about 320 mm. Most of the rainfall is lost to evaporation and transpiration, and only a very small percentage reaches the water table.

Groundwater

All of the existing groundwater supplies are derived from a granite fracture-zone which varies in thickness between 6 m and 55 m.

The following hydrological characteristics have been recognized:

1. The rapidly changing bedrock relief is unrelated to the surface contours. The deeper zones of decomposition are not in the depressions and valleys, but in the middle and upper parts of the slopes. Valleys and depressions are unproductive and all the producing bores are on higher ground.

2. In the great majority of cases the zones of decomposition (potential aquifers) are impermeable, consisting of a uniform sequence of highly kaolinized granite with varying amounts of quartz grit. Many of these zones are water saturated but cannot be developed into production because of the excessive amount of fines.

3. Horizontal salinity variations are extreme within short distances. In one instance the variation amounted to 8 000 mg/l within less than 30 m. This must be due to the very irregular granite configuration, which brings about the formation of unconnected bodies of groundwater, each with its own water table and chemical characteristics.

4. Salt affected areas on higher ground deserve special attention because they indicate a shallow water table, and can be developed into soaks, 3 m to 6 m in depth. The groundwater below these salt patches is saline enough to kill the vegetation, but is still usable for stock. Salinities are in the order of 5 000 to 7 000 mg/l.

5. By far the most promising bore sites are on the periphery of granite rocks, but it is essential that the basins in which the bores are situated are closed. A closed basin is one in which a pronounced ridge of solid rock occurs on the side towards which the groundwater gravitates. This has an impounding effect preventing outflow of groundwater.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 9)

Number of properties inspected	32
Number of Government Reserves inspected	2
total	34
Number of properties recommended for drilling ..	25
Number of Government Reserves recommended for drilling ..	2
total	27
Number of properties drilled successfully	8
Number of Government Reserves drilled successfully ..	1
total	9
Number of properties drilled unsuccessfully	17
Number of Government Reserves drilled unsuccessfully ..	1
total ..	18

Table 9: Summary of drought relief drilling: Mount Walker

	Properties		Government reserves	
	No.of bores	Total depth m	No.of bores	Total depth m
Dry	81	2 352	4	128
Wet-Insufficient Supply	12	322	3	108
Wet-Saline Supply	14	379	-	-
Wet-Suitable Supply	11	318	1	43
Abandoned	11	424	8	314
totals	129	3 795	16	593

FOLLOW—UP SURVEY 1976 (Table 10)

During August, 1976, a follow-up survey was conducted to establish how many of the 12 successful 1969-1970 drought relief bore sites had been developed.

Results : 1 successfully developed
11 Not developed.

Four of the eleven undeveloped sites were considered failures by the farmers because of low yields and high salinities, even though these were still within the drought relief limits. One bore was abandoned due to drilling difficulties. The remaining six sites were not developed because either the farms changed ownership or the drought ended before the bores were required.

Table 10: Status of drought relief successful bores: Mount Walker, August 1976

				1969-1970			1976		
Owner	Litho	Loc.	Bore No.	Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
J.R.Sprigg	5/80	24258	2634-IIIC30	45.7	5+	1290	x		
J.Starcevich	5/80	24850	2634-IIIC13	6.1	9	8650			x
I.Starcevich	5/80	10202	2634-IIIA17	31.1	5+	7650			x
M. & A.N. Romanelli	5/80	19183	2634-IIIA9	55.2	5	5230			x
"	"	19183	2634-IIIA10	12.2	5	3770			x
Caughey & Copley	345/80	2339	2633-IVB10	51.8	5	3670			x
"	"	2338	2633-IVB12	9.1	9	4220			x
F.G. & M.I. Harders	345/80	2397	2633-IC1	42.7	14	4050			x
A.B.Lethlean	5/80	2217	2633-IVA2	36.6	5+	8750			x
"	"	2217	2633-IVA3	3.0	5	7300			x
Coker & Co.	346/80	2102	2633-IA5	24.4	14	9945			x
Gibb Rock	346/80		2733-IVD24	43.0	14	200			x
totals							1	0	11

COMMENTS ON FUTURE SITING OF BORES

All of the successful bore sites have been drilled in weathered and fractured granite, the most successful being those near the periphery of granite rocks, especially if on fairly high ground. In the future these areas should be investigated first.

Additional supplies may also be obtained from the high level salt-affected areas by digging soaks. In these situations the groundwater will be quite brackish but probably suitable for dry stock.

KULIN - KONDININ

LOCATION AND TOPOGRAPHY

The main area covered by this section is north and (mostly) south of the road from Kondinin to Hyden, extending from a point 19 km east of Kondinin to the township of Karlgarin.

The landscape is featureless except for a number of granite hills on the highest parts of the divides (Karlgarin Hills, Scriveness, Dandagin Rock).

The southwestern portion of the area is in a wide ill-defined, flat-floored trunk valley occupied by a chain of salt lakes, of which Jilakin Lake is the most prominent.

GEOLOGY

Most of the surface is covered by a blanket of yellowish or pale-grey sands overlying either fresh granite or weathered zones of varying thickness. Iron-capped lateritic residuals, bounded by breakaways occur on the higher ground.

HYDROGEOLOGY

Rainfall

The average annual rainfall which mainly falls during the winter months is about 350 mm. Most of the rainfall is lost to evaporation and transpiration and only a very small percentage reaches the water table.

Groundwater

An attempt was made to establish community supplies and for this purpose a number of reserves, surrounding the more prominent granite bosses, were tested. With the exception of Horsecollar Rock this was not successful because of shallow basement rocks within the reserve boundaries.

Away from the granite rocks the conditions are generally not favourable for infiltration, because of lack of relief. The result is that supplies are insufficient, or saline because of the combined effects of high evaporation, slow absorption and sluggish groundwater movement. Closely spaced drilling in many areas has shown that the flow paths from intakes to discharge areas are not short and simple, but very irregular and sinuous. Often they are narrow zones in which the depth and degree of weathering are most favourable. These zones are difficult to locate under soil cover and, in the absence of geophysical work, the only way to find them is by drilling.

Occasionally very high salinity groundwater may be found at high elevations if the water-bearing sands are small and locally confined.

DROUGHT RELIEF INVESTIGATIONS 1969-1970

(Table 11)

Number of properties inspected	33
Number of Government Reserves inspected	14
Total ..	47
Number of properties recommended for drilling ..	31
Number of Government Reserves recommended for drilling ..	7
Total ..	38
Number of properties drilled successfully	6
Number of Government Reserves drilled successfully ..	2
Total ..	8
Number of properties drilled unsuccessfully	25
Number of Government Reserves drilled unsuccessfully ..	5
Total ..	30

Table 11: Summary of drought relief drilling: Kulin-Kondinin

	Properties		Government Reserves	
	No.of bores	Total depth	No.of bores	Total depth
		m		m
Dry	105	2 471	15	276
Wet-Insufficient Supply	14	598		
Wet-Saline Supply	12	447	2	103
Wet-Suitable Supply	8	336	2	73
Abandoned	4	94		
Totals	143	3 946	19	452

FOLLOW—UP SURVEY 1976 (TABLE 12)

During August, 1976, a follow-up survey was conducted to establish how many of the 10 successful 1969-1970 drought relief bore sites had been developed.

Results: 3 successfully developed
7 not developed.

Exploratory bores 2633-IIIB15 and 2532-IID10 were not developed because they contained groundwater with salinities too high for the farmers' requirements. Site 2632-IVA13 was not developed because the farm changed ownership and the remaining four undeveloped sites were not required because the drought ended before the farmers' existing water supplies were depleted.

COMMENTS ON FUTURE SITING OF BORES

The most prospective areas for groundwater are fairly high on the drainage slopes and, as a general rule, are about one to one and a half kilometres downslope from the granite intake areas. Many of the successful 1969 drought relief bores were located at about this level. This may indicate a more or less regular slope of the bedrock surface away from the outcrop areas.

TABLE 12: Status of drought relief successful bores: Kulin-Kondinin, August 1976

Owner	Litho	Loc.	Bore No.	1969-1970			1976		
				Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
J.I. Murray	376/80	27476	2533-II B11	63.4	16	3500			x
"	"	27476	2533-II B10	68.9	91	3600	x		
R.B. & J.K. Richter	376/80	1298	2633-IIIB28	30.5	29	1750	x		
A.C. & E.M. Far	376/80	2517	2632-IV A13	26.2	5	850			x
D.J. & P.A. Maloney	345/80	784	2633-IIIB15	18.3	52	10900			x
"	"	"	2633-IIIB17	36.6	39	7450			x
R.H. & D.G.Tuckwell		25815		54.3	26	5250			x
C.V. Hinkley	387/80	15128	2532-II D10	38.4	15	10750			x
Road Reserve (Pederah)	376/80	8901	2632-IV A17	26.8	30	4500	x		
Horse Collar Res.		14377		46.0	79	1750			x
Totals							3	0	7

HOLT ROCK

LOCATION AND TOPOGRAPHY

The Holt Rock area is east, south and southeast of Hyden and extends to just east of Lake Varley. It is moderately undulating sandplain country covering deeply weathered Archaean granite and gneiss. The weathering of the Quaternary surface has left numerous inliers of granite standing slightly above normal plain level, and also relict drainage features now represented as a chain of salt lakes from Lake Carmody to Lake King.

GEOLOGY

Most of the area is covered with sand of varying thickness passing downwards into clayey sand overlying weathered granitic basement. Granitic rock is exposed at the surface to form low hills.

HYDROGEOLOGY

Rainfall

The average annual rainfall is about 300 mm, most of which falls during the winter months and is lost to evaporation and transpiration. Only a very small percentage reaches the water table.

Groundwater

Property owners mainly rely on surface catchments and dams for water supplies. Only a few farms in the Hyden area had successful groundwater supplies prior to the 1969-1970 drought relief drilling.

Many of the successful bores were sited downslope from residual granite hills but above drainage base level. About 24 m of variable weathered granite was usually penetrated by bores, which were completed in hard granite. Most water came from the more permeable, fractured interface between the weathered and hard rock. The highest yielding bores were sunk in depressions where granite was exposed on hills around the depression.

The freshest groundwater was found in bores close to the larger hills, e.g. King Rock, Hyden. Bores drilled in the gently undulating areas usually were dry or gave small supplies of saline water.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 13)

Number of properties inspected	49
Number of Government Reserves inspected	53
total	102
Number of properties recommended for drilling..	49
Number of Government Reserves recommended for drilling	37
total	86
Number of properties drilled successfully	28
Number of Government Reserves drilled successfully	12
total	40

Number of properties drilled unsuccessfully	21
Number of Government Reserves drilled unsuccessfully ..	25
total	46

Table 13: Summary of drought relief drilling: Holt Rock

	Properties		Government Reserves	
	No.of bores	Total depth	No.of bores	Total depth
		m		m
Dry	76	1 577	29	454
Wet-Insufficient Supply	18	507	6	240
Wet-Saline Supply	26	746	8	236
Wet-Suitable Supply	30	954	12	380
Abandoned	1	51	-	-
Totals	151	3 835	55	1 310

FOLLOW—UP SURVEY 1976 (Table 14)

During August, 1976, a follow-up survey was conducted to establish how many of the 42 successful 1969-1970 drought relief bore sites had been developed.

Results : 27 successfully developed
1 not successfully developed
13 not developed
1 not located

The salinity of the groundwater at the unsuccessfully developed site rose to more than 11 000 mg/l TDS.

The 13 sites were not developed because:

(a) the groundwater was too salty for farmers' requirements.
(b) insufficient supply for farmers' requirements.
(c) the drought ended before the bores were required.

Number of properties drilled unsuccessfully	21
Number of Government Reserves drilled unsuccessfully ..	25
total	46

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		m		m
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(b) insufficient supply for farmers' requirements.
(c) the drought ended before the bores were required.

Table 14: Status of drought relief successful bores: Holt Rock, August 1976

Owner	Litho	Loc.	Bore No.	1969-1970			1976		
				Depth m	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
J.B. Howe	375/80	1412	2732-I C18	43.6	13	3000	x		
P.J. Harvey	375/80	1404	2732-I A10	32.9	20	4500	x		
F.B. Harvey	375/80	1121	2732-I A14	46.6	11	3000	x		
R.G. Strothers	375/80	1339	2732-I B16	42.1	9	8000			x
G. Strothers	375/80	2809	2732-I B15	40.5	13	8000		x	
R. Baker	375/80	1124	2732-I D33	37.5	10	2500	x		
K. Ingham	375/80	1126	2732-I D50	28.3	78	6500	x		
G. Continibali	375/80	2506	2732-IV B4	31.1	6	600	x		
C.G. Murray	375/80	2507	2732-IIIA3	23.8	20	800	x		
G. Henderson	374/80	2513	2832-IV C23	42.1	26	2600	x		
K. Barron	374/80	2481	2832-IV C19	19.2	77	8000	x		
T.E. Fagent	374/80	2480	2832-IIID16	28.3	14	4500	x		
D.B. Abernethy	374/80	2181	2832-IIID15	19.2	16	1200	x		
K. Naughton	374/80	1204	2832-IIID17	37.5	16	5000			x
K. Naughton	374/80	1205	2832-IIIA1	42.1	13	3200	x		
W.R. Abernethy	374/80	1201	2832-IIID18	37.5	16	3100	x		
T.L. Naughton	374/80	1216	2832-IIIA2	27.7	6	6600	x		
C.R. Burgess	375/80	2509	2732-I C32	32.6	99	7000	x		
P.H. Douthie	346/80	2374	2733-IIIA19	18.9	8	6000			x
N. McLennon	345/80	2529	2633-IIIB4	23.8	16	5000	x		
A. Cusmano	375/80	2469	2732-IVC 1	26.5	13	6500	x		
U. Brown	375/80	189	2633-II C2	19.2	13	6500	x		
C. Nicholl	375/80	1511	2732-IV D9	22.3	18	7500	x		
J. Marshall	375/80	2368	2732-IV D10	25.9	20	4000			x
P. Padovan	346/80	2639	2733-II D9	34.4	41	6000	x		
P. Douthie	346/80	2374	2733-IIID2	41.5	18	200			x
D. Lamont	375/80	2362	2732- IA17	29.0	16	6000	x		
R. Cornwell	374/80	1411	2832-IV C18	32.0	7	4000	x		
C.J. Lord	375/80	2347	2832-IIID23	27.4	20	4000	x		
J. Barron	374/80	1214	2832-IIID20	40.2	26	5500			x
Road Reserve	375/80	Near 1722	2732-IV C7	32.3	39	10000			x
Crown Reserve	375/80	19770	2732-I D39	32.9	10	1860			x
Crown Reserve	375/80	27928	2732-I C27	29.6	7	5000	x		
Road Reserve	375/80	Near 1158	2732-I B22	37.5	41	10360	x		
Crown Reserve	375/80	19770	2732-I D40	21.6	33	2060			x
Road Reserve	375/80	Near 2432	2732-I B21	37.5	8	8500			x
Road Reserve	374/80	Near 2512	2832-IV C26	31.4	7	4400	x		
Crown Reserve	375/80	27927	2732-IC22	29.9	7	3800			x

Table 14 - continued

Owner	Litho	Loc.	Bore No.	1969-1970 Depth m	Supply m^3/d	Salinity TDS mg/l	1976 Successfully developed	Unsuccessfully developed	Not developed
Road Reserve	375/80	Near 1123	2732-IA16	40.2	14	9000			x
Crown Reserve	375/80	2706	2732-I C29	21.3	14	11000			x
King Rocks	346/80	8390	2733-IIIA18	28.3	39	500	x		
Road Reserve		Near 8390		37.5	27	1500	not located		
Totals							27	1	13

COMMENTS ON FUTURE SITING OF BORES

The best sites for groundwater prospecting in the Holt Rock area are above drainage base level near granitic hills. Large sand infilled depressions surrounded by granite are also prospective drilling sites.

Because most of the groundwater is held in the weathered zone and in the uppermost fractures and joints in the fresh granite, drilling should not be terminated until at least 5 m of fresh granite is penetrated.

NYABING-PINGRUP

LOCATION AND TOPOGRAPHY

This drought relief area is centred about the towns of Nyabing and Pingrup and extends southwards almost to Gnowangerup, Ongerup and Jerramungup.

The area has a system of salt lakes through its centre, with a divide on either side of it. The western side of the divide is deeply dissected with valleys incised to the granite, while the eastern side is high, undulating sandplain.

GEOLOGY

The area is in Archaean granitic rocks, most of which are foliated granites with considerable contamination from absorption of metamorphic belts. The area northwest of Nyabing has a small intrusion of primary granite which is well-jointed. East of Nyabing a divide, which runs north-south, has sandplain developed on it.

A series of large and small salt lakes east of Pingrup have alluvium up to 30 m thick and generally contain saline water, although one hole on the property of E and S Altham was drilled to 30 m without reaching the Archaean and was dry. This hole was less than 1.5 km from the salt lakes and approximately 10 m above the level of them. The area east of the lake system is predominantly sandplain with isolated areas of granitic rocks exposed, e.g. Hollands Rock.

HYDROGEOLOGY

Rainfall

The average annual rainfall is between 340 mm and 420 mm.

Groundwater

There are several perched water tables in the eastern area which have produced salt lakes and in some cases fresh lakes, e.g. Lake Bryde.

Soaks are sometimes developed in the sandplain particularly where there has been a dolerite dyke in the underlying rocks.

Groundwater occurs in four different types of environment.

1. Alluvium: Bore 2530-IVD18, located in a road reserve adjacent to location 5429, is situated in a broad alluvial valley. This valley is flanked by sandplain and granite which probably gives rise

to the average salinity groundwater of 4500 mg/l TDS.

2. Sandplain: Three areas of sandplain produced groundwater of good quality and in reasonable supplies. The sandplain contains numerous clay bands and the quality of water these aquifers yield depends on the amount of sand there is in the intersected section. The area on Location 9219, west of Nyabing, was drilled with 15 holes; 14 of these yielded more than 5 m^3/d and one was dry. The salinity of these varies from 1500 to 10 720 mg/l TDS. These aquifers appear to require little slope and approximately 120 ha intake area.

3. Granite joints: Ten bores were successfully drilled into the sheet joints in the granite. In Several of the bores there was saline water seepage from the alluvium above the granite. The water in the underlying granite and its joints was generally fresh ranging from 500 mg/l to 9000 mg/l at depths of between 12 m and 24 m. The largest supply from this type was 52 m^3/d.

4. Dolerite contacts: Two holes were drilled on road reserves adjacent to dolerite dykes, both of these yielding water. The supplies obtained from these bores were about 7 m^3/d and the salinity ranged from 4500 mg/l to 12 000 mg/l TDS.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 15)

Number of properties inspected	86
Number of Government Reserves inspected	76
Total	162
Number of properties recommended for drilling ..	80
Number of Government Reserves recommended for drilling ..	50
Total	130
Number of properties drilled successfully	10
Number of Government Reserves drilled successfully ..	9
Total	19

Number of properties drilled unsuccessfully	70
Number of Government Reserves drilled unsuccessfully	41
Total	111

Table 15: Summary of drought relief drilling: Nyabing-Pingrup

	Properties		Government Reserves	
	No.of bores	Total depth m	No.of bores	Total depth m
Dry	194	3 896	57	1 126
Wet-Insufficient Supply	19	398	6	127
Wet-Saline Supply	91	2 039	18	368
Wet-Suitable Supply	12	211	22	695
Abandoned	16	259	10	263
Totals	332	6 802	113	2 579

FOLLOW—UP SURVEY 1976 (Table 16)

During August, 1976, a follow-up survey was conducted to establish how many of the 34 successful 1969-1970 drought relief bore sites had been developed.

Results : 6 developed
28 not developed.

Fourteen successful bores were drilled on Crown Land Location 9219 and only two were required for developing into a community supply, the remaining twelve were not required.

Two of the twenty eight undeveloped sites (2329-IB13 and 2530-IVC19) were considered failures by the farmers because of low yields and high salinities.

Table 16: Status of drought relief successful bores: Nyabing-Pingrup, August 1976

Owner	Litho	Loc	Bore No.	1969-1970 Depth m	Supply m^3/d	Salinity TDS mg/l	1976 Successfully developed	Unsuccessfully developed	Not developed
W. Griffith	437/80	7006	2329-IB14	18.3	13	10 000			x
K. Marshall	437/80	6336	2329-IB13	15.2	7	8 000			x
N.G. Patterson	408/80	5877	2431-IIB15	17.7	10	500	x		
H.P. Harvey	417/80	5540	2530-IVC19	22.3	23	11 000			x
Crown Land	417/80	near 8926	2530-IVC20	27.4	7	4 500			x
"	407/80	Nowcrellup	2530-IVA33	46.3	5	600			x
"	417/80	near 7434	2430-IA14	15.2	7	9 500			x
"	408/80	near 1827	2531-IIIC33	21.3	5	6 500			x
"	408/80	Near 5757	2531-IIIC34	23.8	5	1 620			x
"	417/80	9219	2530-IVD31	24.4	7	1 000			x
"	417/80	9219	2530-IVD32	30.5	20	1 880			x
"	417/80	9219	2530-IVD33	21.3	18	1 800			x
"	417/80	9219	2530-IVD34	27.4	8	1 120			x
"	417/80	9219	2530-IVD35	39.6	32	635	x		
"	417/80	9219	2530-IVA19	44.2	39	5 000	x		
"	417/80	9219	2530-IVA20	48.8	31	4 000			x
"	417/80	9219	2530-IVA21	30.5	49	5 250			x
"	417/80	9219	2530-IVA23	27.7	9	1 000			x
"	417/80	9219	2530-IVA24	32.3	20	1 800			x
"	417/80	9219	2530-IVA25	26.2	34	3 500			x
"	417/80	9219	2530-IVA26	36.0	18	2 000			x
"	417/80	9219	2530-IVA27	36.0	13	2 000			x
"	417/80	9219	2530-IVA29	26.2	14	5 000			x
W. Filmer	408/80	5844	2531-IIIC23	16.5	52	1 800	x		
H.M. & L.A. Garlich	417/80	5971	2530-IVD29	24.4	14	7 900			x
"	417/80	8193	2430-IA10	12.2	5	5 300			x
L.R. & A.D. Browne	408/80	8846		13.7	13	10 200			x
"	408/80	8846	2430-IA4	12.2	14	4 500	x		
P.H. Webse	417/80	2847	2430-IA6	21.3	9	9 000			x
"	417/80	4547	2430-IA7	15.2	11	4 000			x
B.F. Goodchild & Co.	417/80	6149	2530-IVD28	24.4	8	4 000			x
Crown Land	417/80	Near 5429	2530-IVD18	36.6	11	4 500			x
"	417/80	2606	2631-IIIA7	30.5	55	2 000	x		
"	417/80	Badgebup	2430-IB15	42.7	11	10 000			x
Totals							6	0	28

COMMENTS ON FUTURE SITING OF BORES

The most prospective areas for obtaining fresh to stock quality groundwater are on the sandplains particularly if deep sand overlies jointed granite. Under these conditions drilling should continue down about 5 m into the unfractured fresh granite and the entire saturated thickness made open to the bore.

The divides on either side of the salt lakes are poor areas for obtaining groundwater.

LAKE GRACE

LOCATION AND TOPOGRAPHY

The boundary of the Lake Grace Shire was taken as the boundary of the drought area, most of the farm properties being within the western two-thirds of the Shire.

The topography is regionally dominated by three north-south chains of salt lakes. These may be called the Lake Grace, Newdegate and Lake King systems. The areas around the salt lakes are generally flat-lying or very gently undulating with a few exposures of granite-gneiss on the higher ground. The drainages into the salt lakes are broad and ill defined. Soils are dominantly clays. The natural vegetation was originally eucalyptus forest with a scattered to moderately dense undergrowth.

The higher ground between the salt lake systems is moderately undulating with deep valleys and broad hills. The small gullies, draining from small flat gneiss outcrops, are usually well-defined but the large drainages are anastomosing and diffuse. Soils are mainly sandy clays and, more rarely, deep sands. The vegetation is mainly sand-plain scrub, but in the deep valleys tall eucalyptus predominates.

GEOLOGY

The area is underlain by Archaean gneisses and foliated granites. These gneisses are often migmatitic and very frequently show evidence of contamination from absorption of country rock. The gneisses generally show foliation trends between northwest and north and show evidence of strong folding in places. They are cut by aplite and pegmatite veins and dolerite dykes. The dolerite dykes which trend between east and north-east, do not appear to be as abundant as in some adjacent areas. The granitic rocks have been deeply-weathered to kaolinitic clays. The average depth to fresh rock is about 30 m though depths of 50 m were occasionally reached before fresh rock was encountered.

HYDROGEOLOGY

Rainfall

The average annual rainfall is:

Lake Gracé	360 mm
Newdegate	350 mm
Lake King	340 mm.

Groundwater

Of the eleven successful drought relief bores seven were situated in gullies down drainage from outcrops of gneiss or foliated granite, the soils being either sandy or sandy-clays. Three of the successful test-bores were situated in shallow gullies draining long sandy or sandy-clay slopes. The other suitable supply was a shallow soakage type tested by five shallow bores.

Attempts were made to find groundwater in other situations such as in sheet joints in the foliated granites, in assumed faults (from photo lineaments), and at the margin of dolerite dykes. None of these proved successful.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 17)

Number of properties inspected	52
Number of Government Reserves inspected	79
Total	131
Number of properties recommended for drilling ..	43
Number of Government Reserves recommended for drilling ..	40
Total	83
Number of properties drilled successfully	6
Number of Government Reserves drilled successfully ..	4
Total	10
Number of properties drilled unsuccessfully	37
Number of Government Reserves drilled unsuccessfully ..	36
Total	73

Table 17: Summary of drought relief drilling: Lake Grace

	Properties		Government Reserves	
	No.of bores	Total depth (m)	No.of bores	Total depth (m)
Dry	97	2 200	76	2 138
Wet-saline supply	21	546	10	242
Wet-insufficient supply	6	268	5	205
Wet-suitable supply	7	226	4	173
Abandoned	10	250	10	256
Totals	141	3 490	105	3 014

FOLLOW-UP SURVEY 1976 (Table 18)

During August, 1976, a follow-up survey was conducted to establish how many of the 11 successful 1969-1970 drought relief bore sites had been developed.

Results : 3 successfully developed
1 unsuccessfully developed
7 not developed.

The failure bore contains groundwater with a salinity of about 20 000 mg/l TDS.

Table 18: Status of drought relief successful bores: Lake Grace, August 1976

				1969 - 1970			1976		
Owner	Litho	Loc	Bore No.	Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully devoloped	Not developed
E.C. & J.E. Smith	387/80	13281	2632-IIIC10	30.5	7	2500	x		
V.J. Newman	406/80	919	2731- IVB 9	21.3	6	6200			x
"	406/80	919	2731- IVB10	21.3	14	5800	x		
C.M. & K.R. Hodgson	388/80	2667	2731- IVD 5	48.8	24	8200			x
P.B. & J.H. Webb	388/80	847	2732-IIIC 4	30.5	14	8500			x
B.F. Waddell	388/80	2077	2631- IA 10	6.1	5	2500			x
D.J. & M.M. McDonald	388/80	966	2732-IIID 1	33.5	5	7500			x
Railway Water Supply	388/80	20629	2631- IA 4	48.8	18	4170	x		
Road Reserve	388/80	Near 847	2732-IIIC 2	36.6	5	5750			x
Water Reserve	406/80	18961	2731- IVC 3	35.1	9	3000			x
Reserve	389/80	2870	2832-IIIC11	39.6	11	7500		x	
Totals							3	1	7

COMMENTS ON FUTURE SITING OF BORES

The best areas for groundwater prospecting are in sandy gullies which receive run-off from rock outcrops further up slope.

RAVENSTHORPE

LOCATION AND TOPOGRAPHY

The area extends eastward from Ravensthorpe to just east of Munglinup and to the south coast.

Essentially there are two geologic and topographic controls, one being the Archaean greenstones of the Ravensthorpe mineral belt, which outcrop as a north-northeast to south-southwest trending range passing through Ravensthorpe. To the east and west of the mineral belt the second control is the gently undulating "Esperance Sandplain" developed over Archaean gneiss in the north, and over thin Tertiary Plantagenet Group sediments nearer the coast.

GEOLOGY

The underlying basement of granitic gneiss is exposed at the surface through the soil cover and in the dissected river valleys. Associated with the gneiss are dyke rocks, which have undergone high-grade metamorphism. The foliation in these rocks shows a general southwesterly trend.

North of the Esperance-Ravensthorpe road the basement rocks lie about 5 m beneath the Quaternary soil mantle. South of the road thin Tertiary sediments, with a maximum thickness of 46 m, unconformably overlie gneiss.

The Quaternary soils are divisible into two distinct units which are developed over the Precambrian and Tertiary rocks - red, sandy loam over limestone, and sand over pisolites and yellow clay.

HYDROGEOLOGY

Rainfall

The average annual rainfall is between 380 mm and 500 mm.

Groundwater

Groundwater characteristics are closely related to the geology.

Gneiss is the predominant rock type, and the groundwater overlying it is usually very saline. Stock quality water occasionally occurs within coarse, sandy colluvium found in shallow depressions and drainage lines, and in zones of deeply weathered gneiss. These occurrences are rare.

Domestic and stock quality groundwater is available from Eocene siltstone and spongolite which are thinly draped over gneiss in the southernmost part of the area.

The alluvial flats along the rivers may yield small supplies of groundwater.

The coastal dune system which lies mainly within Crown land is a suitable environment for the accumulation of potable groundwater.

Bores drilled in the greenstone belt indicated large supplies of very saline water.

Because of the shallowness to water table in some parts of the southern area, soaks have been dug and successfully used.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 19)

Number of properties inspected	45
Number of Government Reserves inspected	2
Total	47
Number of properties recommended for drilling	40
Number of Government Reserves recommended for drilling	2
Total	42
Number of properties drilled successfully	21
Number of Government Reserves drilled successfully	1
Total	22

Number of properties drilled unsuccessfully	19
Number of Government Reserves drilled unsuccessfully	1
Total	20

Table 19: Summary of drought relief drilling: Ravensthorpe

	Properties		Government Reserves	
	No.of bores	Total depth (m)	No.of bores	Total depth (m)
Dry	30	573	-	-
Wet-insufficient supply	20	664	-	-
Wet-saline supply	18	359	-	-
Wet-suitable supply	21	562	1	25
Abandoned	4	49	1	7
Totals	93	2 207	2	32

FOLLOW—UP SURVEY 1976 (Table 20)

During August, 1976, a follow-up survey was conducted to establish how many of the 22 successful 1969-1970 drought relief bore sites had been developed.

Results : 11 successfully developed
2 unsuccessfully developed
9 not developed.

2930-IIA3 failed because the yield dropped below 2 m^3/d.

2930-IIB5 failed because the salinity increased to more than 11 000 mg/l TDS.

Four of the undeveloped sites were considered failures by the farmers because the groundwater was too salty for their needs.

Five sites were not developed because either they were not required or the farms changed ownership.

Instead of a bore a soak was dug at 2930-IIA1.

Table 20: Status of drought relief successful bores: Ravensthorpe, August 1976

				1969 - 1970			1976		
Owner	Litho	Loc.	Bore No.	Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
K.R.Jenkins	421/80	733	3030-IVB4	43.0	20	10100			x
P.C.Donkin	421/80	926	3030-IVC2	47.5	13	2270	x		
R.G.Field	421/80	734	3030-IVB3	33.8	33	8680	x		
W.Fricker & Son	421/80	790	2930-IIA4	11.0	26	1460	x		
D.Powell & Co	421/80	819	2930-IID10	21.6	8	840			x
M. & N.Moylan	433/80	95	2930-IIIC27	20.1	33	2000	x		
W.J.Tilbrook	405/80	1580	2831-IC6	33.5	10	1500	x		
A.E.Cunningham	422/80	746	3030-IC9	24.7	17	3000			x
P.L.Lawrence	422/80	745	3030-IC3	29.3	13	4000			x
M. & T.Cowell	421/80	740	3030-IC8	20.1	13	8050			x
R.Silburn	421/80	752	3030-IID5	15.5	26	149	x		
Balga Esperance Pastoral Co	421/80	1011	3030-IC4	17.7	13	8680			x
M. & H.Prebble	433/80	638	2930-IIIC28	38.4	10	690	x		
R.K.Purvis	421/80	798	2930-IIA3	31.1	10	2400		x	
B.D.Auld	421/80	823	2930-IIA1	33.8	13	1500	x		
W.Loffler	421/80	840	2930-IIB5	18.6	20	9790		x	
M.Lamperd	421/80	848	2930-IIC5	6.4	10	930	x		
Tennisdale Grazing Co	389/80	1597	2831-IVA3	40.8	20	11300			x
C. & T.Johnson	389/80	2840	2832-IIIB4	42.1	7	6300			x
B. & B.Orchard	375/80	1157	2732-IB24	6.4	13	10000	x		
D.J.Atkins	375/80	2885	2732-IC39	26.5	20	7000	x		
Road Reserve	421/80	Near 831	2830-IIIB23	24.7	26	8050			x
Totals							11	2	9

COMMENTS ON FUTURE SITING OF BORES

The most prospective areas for siting groundwater bores are in the sand plain area east and southeast of Ravensthorpe and downslope from steeper topographic rises or gneissic hills. Bores in the sandplain area should penetrate about 20 m of yellowish to red silty and clayey sand of Tertiary age before being completed in gneiss. An average groundwater salinity

is possibly 5 000 mg/l TDS.

The coastal sand dunes and associated limestone could also be an important aquifer.

ONGERUP

LOCATION AND TOPOGRAPHY

The main area is bounded by the Gnowangerup-Jerramungup bitumen road on the north, Gairdner River on the east, Hassell Highway and the Boxwood Hills-Bremer Bay Road on the south, and a line from South Stirling townsite through Borden on the west.

The western and central parts are drained by the Pallinup River and its tributaries Peenebup Creek, Corackerup Creek and Peniup Creek, and on the east by Bremer River, Gairdner River and their tributaries.

The northern half is well dissected and hilly to undulating, while the remainder is generally gently undulating to flat with numerous internal drainage depressions. Some of the latter are occupied by shallow salt lakes or fresh-water swamps, but most are dry throughout the greater part of the year. On the south-western side the east-west trending Stirling Range rises to a height of 1 109 m at Bluff Knoll.

GEOLOGY

In the northern half the rivers and their tributaries drain to the southeast and exhibit rectilinear patterns controlled by faulting and jointing in the well-exposed granitic basement complex. The remainder of the area is poorly drained and the rivers and their short tributaries have cut relatively narrow gorge-like channels into the flat-lying Plantagenet Group sediments which overlie the granitic rocks. The Plantagenet Group sediments are relatively thin in this area and granitic rocks are often exposed in the bottoms of the drainages.

The basement rocks are mainly a complex of fine- to coarse-grained acid to intermediate plutonic types, granite-gneiss, schist, and minor arenaceous metasediments of Archaean and Proterozoic age. A coarse-grained granite with prominent feldspar phenocrysts is well-exposed between Jerramungup and Boxwood Hills. ?Middle Proterozoic Albany Granite crops out along the south coast. There are numerous dolerite dykes, generally trending east-northeast and east-southeast, and some of these are highly fractured. Quartz veins also crop out in places but no main trend direction was determined for these. In the northern half the basement rocks are well-exposed or carry only a thin cover of Recent alluvium and weathering products. A maximum of 37 m of such sediments was encountered, but at most sites selected for drilling the average thickness was about 15 m. In places in the weathered zone appreciable thicknesses of white kaolin, usually more or less mixed with free quartz, were penetrated.

In a limited area in the southwest ?Middle Proterozoic "Stirling-Barren Series" reach an elevation of more than 914 m. The Range is made up of steeply dipping low-grade metasediments intruded by basic dykes. The beds rest unconformably on the Archaean rocks.

About halfway through the area, Upper Eocene Plantagenet Group sediments abut against the surface of the Archaean rocks which rise gradually to the north. They also abut against the "Stirling-Barren Series" on the southwest and the Proterozoic granite to the south. The highest elevation at which the Plantagenet Group sediments were observed was about 229 m above sea level, approximately 24 km southeast of Ongerup. South of here, the Plantagenet Group sediments drape over terraces and fill valleys and basins in the old dissected granitic surface. In this area the granitic rocks can only be observed in the bottoms of present day valleys, or as rubble on sand-covered rises.

The maximum thickness of sediment penetrated was 85 m above granite. The sedimentary section in this area consists of generally unconsolidated thinly interbedded clay, silt, sand, conglomerate and spongolite. The conglomerate is usually basal and the sand associated with this is usually angular to sub-angular, but other

sand grains were moderately to well-rounded. A black, carbonaceous clay with scattered lignite was penetrated about midway through the section in places. Limestone was only found at the surface as a poorly developed kankar, quite often associated with gilgai-type soil, but a low carbonate content in some beds may have been unnoticed during logging of the cuttings.

Some thin discontinuous patches, lenses, and stringers of hard ferruginized and silicified siltstone and fine-grained sandstone were recorded from bores in the south-west of the area, mostly above 24 m depth. Concentrations of fine, heavy black minerals were observed in the Plantagenet sediments in places, both from core cuttings and as slicks on the ground.

The Plantagenet Group sediments appear to have an overall low dip to the south or southeast, but there are significant local variations due to draping and compaction over the uneven basement. Some of the local depressions may be almost closed at depth.

HYDROGEOLOGY

Rainfall

Annual rainfall is 406 to 508 mm and the evaporation rate from the free water surface is about 1 020 mm per year. Controlled by the westerlies, most of the rainfall occurs between April and October, but useful falls, sometimes up to 25 mm, may be experienced in the drier months.

Groundwater

The mainly granitic and mainly sedimentary areas may be considered separately when studying the hydrogeology, although highly saline waters draining off the granite have access to some of the Plantagenet aquifers and increase the salinity in these to beyond usable limits.

Finding successful bore sites in the northern granitic areas was very difficult due mainly to the prevalence of highly saline groundwater. Low rainfall spread over a good many months of the year brings down cyclic salt carried from the nearby coast by the prevailing

westerlies and sea breezes, and this is then concentrated at or near the ground surface by the high evaporation rate. Shallow, sluggish, intermittent streams meandering over the granitic areas pick up most of the salts from rock decay and these add to the salinity of the water. The problem was to find sufficient thickness of sedimentary material in the higher tributary valleys which had a reasonably short catchment above them to give adequate recharge of reasonably fresh water. In many places it was impossible to find a big enough reservoir in the sediments, and zones of fractured basement rock had to be tested with the drill.

There are unconnected aquifers of different salinities in the Plantagenets, a fact which is borne out by the intersection of slightly fresher deeper aquifers. If development holes were drilled in which excessively saline upper waters could be sealed off, perhaps useful supplies of stock water could be found.

Several good holes were sited close to the eastern end of Stirling Range and these are no doubt tapping low salinity run-off water from the Range. However, surface drainages running north and northeast to Pallinup River from the eastern end of Stirlings are surprisingly saline. Several unsuccessful holes struck excessively saline water at relatively shallow depths south of Stirling Range and north of the Chillinup-Kambellup Road. There are a number of shallow salt lakes in this area.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 21)

Number of properties inspected	121
Number of Government Reserves inspected	5
Total	126

Number of properties recommended for drilling	111
Number of Government Reserves recommended for drilling	5
Total	116

Number of properties drilled successfully	35
Number of Government Reserves drilled successfully	1
Total	36

Number of properties drilled unsuccessfully	76
Number of Government Reserves drilled unsuccessfully	4
Total	80

Table 21: Summary of drought relief drilling: Ongerup

	Properties		Government Reserves	
	No.of bores	Total depth (m)	No.of bores	Total depth (m)
Dry	152	3 615	8	248
Wet-insufficient supply	38	1 276	0	0
Wet-saline supply	132	3 761	2	73
Wet-suitable supply	42	1 496	2	61
Abandoned	28	756	4	101
Totals	392	10 904	16	483

FOLLOW-UP SURVEY 1976 (Table 22)

During September, 1976, a follow-up survey was conducted to establish how many of the 44 successful 1969-1970 drought relief bore sites had been developed.

Results : 19 developed
24 not developed (low yields, drought ended)
1 not located

Test bore 2629-IIIC5 was abandoned because of drilling difficulties.

Instead of a bore a soak was dug at 2629-IVC7.

Table 22: Status of drought relief successful bores: Ongerup, September 1976

Owner	Litho	Loc.	Bore No.	1969 - 1970			1976		
				Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
R.V.Miller	435/80	CG 5922	2529-ID3	33.1	9	8610	x		
A.C.Hornsey	435/80	1557	2529-IB2	11.0	11	8175			x
J.R. & H.M. Pither	435/80	430	2629-IVC7	4.9	9	10500	x		
H.T.Reynolds	435/80	1875	2629-IIID10	52.1	36	3111	x		
A.J.Large	446/80	6762	2529-IIA1	29.0	18	3400			x
C.N.H.Hall	446/80	6211	2529-IIB9	72.2	9	6500			x
J.D.Bryant	446/80	6210	2529-IIA4	6.1	39	220			x
P.Morgan	435/80	1250	2629-IVA4	20.4	33	900			x
S.M.Carthew	434/80	1404	2629-ID5	16.8	9	3400			x
F.M.Pritchard	435/80	1862	2629-IIID19	24.4	9	660			x
G.O'Reilly	435/80	1344	2629-IVC17	20.4	5	4500	x		
P.Crossing	446/80	6205	2629-IIID23	39.6	11	8000			x
D.M.Sambell	435/80	830	2529-IA10	18.6	5	1060			x
"	435/80	830	2529-IA11	20.4	32	1300	x		
L.A.Wellstead	446/80	6206	2529-IIA11	35.7	11	2550	x		
"	446/80	6206	2529-IIA10	35.1	18	6680			x
J.G.Enwright	446/80	6845	2629-IIIC3	85.3	22	2300			x
"	446/80	6845	2629-IIIC4	42.7	32	900			x
"	446/80	6845	2629-IIIC5	54.9	5	2800			x
E.J.Opray	434/80	1461	2629-IB15	55.2	32	5600			x
D.C. Sexton	446/80	1730	2629-IIC2	32.9	55	5000			x
G.E.Gaebler	447/80	1526	2629-IIA8	42.7	22	4500	x		
C.R.Peake	447/80	1922	2729-IIIA3	54.9	22	8300	x		
A.J.Stockwell	446/80	6225	2629-IIIC6	79.6	9	6000			x
E.E.Stoneys	446/80	1733	2629-IIC3	34.1	23	2080	x		
"	446/80	1732	2629-IIC4	30.5	41	3850	x		
B.R.Armstrong	447/80	1734	2629-IIB18	51.2	68	5000	x		
J.S.Donald	435/80	1343	2529-IA22	18.6	27	2760	x		
C.Adams	446/80	6217	2629-IIIC9	42.1	9	6750			x
H.A.House	446/80	6528	2528-IA17	21.3	36	2600	x		
E.J.Kirton	446/80	6828	2528-IA18	36.6	14	7200	x		
J.A.Hanlon	446/80	6829	2529-IIB23	32.9	10	1550	x		
M.J.Roe & Son	446/80	6832	2628-IVD4	36.6	52	4500	x		
Mitchell & Sons	446/80	6856	2628-IVD5	33.8	11	2000			x
"	446/80	6856	2628-IVD6	36.6	5	2200			x

D.A.Stoney	446/80	6238	2529-IIB25	24.4	33	4500			x
K.A.Mortimer	446/80	6236	2528-IA23	30.5	22	3000	x		
P.Nowell	446/80	6843	2629-IIIC15	45.7	9	5500			x
R.Kerr	446/80	6830	2528-IA24	27.4	22	5000	Not inspected		
Green Range Pastoral Co	446/80	6837	2629-IIIC17	37.5	9	5000			x
M.H.Hood	446/80	6234	2528-ID10	27.4	16	10500			x
F.Cooke	446/80	6241	2529-IIC8	42.1	8	7000			x
Road Reserve	436/80	Near 4010	2429-IA10	36.6	10	1080	x		
"	436/80	Near 3913	2529-IVD29	24.4	73	2000	x		
Totals							19	0	24

COMMENTS ON FUTURE SITING OF BORES

In the granite areas the most prospective sites for groundwater are where thick alluvium rests on weathered granite.

Only limited success can be expected by drilling next to dolerite intrusions but a better success ratio may be obtained by drilling in fractured rock adjacent to massive granite intrusions.

In the Plantagenet Group sediments successful sites may be located by avoiding areas where long drainages flowing off the granitic areas entered onto and crossed the sediments, and by also avoiding the central parts of the major depressions. These areas are usually very saline.

The most promising sites in the Plantagenet Group sediments are about 300 m from the surface contact of the sediments and the granite. If the granite topography concentrates drainage from a relatively short distance and discharges it directly into the sedimentary aquifers, the quality of the groundwater in the aquifer should be fairly good.

CHILLINUP

LOCATION AND TOPOGRAPHY

The Chillinup area encompasses South Ongerup, Jerramungup, Chillinup and Kojaneerup.

Topographic variation is strongest in the western part of the area where the high Stirling Range creates a rain shadow situation. The area is dissected by minor creeks and the Pallinup River. North of the Pallinup River, granite gneiss forms the country rock, with Tertiary sediments occurring south of the river.

GEOLOGY

Much of the Chillinup District is gently undulating sandplain developed over gneissic granite and/or Tertiary Plantagenet Group sediments.

HYDROGEOLOGY

Rainfall

The average annual rainfall, which varies considerably throughout the area, is about 400 mm.

Groundwater

The occurrence of groundwater can be inferred from the results of the 1969-1970 drought relief drilling which investigated the groundwater prospects of Crown Reserves and roadside verges. Large supplies of groundwater suitable for stock consumption are rare in the Chillinup area as indicated by the high bore failure rate.

Seventy six bore sites were selected in geologically or topographically suitable localities. Of these, 58 sites were drilled, nine successfully.

Bores into the Tertiary rocks usually penetrated a dark, silty, sandy, often carbonaceous clay zone, at about

46 to 61 metres depth. Beneath this zone large supplies of reasonable quality water could be expected.

Two bores, yielding in excess of 136 m^3/d of 2 500 mg/l salinity groundwater were drilled on Gnowellen Reserve Road bordering the eastern end of the Stirling Range. These bores penetrated 60 m of siltstone and claystone.

One supply of groundwater was found near Corackerup Creek in the centre of the granite area, where a supply of 68 m^3/d groundwater of salinity 900 mg/l was obtained. Other small supplies were found in granite but few were worthy of production bores.

Two successful test bores were established in the eastern part of the district near Gairdner River, where they intersected variably coloured and textured schists of the "Stirling-Barren Series". One bore delivered 114 m^3/d of 2 900 mg/l groundwater from a depth of 30 m; 15 m of schist being penetrated. The other bore went to 65 m and gave 18 m^3/d of salinity 2 000 mg/l.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 23)

Number of Government Reserves inspected	30
Total number of sites pegged on reserves	16
Total number of sites pegged on roads	60
Total number of bore sites selected, roads and reserves ..	76
Total number of sites drilled	58
Total number of sites drilled successfully	9
Total number of sites drilled unsuccessfully	47

Table 23: Summary of drought relief drilling: Chillinup

	Government Reserves and Roads	
	No.of bores	Total depth (m)
Dry	26	619
Wet-insufficient supply	4	176
Wet-saline supply	17	588
Wet-suitable supply	9	407
Abandoned	2	78
Totals	58	1 868

FOLLOW—UP SURVEY 1976 (Table 24)

During September 1976, a follow-up survey was conducted to establish how many of the 9 successful 1969-1970 drought relief bore sites had been developed.

Results : 3 developed
6 not developed.

Most of the sites were not developed because the drought ended and the bores were not required.

Table 24: Status of drought relief successful bores: Chillinup, September 1976

				1969 - 1970			1976		
Owner	Loc.	Litho	Bore No.	Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
C8	Near 1462	434/80	2629-IB23	43.9	11	2200			x
CA	Near 1914	434/80	2729-IC5	30.2	114	2900			x
C122	Near 1840	435/80	2629-IVB15	38.1	68	900			x
C126	Near 1344	435/80	2629-IVC19	14.6	6	6000			x
CB	Near 1913	434/80	2729-IC4	64.6	18	1900			x
C19	Near 6210	446/80	2529-IIA15	64.3	136	2720	x		
C14	Near 6228	446/80	2629-IIIB9	58.2	49	6700	x		

C17	Near 6762	446/80	2529-IIA14	49.1	45	1980			x
C24	Near 6763	446/80	2529-IIA16	58.2	196	2500	x		
							3		6

COMMENTS ON FUTURE SITING OF BORES

The most prospective area for groundwater is probably south of the Pallinup River in the Tertiary sediments, where depths of up to about 100 m may be expected.

Small local supplies of groundwater from weathered granitic rocks and schists have been found but new areas of similar geology would require inspecting before test drilling.

NORTH STIRLING

LOCATION AND TOPOGRAPHY

The North Stirling drought relief area covers the East (Stirling) Ward of Cranbrook Shire; West Ward and part of East Ward, Tambellup and Magitup-Amelup localities, Gnowangerup Shire.

Topographic variation is strongest in the west Tambellup area as a consequence of streams trending seaward. Here also vegetation is well-developed with tall stands of white gum while elsewhere on the sandplain mallee eucalypts are predominant.

GEOLOGY

Much of the North Stirling district is gently undulating sandplain over gneissic granite, with sandplain over Tertiary Plantagenet Group sediments in the Magitup-Amelup area.

HYDROGEOLOGY

Rainfall

The average annual rainfall is between 380 mm and 460 mm.

Groundwater

Most property owners in the district have relied on surface catchments and dams for water supplies.

The occurrence of groundwater can be inferred from the results of the 1969-1970 drought relief drilling.

Most water was found in the West Tambellup area where bores were sited downslope of the larger topographic rises, particularly where dolerite dykes cut drainage lines. Three successful bores were in Proterozoic quartzite of the "Stirling-Barren Series", which although hard is moderately permeable.

Bores in the Tambellup area usually penetrated about 18 m of mottled, kaolinized granite before being completed in hard rock. Most water came from the more permeable hard rock-weathered rock interface zone. Groundwater salinities are fairly high, averaging around 6 000 mg/l TDS and yields are about 10 m^3/d.

Bores drilled in the sandplain overlying Tertiary sediments in the Magitup-Amelup area indicated large supplies of saline water. Further north, near Gnowangerup, bores intersected poorly permeable kaolinized granite and thus were usually dry or had small supplies of saline water.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 25)

Number of properties inspected	26
Number of Government Reserves inspected	4
Total	30
Number of properties recommended for drilling	24
Number of Government Reserves recommended for drilling	4
Total	28

Number of properties drilled successfully	14
Number of Government Reserves drilled successfully	2
Total	16

Number of properties drilled unsuccessfully	10
Number of Government Reserves drilled unsuccessfully	2
Total	12

Table 25: Summary of drought relief drilling: North Stirling

	Properties		Government Reserves	
	No.of bores	Total depth (m)	No.of bores	Total depth (m)
Dry	17	375	3	88
Wet-insufficient supply	8	228	1	38
Wet-saline supply	20	483	1	19
Wet-suitable supply	14	336	2	42
Abandoned	0	0	2	33
Totals	59	1 422	9	220

FOLLOW UP— SURVEY 1976 (Table 26)

During September, 1976, a follow-up survey was conducted to establish how many of the 16 successful 1969-1970 drought relief bore sites had been developed:
Results : 10 developed (4 partially equipped)
6 not developed.

Two of the undeveloped sites (2329-IA12 and 2429-IVA1) were considered to be failures because the groundwater was too salty.

Instead of a bore a soak was dug at 2330-IIB2.

Table 26: Status of drought relief successful bores: North Stirling: September 1976

Owner	Litho	Loc.	Bore No.	1969 - 1970			1976		
				Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
E.Hancock	445/80	4521	2429-IIIA1	39.9	79	3000	x		
Jebarjup Pastoral Co	445/80	4447	2429-IID2	43.6	39	5000	x		
A.Muir	445/80	1463	2529-IIID4	14.0	11	7000	x		
J.Bradshaw	436/80	6078	2429-IC7	33.8	26	2500	x		
R.Sadler	437/80	492	2429-IVD6	7.3	21	3000	x		
E.A.Crosby	437/80	1979	2329-IA10	15.5	8	11000	x		
Nymbup Pastoral Co	437/80	6429	2329-IA13	18.3	15	3500			x
E.P.Bradshaw	437/80	6078	2329-IA8	29.3	49	2500	x		
B.C.Bowman	437/80	6456	2329-IA9	24.1	43	6000			x
J.Trevennen	437/80	2542	2330-IIB1	12.8	5	7280	x		
K.P.Taylor	436/80	3970	2429-IVA3	33.8	39	5000			x
K.H.Altus	436/80	8853	2430-IIIC4	33.8	15	6000			x
N.J.Witham	437/80	8781	2330-IIB2	15.5	96	7000	x		
Hilder & Son	437/80	5281	2329-IA12	13.7	15	10400			x
Road Reserve	436/80	Near 2607	2429-IVB2	21.6	49	6500	x		
Playing Field Tambellup	436/80		2429-IVA1	20.1	131	16000 11000			x
Totals							10		6

COMMENTS ON FUTURE SITING OF BORES

The most prospective areas for locating groundwater are downslope of the larger topographic rises, particularly if the drainage lines are cut by dolerite dykes or quartz veins.

Small local supplies may be obtainable from quartzite of the "Stirling-Barren Series" but these areas require inspection before test drilling.

Elsewhere the groundwater is predominantly saline.

SOUTH STIRLING

LOCATION AND TOPOGRAPHY

The South Stirling drought relief area covers the Wellstead, Kojaneerup and South Stirling localities of Albany Shire, and the Kamballup, Woogenellup, Kendenup localities of Plantagenet Shire.

Much of the South Stirling district is gently undulating, and the most deeply dissected area is the Vale of Kalgan which passes through the Woogenellup locality.

GEOLOGY

South of the Stirling Range, sandplain country overlies Tertiary Plantagenet sediments. Some granitic inliers, such as Green Range, protrude through the sandplain, and these act as recharge areas for groundwater.

HYDROGEOLOGY

Rainfall

The average annual rainfall is between 460 mm and 640 mm. Farm dams only have natural catchments, there being few roaded or sealed catchments which might concentrate rainfall toward dams.

Groundwater

The occurrence of groundwater can be inferred from the results of the 1969-1970 drought relief drilling.

Most property owners have relied mainly on surface catchments and dams for water supplies, although some farmers in the Green Range area have been using bore water for many years.

Most of the usable groundwater came from Tertiary sediments in the southern part of the area. Further north, near the Stirling Range, only saline water was

recovered from bores into the sediments, but some successful bores were sited downslope from the larger granitic inliers.

The average depth of successful bores is about 24 m, giving a groundwater supply of about 27 m^3/d of 5 000 mg/l salinity. One bore yielded 196 m^3/d of 8 000 mg/l water and a number of other bores had yields between 77 and 127 m^3/d. These bores all penetrated a dark silty, sandy, clay zone having a surprisingly high permeability.

Bores drilled in the Vale of Kalgan gave mostly saline water except for a few which were sited near granitic inliers.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 27)

Number of properties inspected	43
Number of Government Reserves inspected	9
Total	52
Number of properties recommended for drilling	39
Number of Government Reserves recommended for drilling	8
Total	47
Number of properties drilled successfully	24
Number of Government Reserves drilled successfully	5
Total	29
Number of properties drilled unsuccessfully	15
Number of Government Reserves drilled unsuccessfully	3
Total	18

Table 27: Summary of drought relief drilling: South Stirling

	Properties		Government Reserves	
	No.of bores	Total depth (m)	No.of bores	Total depth (m)
Dry	31	691	3	66
Wet-insufficient supply	26	928	2	58
Wet-saline supply	31	631	4	110
Wet-suitable supply	25	885	6	287
Abandoned	10	294	0	0
Totals	123	3 429	15	521

FOLLOW UP SURVEY—1976 (Table 28)

During September, 1976, a follow-up survey was conducted to establish how many of the 31 successful 1969-1970 drought relief bore sites had been developed.

Results : 15 developed
16 Not developed.

Two of the undeveloped bore sites were considered failures by the farmers because of high groundwater salinities. The remaining 14 sites were not developed because either the drought ended or the farm changed ownership.

Table 28: Status of drought relief successful bores: South Stirling: September 1976

				1969 - 1970			1976		
Owner	Litho	Loc.	Bore No.	Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
S.Ferguson	446/80	6835	2528-IA28	38.4	20	11600			x
W. & D.Gracock	445/80	5666	2528-IVA26	29.9	9	6800			x
J. & G.Cheney	445/80	6050	2528-IVD36	24.1	66	9000	x		
R. & D.Pyle	451/80	5948	2528-IVC17	28.3	33	10700	x		
S.Masny	450/80	6473	2528-IC17	36.6	39	2200			x
I. & B.Dunn	450/80	6467	2528-IB1	43.0	36	1200			x
T. & R.English	446/80	6834	2528-IA31	47.5	65	5170			x

W.Sullivan & Co.	446/80	6833	2528-IA32	47.5	26	3800			x
R. & L.Lawrence	446/80	6847	2629-IIIC19	48.2	16	2400	x		
W. &G.Ovens	446/80	5669	2528-IVA36	27.4	26	900			x
R. & D.Snader	446/80	6838	2629-IIIC21	44.2	13	8200	x		
Lloyd	446/80	6235	2528-ID34	38.4	13	6300			x
D. & J.Thomson	446/80	6459	2528-ID40	20.1	20	2600	x		
N. & A.Cameron	446/80	6458	2528-IVA37	33.8	5	2600	x		
T.Smith	446/80	6461	2528-ID35	30.8	76	9100	x		
W. & G.Grant	446/80	5943	2528-IVB16	24.7	26	5800			x
W.S.Ovens	446/80	5944	2528-IVB14	23.8	196	8000	x		
W.Monk	445/80	5968	2528-IVC14	43.0	33	4800			x
W.Monk	445/80	4563	2428-IA4	43.0	5	8000			x
W.J.Hunt	445/80	4036	2428-IA5	24.7	26	3000	x		
S. & E.Baesjon	445/80	5137	2428-ID8	33.8	58	2400	x		
G.Williss & Co.	445/80	3978	2428-ID5	33.8	11	10000			x
D.Silvester	445/80	954	2428-IVA23	29.3	131	10000	x		
R.De Pledge	445/80	4050	2429-IIIB6	47.5	131	8000			x
I.L.Keen	445/80	6008	2428-ID4	43.0	7	1000	x		
Crown Reserve	450/80	6464	2528-IC19	47.5	39	2600			x
Road Reserve Wellstead	446/80	Near 6834	2528-IA33	65.8	131	5500	x		
Crown Reserve	446/80	6864	2629-IIIC20	65.8	78	4600	x		
Crown Reserve	446/80	6095	2528-IVA38	36.3	79	8000			x
Crown Reserve	446/80	6095	2528-IVA39	33.8	27	5300			x
Road Reserve	445/80	Near 1891	2428-ID9	37.2	79	4650	x		
Totals							15		16

COMMENTS ON FUTURE SITING OF BORES

The most prospective area for establishing a community supply of groundwater is in the South Kojaneerup-Wellstead area where drilling will be in the Tertiary sediments.

Target drilling depths of between 30 m and 50 m should be encouraged.

FITZGERALD

LOCATION AND TOPOGRAPHY

The Fitzgerald area is situated north and south of the Jerramungup-Ravensthorpe road, extending from the Rabbit Proof Fence, about 19 km east of Jerramungup, to about 24 km east of the West River. The Fitzgerald School is about half-way between these two points.

The landscape shows very little relief, consisting of flat, near-flat, or broadly undulating sandplain. The main drainage is effected by the Fitzgerald River and the West River, but there are also numerous, small, mostly ill-defined or incipient gullies.

GEOLOGY

The land surface is covered with a blanket of greyish to yellowish sand overlying either fresh granite or weathered zones of varying thickness. Throughout the area the weathered granite profiles are thin and seldom exceed 20 m.

HYDROGEOLOGY

Rainfall

The average annual rainfall is about 400 mm, most of which is evaporated before percolation and a very large percentage of the remainder is transpired by the vegetation.

Groundwater

Agriculturally, Fitzgerald is an area of new land, and no drilling had been carried out before the 1969-1970 drought relief drilling. The groundwater potential was entirely unknown and the drilling programme had to be designed to test the conditions in various topographical environments. Consequently the test bores were sited on low-lying flats, along low-level and high-level gullies, and at various elevations on the slopes. The whole area

was tested without success.

No drilling was done along the Fitzgerald and West Rivers, which had salinities in excess of 18 000 mg/l TDS. The salinities of the subsidiary gullies and shallow groundwaters associated with them were also very high. This is probably caused by a change in the hydrological pattern following clearing of the native vegetation for conversion to pasture or crop. It is consistent with some other areas where the first appearance of salting occurred within a few years of clearing and reached a maximum after 10 to 20 years.

DROUGHT RELIEF INVESTIGATIONS 1969-1970 (Table 29)

Number of Government Reserves inspected	19
Total number of sites pegged on reserves	9
Total number of sites pegged on roads	66
Total number of sites drilled	63
Total number of sites drilled successfully	1
Total number of sites drilled unsuccessfully	62

Table 29: Summary of drought relief drilling: Fitzgerald

	No. of bores	Total depth
Dry	43	648
Wet-insufficient supply	1	24
Wet-saline supply	18	398
Wet-suitable supply	1	39
Abandoned	nil	nil
Totals	63	1 109

FOLLOW—UP SURVEY 1976 (Table 30)

The only successful bore site of the 1969-1970 drought relief drilling had not been redrilled and developed when inspected in September, 1976 because the yield was considered too small for a community supply.

Table 30: Status of drought relief successful bore: Fitzgerald, September, 1976

				1969 - 1970			1976		
Owner	Litho	Loc.	Bore No.	Depth (m)	Supply m^3/d	Salinity TDS mg/l	Successfully developed	Unsuccessfully developed	Not developed
Reserve	419/80	Near 1259	2730-IIID4	39.3	7	8000			x

COMMENTS ON FUTURE SITING OF BORES

The drought relief exploratory drilling project of 1969-1970 has shown that groundwater yields are so small that future drilling cannot be recommended.

SUMMARY

The 1969 rainfall for most of the agricultural areas was less than the annual average and it came as scattered bursts of light rain which did little to fill dams. The dry summer from October to February caught many farmers unprepared for drought conditions. Luckily cyclonic rains in February helped relieve a rapidly worsening situation.

In an effort to supply farms with suitable stock water a drought relief exploratory drilling programme was started in 1969 and continued into 1970. A total of 2879 bores were drilled of which only 278 were classified successful (yield more than 4.5 m^3/d and salinity less than 11 000 mg/l TDS).

At the time of the follow-up survey (1976), 125 of the 278 reportedly successful sites had been developed, 7 unsuccessfully. 153 had not been developed and 24 were considered failures by the farmers.

Most farmers do not consider it economical to equip a bore unless the salinity of the groundwater is less than 8 000 mg/l TDS and the yield greater than 7 m^3/d. This is a higher requirement than was imposed on the 1969-1970 drought relief drilling and accounts for the large number of sites not developed.

Many farmers have made an effort to obtain a satisfactory water supply by drilling or dam sinking and those that have not been successful are carting water.

Table 31: Follow up survey 1976: Summary of results

Area	Total No. bores drilled	Considered Successful 1969-1970			
		Successfully developed 1976	Unsuccessfully developed 1976	Not developed 1976	Farmers considered failure 1976
Mt Marshall-Koorda	166	4	2	4	
Westonia	286	7		18	12
Burracopin South	175	8	1	3	
South Yilgarn	106	1			
Mt Walker	145	1		11	4
Kulin-Kondinin	162	3		7	1
Holt Rock	106	27	1	13	
Nyabing-Pingrup	658	6		28	2
Lake Grace	246	3	1	7	
Ravensthorpe	95	11	2	9	3
Ongerup	407	19		24	
Chillinup	58	3		6	
North Stirling	68	10		6	
South Stirling	138	15		16	2
Fitzgerald	63			1	
Totals	2 879	118	7	153	24

CONCLUSIONS

The drought relief districts described in this report have a semi-arid climate and are generally geologically unfavourable for finding domestic or stock quality groundwater. Systematic drilling to test the groundwater

potential of different geological environments and various topographical settings has shown that there are preferred areas for future groundwater prospecting.

Mt Marshall-Koorda: Although not entirely reliable, long gentle drainage slopes, where thick sandy clays cover weathered basement, are probably the most prospective groundwater sites, especially if basement rock crops out at the top of the slope.

Westonia: Long gentle drainage slopes and thick superficial sands adjacent to large granitic outcrops are the most prospective areas for obtaining groundwater.

Burracoppin South: Mt Cramphorne area is probably the most likely area for developing a community groundwater supply.

South Yilgarn: Future drilling cannot be recommended.

Mt Walker: Deep weathered and fractured granite near granitic exposures, particularly if fairly high in the drainage system, offer the best prospects for obtaining groundwater.

Kulin-Kondinin: The most prospective areas for finding groundwater are about 1 to 1.5 km downslope from the granitic intake areas.

Holt Rock: The best sites for groundwater prospecting are above drainage base level near granitic hills and also in large infilled depressions surrounded by granite.

Nyabing-Pingrup: The most prospective areas for obtaining stock quality groundwater are on the sandplains where deep sand overlies jointed granite.

Lake Grace: The best areas for groundwater prospecting are in sandy gullies which receive run-off from rock outcrops further up slope.

Ravensthorpe: The most prospective areas for siting groundwater bores are in the sandplain area east and southeast of Ravensthorpe and downslope from steeper topographic rises or gneissic hills. The coastal sand dunes and associated limestone could also be an important aquifer.

Ongerup: In the granite areas the most prospective sites for groundwater are where thick alluvium rests on weathered granite.

In the Plantagenet Group sediments the best sites are about 300 m from the surface contact between the sediments and the granite. Lower down in the drainage the groundwater is generally too salty.

Chillinup: The most prospective area for groundwater is probably south of the Pallinup River in the Tertiary sediments where depths of as much as 100 m are expected.

North Stirling: The most prospective areas for groundwater are downslope of the larger topographic rises, particularly if the drainage has been cut by dolerite dykes or quartz veins.

South Stirling: The most prospective area for establishing a community supply of groundwater is in the South Kojaneerup-Wellstead area where drilling will be in Tertiary sediments.

Fitzgerald: Future drilling cannot be recommended.

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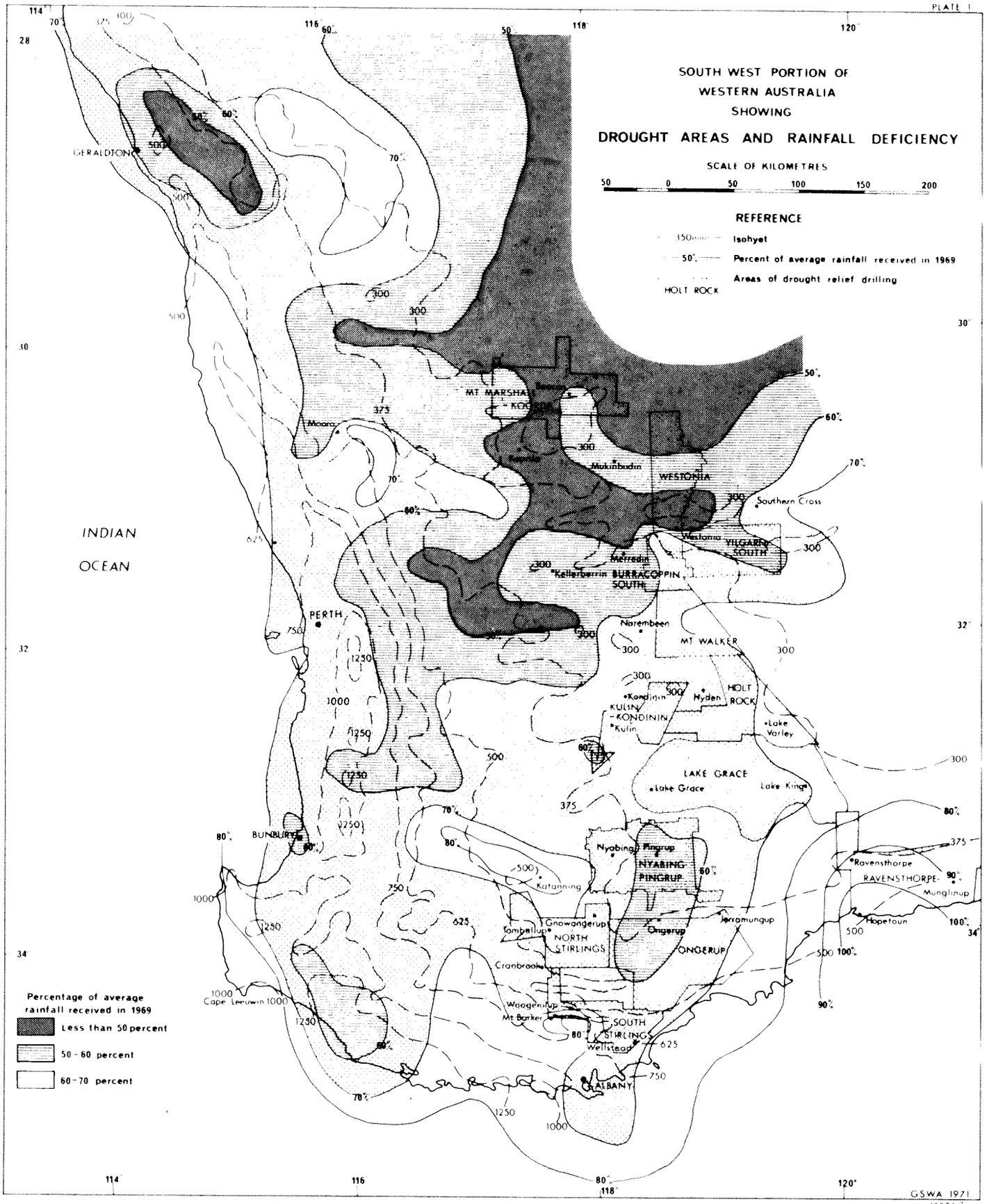
SOUTH WEST PORTION OF
WESTERN AUSTRALIA
SHOWING
DROUGHT AREAS AND RAINFALL DEFICIENCY
SCALE OF KILOMETRES
50 0 50 100 150 200
REFERENCE
350mm Isohyet
50% Percent of average rainfall received in 1969
Areas of drought relief drilling
HOLT ROCK
INDIAN
OCEAN
GERALDTON
Moora
MT MARSHALL
KOORDA
Mukinbudin
WESTONIA
Southern Cross
Merredin
Kellerberrin
BURRACOPPIN
SOUTH
YILGARN
SOUTH
PERTH
Narembeen
MT WALKER
Kondinin
Hyden
HOLT
ROCK
KULIN
KONDININ
Kulin
Lake
Varley
LAKE GRACE
Lake Grace
Lake King
BUNBURY
Nyabing
Pingrup
NYABING
PINGRUP
Katanning
Ravensthorpe
RAVENSTHORPE
Munglinup
Tambellup
Gnowangerup
Ongerup
Jerramungup
NORTH
STIRLINGS
ONGERUP
Hopetoun
Cranbrook
Cape Leeuwin
Waogeenup
Mt Barker
SOUTH
STIRLING
Wellstead
ALBANY
Percentage of average
rainfall received in 1969
Less than 50 percent
50 - 60 percent
60 - 70 percent
GSWA 1971
12261 A