1969/73

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COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

054226

Record No. 1969 / 73

Drought and Groundwater in the Australian Capital Territory

by

G.M. Burton

DROUGHT AND GROUNDWATER IN THE AUSTRALIAN CAPITAL TERRITORY

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Record 1969/73

(Paper presented at the Symposium:
"THE HYDROLOGICAL ASPECTS OF DROUGHT - with particular reference to the A.C.T. & environs" held at Canberra, May 1969, and organized by the Hydrological Society of Canberra)

CONTENTS

(NOTE: This paper should be read in conjunction with the other papers of the symposium (see Appendix). Copies of all papers have been lodged as a volume in the Bureau of Mineral Resources Library, Canberra)

SUMMARY

The nature of a drought is defined and the important differences in both the character and duration of surface and groundwater droughts are stated. The occurrence of groundwater in the Canberra area is explained, and the role of groundwater in maintaining the base flow of rivers and springs is stated.

The 1965-1968 drought started with groundwater storage at a high level: groundwater was able to sustain the flow of rivers and springs during the severe shortage of rainfall in 1965 and ameliorated the severity of the early stages of the drought. Groundwater storage declined progressively and was unable to sustain the flow of most springs and rivers in the very dry summer of 1967/68. The yield of bores was little affected by the drought and the bores continued through the drought to supply badly needed farm water supplies.

The importance of observation bores in hydrological networks is stressed. Attention is drawn to the importance of the hydrograph of Lake George that forms one of the few long term hydrological bench marks of the Canberra area; its interpretation will yield valuable guides to possible climatic changes.

INTRODUCTION

This paper deals specifically with the behaviour of groundwater in the Australian Capital Territory during the drought which commenced in 1965. It also contains supplementary information on the drought gathered during water balance studies in the Lake George catchment adjoining the A.C.T.

Before the 1965 drought can be considered in detail it is necessary to define a groundwater drought, and describe the normal groundwater regime in the A.C.T.

GROUNDWATER DROUGHT

I propose to define drought as the state of strain imposed on the natural environment and human culture of a specified area by an appreciable reduction in the natural supply of moisture.

I would consequently define a groundwater drought in a specified area as a drought in which normal periodic or seasonal recharge becomes insufficient to maintain groundwater at a level where it will carry out its normal natural, and reasonable developed functions in that area. These functions in any area may be several of the following:-

To maintain base-flow of any effluent rivers,
to supply reasonable bore outputs,
to maintain springs,
to supply phreatorphytes by direct contact; and
to promote growth of limited areas of pasture by slow seepage through soil.

The failure of adequate recharge may occur by the complete absence of recharge in one annual recharge season or by the cumulative effect of below-average recharge over a number of seasons. A groundwater drought can usually be considered in terms of years rather than weeks or months. It generally will not develop until a year or more after the onset of a long agronomist's or meteorologist's surface drought, and may not end for several years afterwards. Not all agronomist's droughts lead to groundwater droughts.

The severity of the groundwater drought will be measured by the degree of strain imposed on the environment and culture. Only one of the functions of groundwater, such as the flow of high-level springs, may fail in a mild drought; in severe drought major streams may cease to flow as well as the high-level springs.

Recharge or replenishment of groundwater depends on many factors, the more important of which are rainfall, evaporation, landform (including soil distribution), geology, and vegetation. The areal extent of a groundwater drought will be controlled by the local influence of rainfall and evaporation on the other factors. We may have a severe local groundwater drought in a belt of limestone country, such as Wee Jasper, while immediately adjoining country in volcanic rocks is not as seriously affected. The cause of this difference is the much higher permeability and easier drainage of the limestone than the volcanics; the specific yield of both rocks would not differ greatly.

Before detailed discussion on the 1965-1968 drought, it is important to consider briefly the general occurrence and behaviour of groundwater in the A.C.T.

GROUNDWATER IN THE A.C.T.

Groundwater in the A.C.T. and environs occurs mainly in fractures, joints and weathered zones of crystalline rocks such as porphyry, granite, limestone and metasediments (Fig.1). Alluvial aquifers are restricted to the Lake George basin and small areas along mature sections of the Molonglo and Murrumbidgee Rivers. Very minor perched aquifers occur in a few small areas of special soil or scree.

The Canberra region is part of the headwaters catchment of the Murrumbidgee River. Cainozoic faulting has led to rejuvenation along most major rivers and many minor streams: the drainage network is dense, in keeping with the relative youthfulness of the major streams, which are only two to four miles apart. The rejuvenated streams are effluent and discharge groundwater moving in the neighbouring crystalline rocks for most of almost every year. Most groundwater does not travel far: from the recharge areas (which usually are areas of thin skeletal soils on the

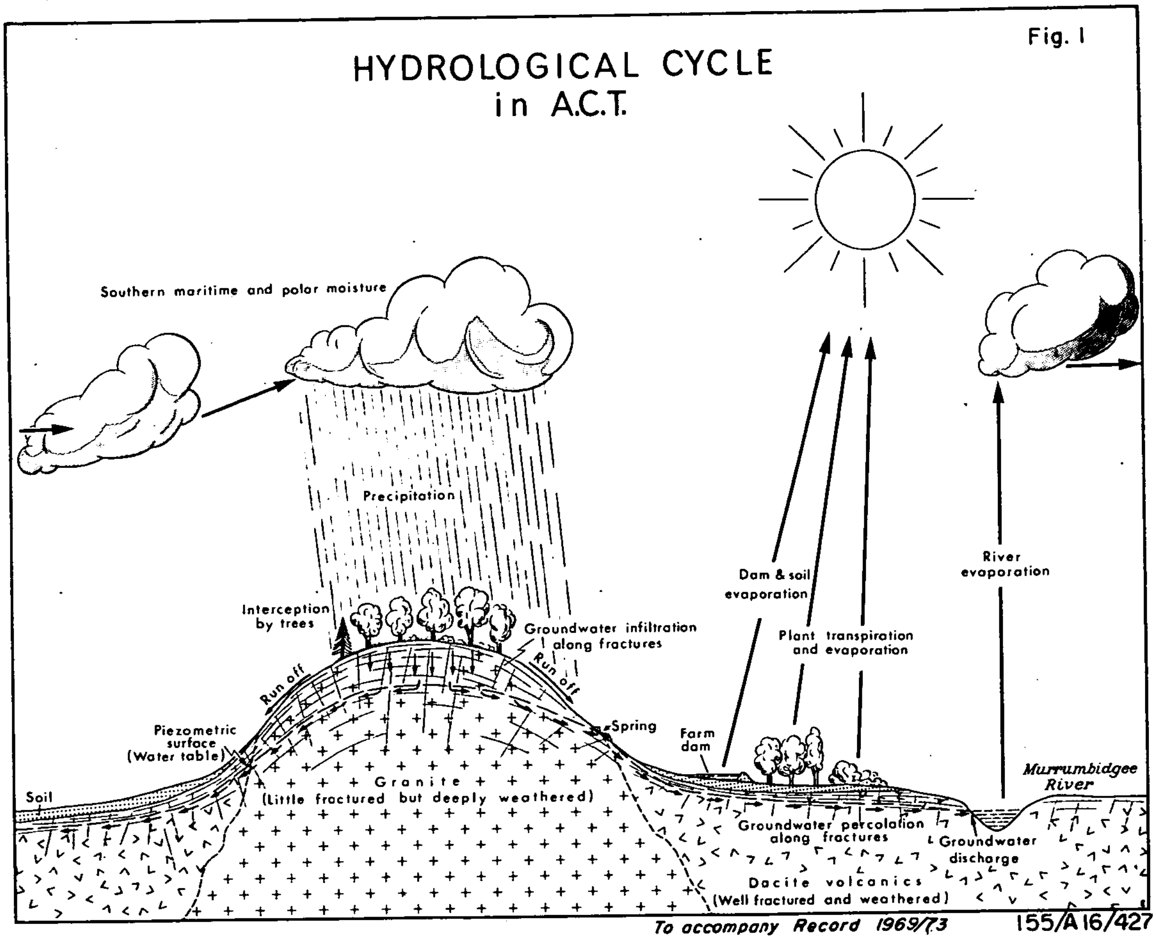


Fig. 1

HYDROLOGICAL CYCLE in A.C.T.

To accompany Record 1969/73 155/A16/427 higher ground and non-perennial water courses on the upper and some of the lower slopes) to springs along the major effluent streams; the distance is commonly only one to four miles.

The aquifer in the crystalline rocks is generally the upper mantle of open-jointed and weathered rock. This mantle follows approximately the form of the local topography: the most permeable and porous part of the aquifer is only about 15 to 100 feet thick. Because the porosity occurs only in fractures and weathered material the specific yields are very low - possibly only about 0.3% to 4%. Transmissibility is low - commonly about 100 to 400 gallons/day/foot. Most importantly, however, the aquifers have a marked natural slope: commonly about 1 in 40 in the ridges and plain country, and about 1 in 4 to 1 in 10 in the ranges.

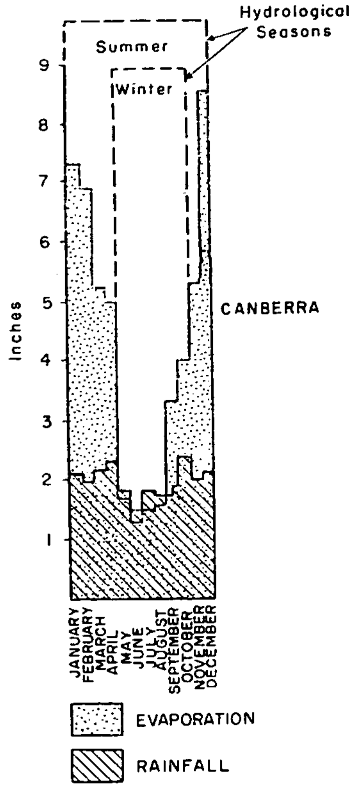
Hence we may summarize: our effluent streams are fed mainly by short thin dipping aquifers of low permeability and very low specific yield. It does not take long to dewater almost completely the main part of the aquifers, which really owe their efficiency to the very great regularity of rainfall in the autumn, winter, and spring (Fig.2). Some faults and shear zones that form thicker parts of the aquifer, and certain geomorphological restrictions, maintain a long slow supply to major streams even after dewatering in a long drought.

The process of recharge is as follows:
In autumn the moisture-deficient soils start to receive appreciable moisture as evaporation decreases in the cooler months (Fig.2), colder temperatures slow down plant growth and their moisture consumption; precipitation continues at approximately the same rate throughout the year. The length of the recharge season and quantity of recharge depend very much on the late April and May and especially, the spring precipitation. Particularly important is frequent steady low to medium intensity rainfall that penetrates rather than runs off soil. Absence of rain in the spring and autumn has a two-fold effect - it increases the length of the groundwater discharge (or recession) season and shortens the recharge. Hence groundwater droughts commonly originate in these months.

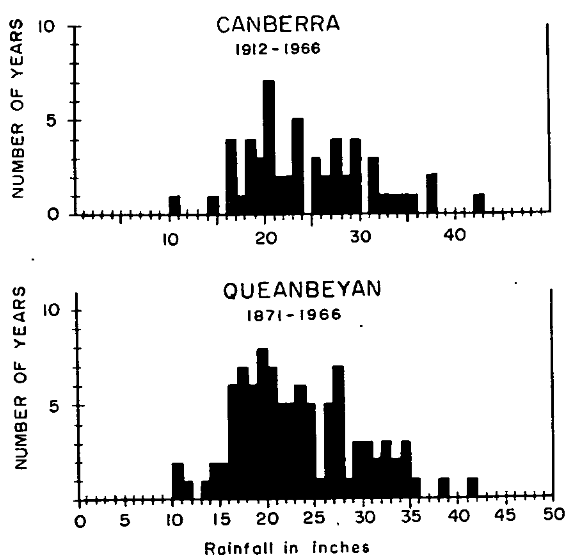
- Fig. 2

Climatological Data
Canberra - Queanbeyan Area

MEAN RAINFALL AND EVAPORATION



ANNUAL RAINFALL HISTOGRAMS



Bureau of Mineral Resources, Geology and Geophysics. To accompany Record 1969/73

155/A16/436

The Canberra region is only about 1,000 square miles in area, but the natural environment varies markedly across the region. Different combinations of geology, landform, elevation, rainfall, evaporation and vegetation have led the Bureau of Mineral Resources to divide the region into six groundwater provinces (Fig.3), which are only slight modifications of Griffith-Taylor's physiographic subdivision of the Territory.

Observation bores

Groundwater observation bores are a normal part of a well-designed hydrologic network. However, they are commonly one of the last parts of the network to be established. This is understandable because they can be expensive to construct, the design of a network requires considerable hydrogeological knowledge and experience, and commonly some experience in systems design, if maximum efficiency and economy are to be achieved.

As part of a policy of assessing the groundwater resources of the Canberra region and gathering basic hydrogeologic data for its various provinces, the Bureau has progressively established a small network of observation bores over the last 12 years.

Economy has been achieved by using Bureau drills in short slack periods. Several graziers have also made their private bores available. The Bureau has kept liaison with officers of the Department of Works and Bureau of Meteorology, the Forestry and Timber Bureau and other organizations in order to close the important groundwater gap in the data of the network covering the local hydrologic cycle. Exchange of data during the recent drought suggests substantial progress in our knowledge of the cycle.

Also, under a limited educational programme, a number of local graziers have been trained to record and understand groundwater levels in their bores, along with their usual rain and stream measurements. This should help the graziers to understand the full water-budget of their properties. With experience they will be able to predict the failure of springs or streams in time of drought.

The location of the observation bores are shown in Fig.3 and details of the terrain, rainfall and bore data are given in Table 1.

GROUNDWATER PROVINCES OF AUSTRALIAN CAPITAL TERRITORY

Fig. 3

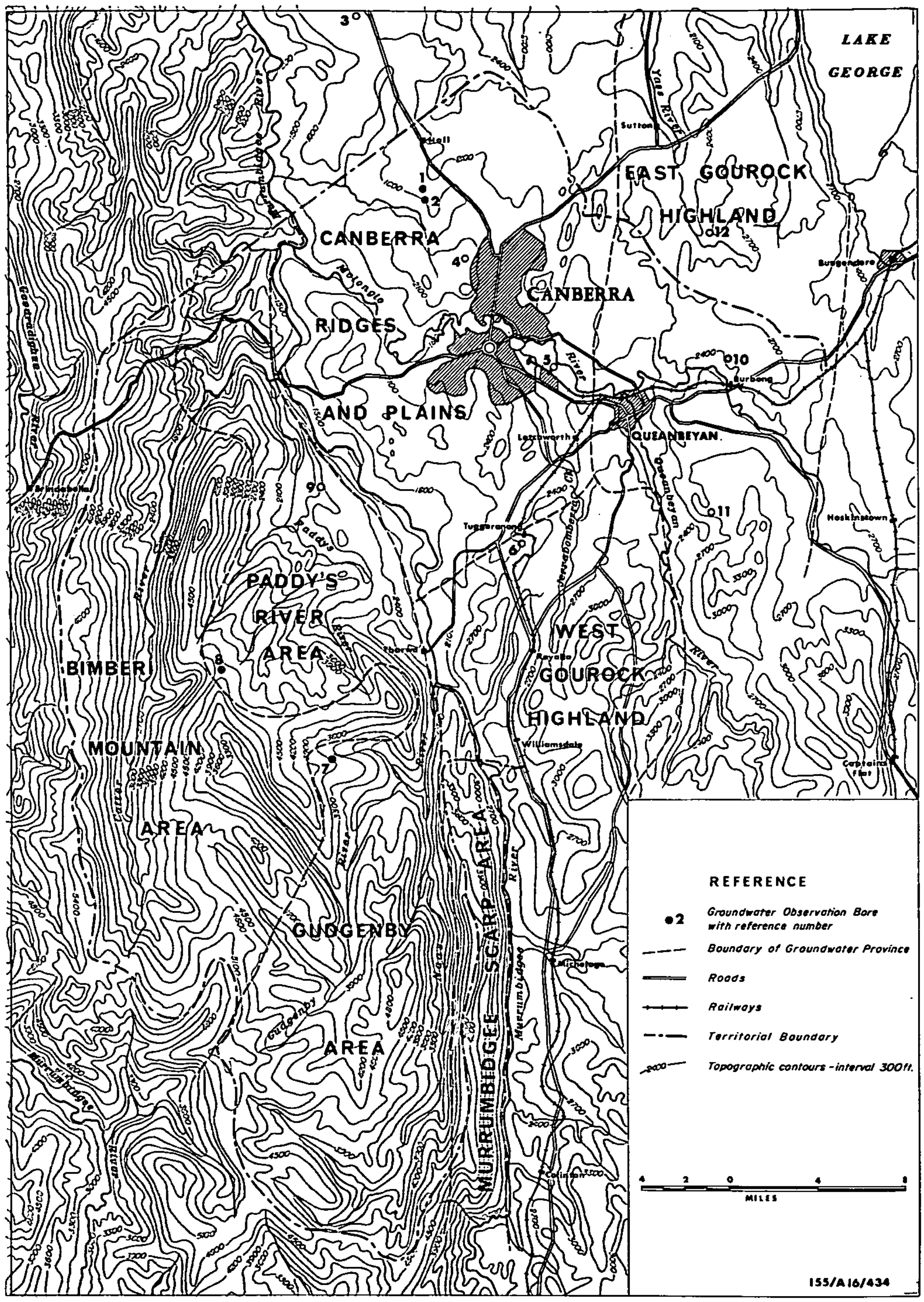


TABLE I : REGIONAL GROUNDWATER OBSERVATION BORES, A.C.T. & ENVIRONS

Ref. No.	Bore Name & Location	Groundwater Province (Plates 1 & 2)	Elevation of bore ft. a.s.l.	Nature of Catchment: Ann. Rainfall in inches	Geology	Physiography	Vegetation & Culture	Gauging Started	Depth to water 1/ 2/67	Maximum variation in levels	Approx. yield of Bore - g.p.h.
1	Belconnen 5 (Gribble's Farm)	Ridges & Plain	2140	25	Porphyry-intrusive	Higher slopes of low divide	Natural grassland	Dec. 1958	48.8 ft	22 ft	200
2	Belconnen 6 7 & 8 (C.S.I.R.O. Farm)	" "	1940(8)	25	Porphyry-intrusive	Small perched basin with granite bar	Grasslands, partly pasture improved	Dec. 1958	9.3 (Bore 8)	10	1500(6) 20(7) 900(8)
3	Jeir 1 (Jeir Station)	" "	1875	25	Acid volcanics - medium dip	Margin of broad plain	Mainly natural grassland	Oct. 1961	19.7	5	>100
4	Belconnen 13 (Black Mountain)	" "	2032.6	25	Siltstone and slate - strongly folded	Lower slopes of strong dividing ridge	Mainly natural Eucalyptus forest	Mar. 1966	88.0	1	20
5	City 13 (B.M.R. Fyshwick)	" "	1895	25	Volcanics and sediments - strongly sheared	Low ridge on rolling plain	Natural grassland - partly developed as light industrial area	June 1966	19.7	6	>10,000
6	Lanyon 5 ("Melrose Valley")	W. Gourock Highland	2350	25	Porphyry	Lower slopes of major perched valley partly rejuvenated	Grassland - pasture improved with clover	Aug. 1960	36.9	13	100
7	Tennent 1 (Honeysuckle Tracking Station)	Gudgenby	3520.8	35	Granite - deeply weathered on possible lineament	Lower slopes of deeply dissected valley	Mainly natural Eucalyptus forest	April 1966	22.5	2	>100
8	Cotter River 1 (Corin Dam Road)	Bimberi Mt. & Paddy's River	4064.2	40	Granite - deeply weathered on possible lineament	Major saddle in major dividing range	Natural Eucalyptus forest	April 1966	7.2	14	>100
9	Paddy's River 2 (Tidbinbilla Tracking Station)	Paddy's River	2300(?)	30	Granite - some strongly folded slate	Lower slopes on margin of broad valley	Mainly Eucalyptus forest in recharge area - remainder natural grassland; some lawn at Station	May 1967	8.1 (12/5/67)	-	1800

Groundwater hydrographs

The hydrographs from several of the observation bores are shown in Fig.4. It is impossible to discuss each hydrograph in detail. Several points, however, should be made.

The regularity of recharge in the cooler months can be clearly seen. Significant differences can be seen between the hydrographs. Bore 1 gives the best record; it is in an ideal situation on the groundwater divide between Hall and Ginninderra Creeks. Here the water table is deep; movements are obvious and large. This contrasts with Bore 2, where the water table is shallow; here the effects of use of water by plants can be seen, but slight "noise" due to barographic changes affects the record.

Figure 5 shows two of the hydrographs together with rainfall, evaporation (data from Forestry and Timber Bureau), and minimum flow in the Queanbeyan River (data from the Commonwealth Department of Works).

THE 1965-1968 DROUGHT

I am sorry that so much has had to precede the main point of this lecture.

Reference to Figures 4 & 5 shows very clearly the course of the groundwater drought. Several points stand out.

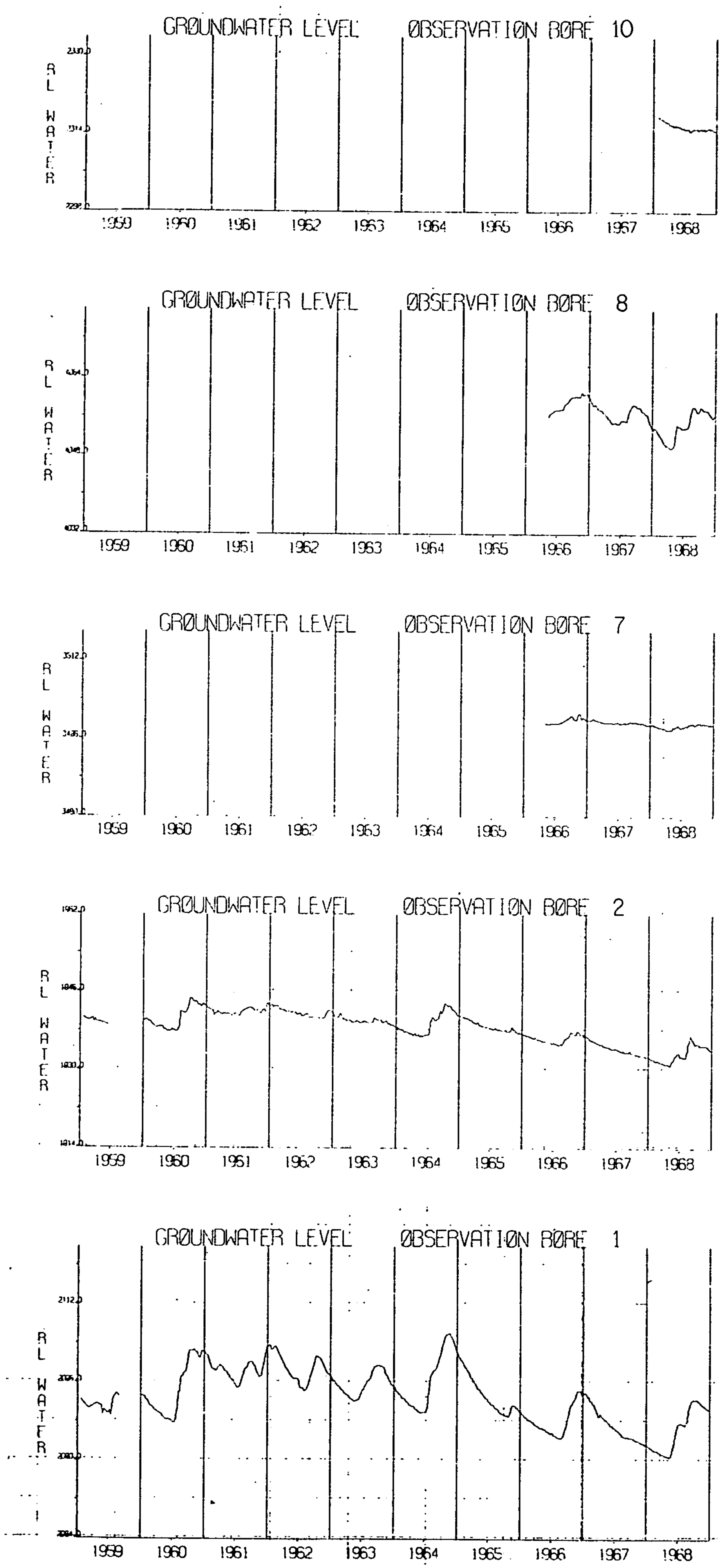
(1) Late winter and spring rain in 1964 brought groundwater to record storage levels.

(2) During the severe surface drought of the first four months of 1965 there was no groundwater drought.

(3) The abnormally high level of groundwater storage of January and February kept many rivers and springs flowing more strongly than would normally have been expected.

(4) The groundwater drought started about June when the poor autumn and winter rains failed to build up soil moisture after the summer and caused an almost complete failure of recharge.

(5) The groundwater drought became progressively worse until September 1966, when reasonable recovery occurred.

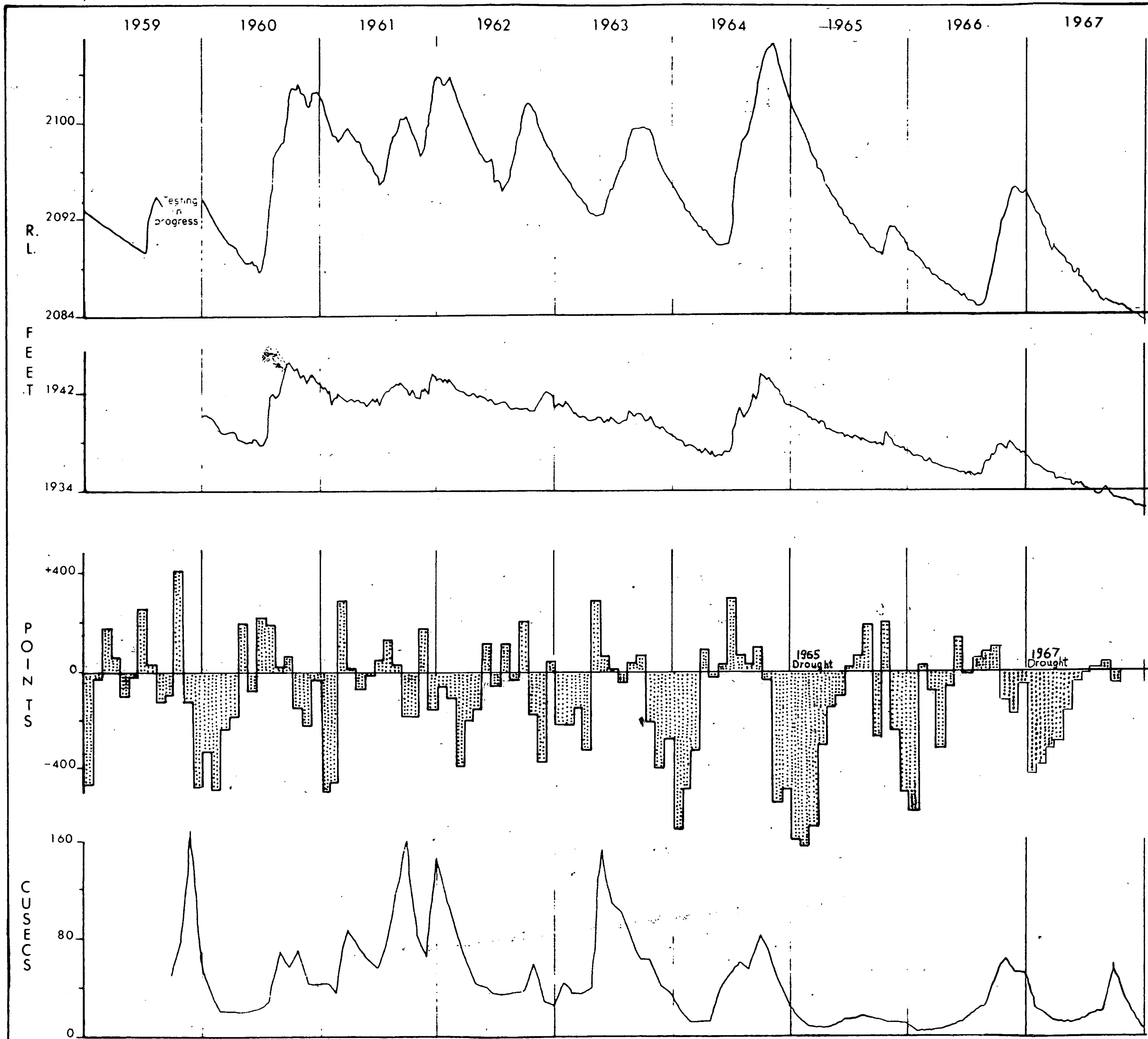


To accompany Record 1969/73 I 55/A16/600 Fig 4

FIG. 5

HYDROGRAPHIC DATA

A. C. T. & ENVIRONS



GROUNDWATER LEVEL in OBSERVATION BORES

Belconnen Nº 5

Belconnen Nº 7

NETT MOISTURE (RAINFALL- POTENT. EVAPORATION) (4-Weekly- Periods) Canberra

MINIMUM MONTHLY FLOW

Queanbeyan River

To accompany Record 1969/73

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(6) The low rainfalls of autumn and winter 1967 were disastrous; the groundwater record started to show that recharge for 1967 was unlikely, and that base-flows of rivers in the summer of 1967/68 would be very low. Warnings were issued to various agencies of the probable low flows.

(7) Substantial recharge occurred in 1968.

(8) The drought had a noticeable effect (change $>$15%) on the maximum rate of pumping of probably only about 10% of the bores in the area; the effect was very noticeable (change $>$25%) in about half of this 10%. In all cases of changes in output that came to the Bureau's attention it was possible to suggest simple changes in the pumping programme so as to produce the same overall daily yield as before the drought.

(9) For the past five or six years the Bureau has been able to use the results from its observation bores to site and determine the correct depth for bores so that droughts will have no appreciable effect on their output.

(10) Thus although I would say the surface drought of 1965-1968 was very severe I would say the groundwater drought was only moderately severe. Groundwater continued to supply most bores with their normal outputs; it continued to maintain the base flows of rivers and springs in the early stages of the drought and only failed to maintain useful flows in most of these in the summer of 1967/68.

(11) I would still hesitate to say that the groundwater drought ended completely in 1968. I believe the rainfall of May and June 1969 will be the deciding factor.

The importance of farm bores can be seen from the foregoing points. Apart from their normal uses they are a safeguard against the complete failure of farm water supplies during the severe droughts that occasionally occur in the Canberra area and cause most surface water supplies to dry up.

The hydrographs show the importance of observation bores. They give an added certainty to interpretation of river hydrographs. In a river hydrograph light winter rains and shallow perched springs may mask the main base-flow which comes from the main deep aquifer; the observation bore, however, records the occurrence of recharge and helps in prediction up to five months or so ahead.

Catchments in drought

The behaviour of catchments in drought is interesting.

The Cotter is a long narrow catchment. Much of the aquifer supplying base-flow dips steeply into the valley and has quite open joints. The ratio of the area of discharge to general area of storage is surprisingly large. In normal times the aquifer is regularly recharged by the excellent rainfall of the catchment and the aquifer provides an excellent continuous base flow. However, in the rare lengthy near-total absence of rain the storage of the aquifer rapidly declines and base flow declines rapidly also.

CLIMATIC CHANGE

I draw attention to Lamb's (1966) hypothesis of a major climatic change in 1960. I believe that some of the local hydrologic records, including Lake George, support it.

One can see how even a small change in our autumn and spring rainfalls, or an increase in their variability, could affect our water resources management.

The more complete are our hydrologic networks recording all elements of the hydrologic cycle the more easily will we be able to detect long term variations in climate and measure their effect on each element of the cycle.

Lake George, which has one of the longest hydrologic records in Australia, may be a very useful tool in the examination of such climatic changes. We still need, however, to know much more about the behaviour of the lake in its lower stages.

Lake George

Figure 6 shows the hydrograph of Lake George since 1819.

The Bureau has tried to gather carefully measurements of the lake during 1965-1968 drought, and these are shown in Figure 8. The graphs show the mean of rainfall from the Bureau of Meteorology's stations at Bungendore and Collector, the temperature of the water, and salinity (total dissolved salts in parts per million). Since the lake has shallowed the salinity has fluctuated rapidly; it will be understood that one inch of rainfall or evaporation makes a marked change on the salinity of 6 inches of water near the western shore: wind and waves will ultimately mix the shallow component with deeper water to the east.

When one looks at Figure 8 one wonders if the 1965 drought did end in 1968. The trend has not changed substantially.

ACKNOWLEDGEMENTS

I gratefully acknowledge the considerable help of colleagues in the Bureau of Meteorology, Commonwealth Department of Works, Forestry and Timber Bureau, and Land Research, C.S.I.R.O., in supplying data and helpful discussion.

The co-operation of local graziers has been outstanding. Of particular note is the help of Mr T. Gribble, Gribble Estate, Dr R. Reader, "Melrose Valley", Jeir Station Pty Ltd, Mr J. Gorman, "Taliesin", Mr P. Osborne, Grantham Park and Mr S. Smith, Leonia.

Hydrologic records would not be gathered without dedicated Technical Assistants and I have been grandly served by mine. The encouragement of senior officers is always an aid and I have had this both in the Bureau and the Department of National Development.

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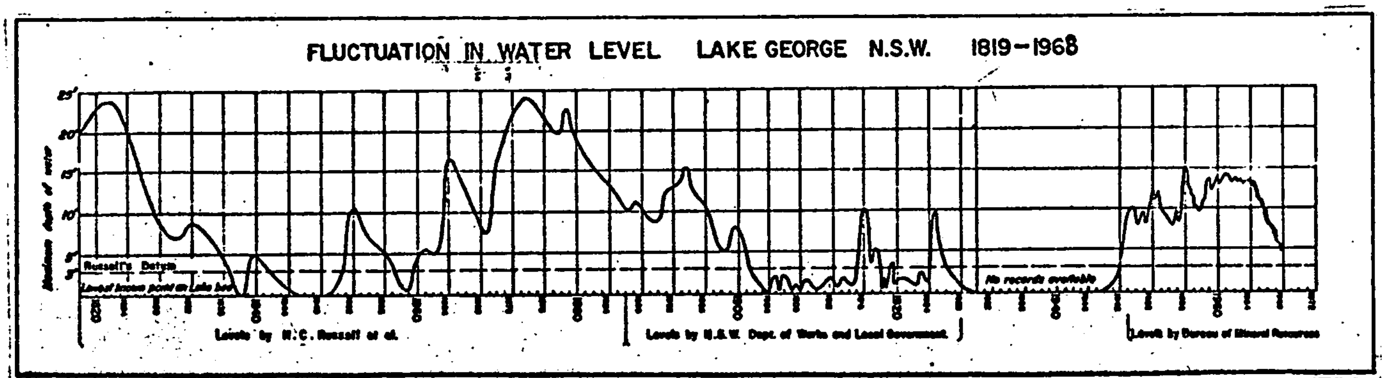
NOAKES, L.C., JENNINGS, J.N., & BURTON, G.M., 1964 - Notes on the Lake George and Lake Bathurst Excursion, in Geological Excursions Canberra District, Bur. Miner. Resour. Publ.

Fig.6

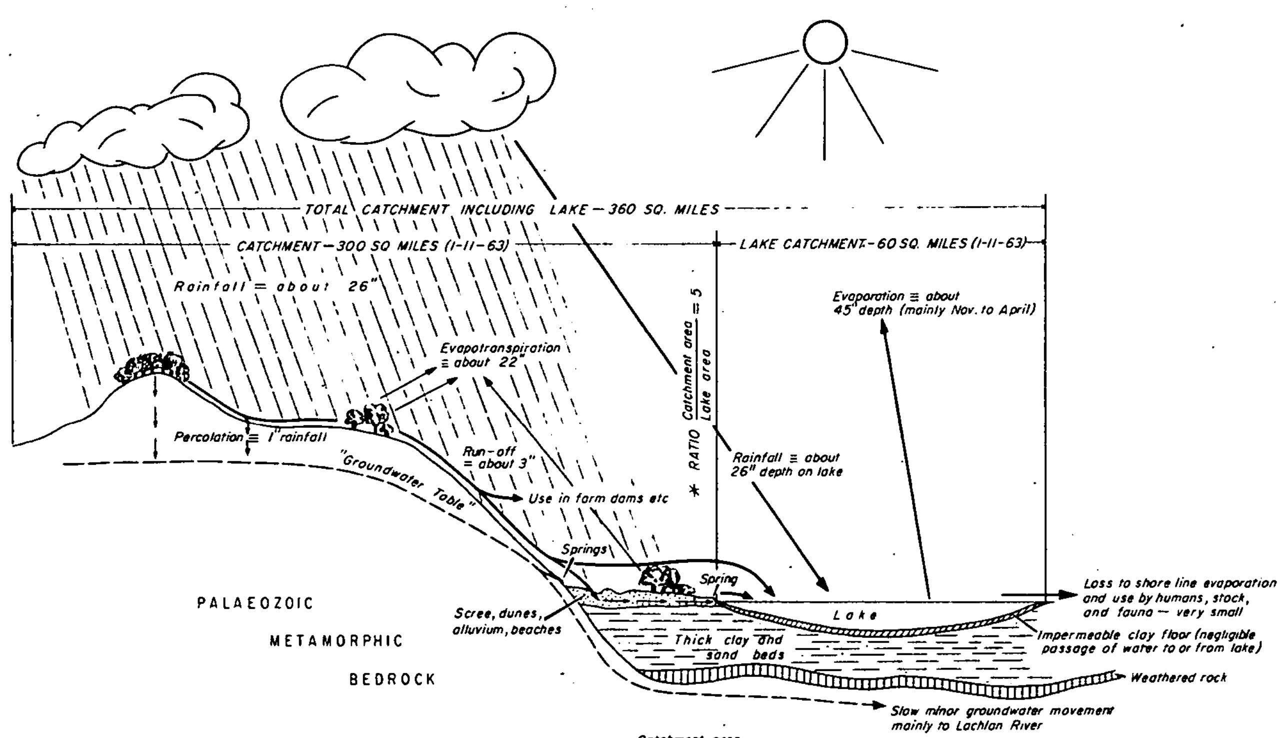


Amended from: Noakes,Jennings & Burton (I964)

Fig. 7

LAKE GEORGE, N.S.W

ANNUAL APPROXIMATE WATER BALANCE



* RATIO $\frac{\text{Catchment area}}{\text{Lake area}}$ varies as lake rises or falls

Ratio = 5 1-11-63

Ratio = 8 1-3-69

and hence depth of run-in will vary even though depth of run-off is the same

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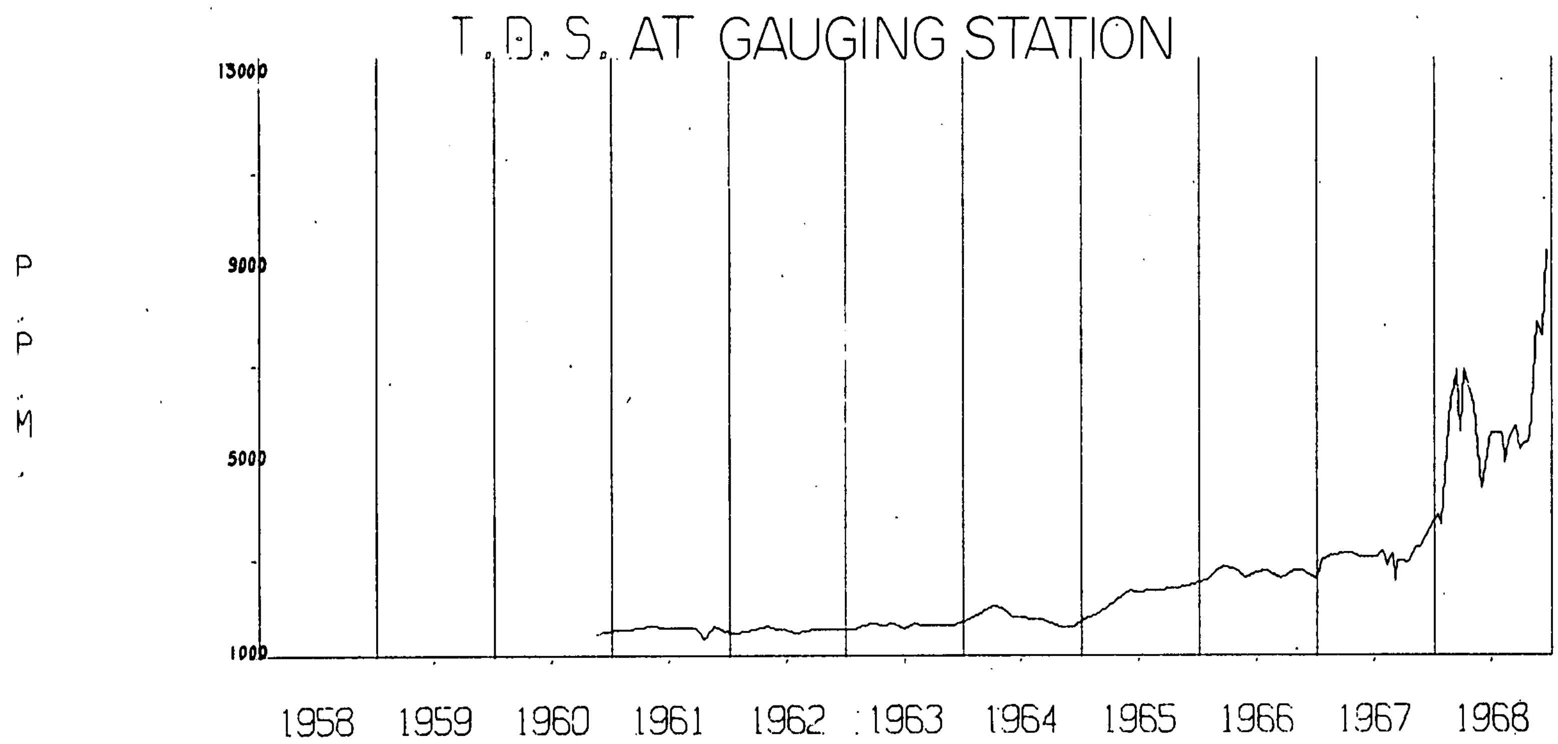

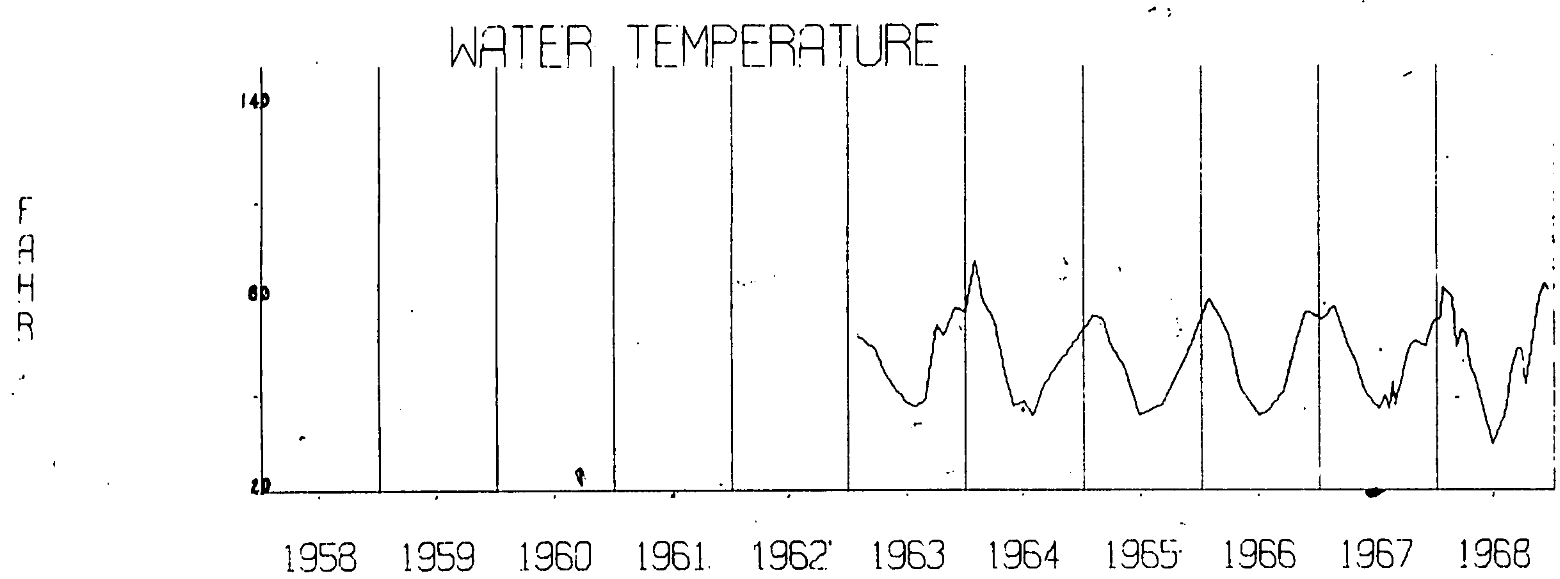

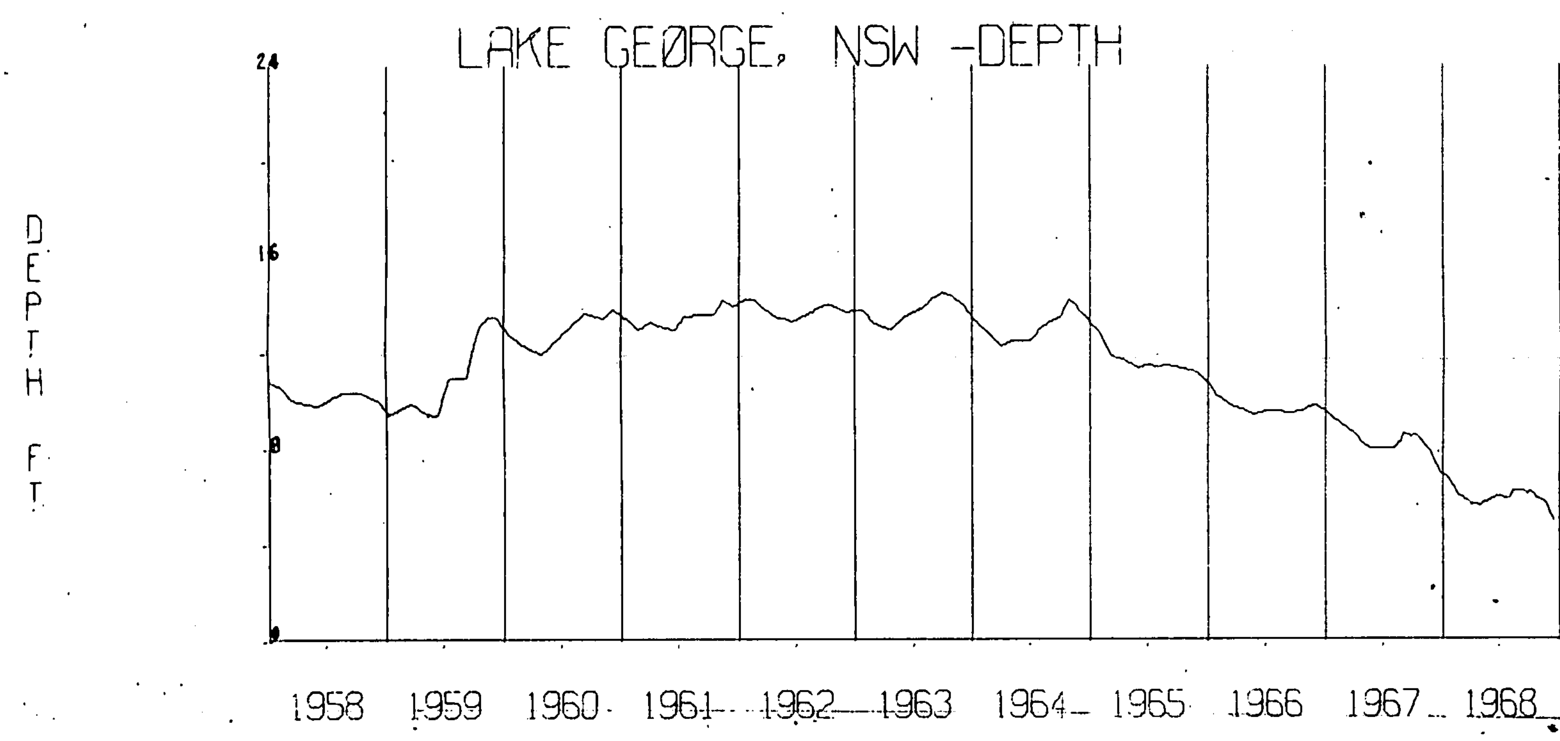

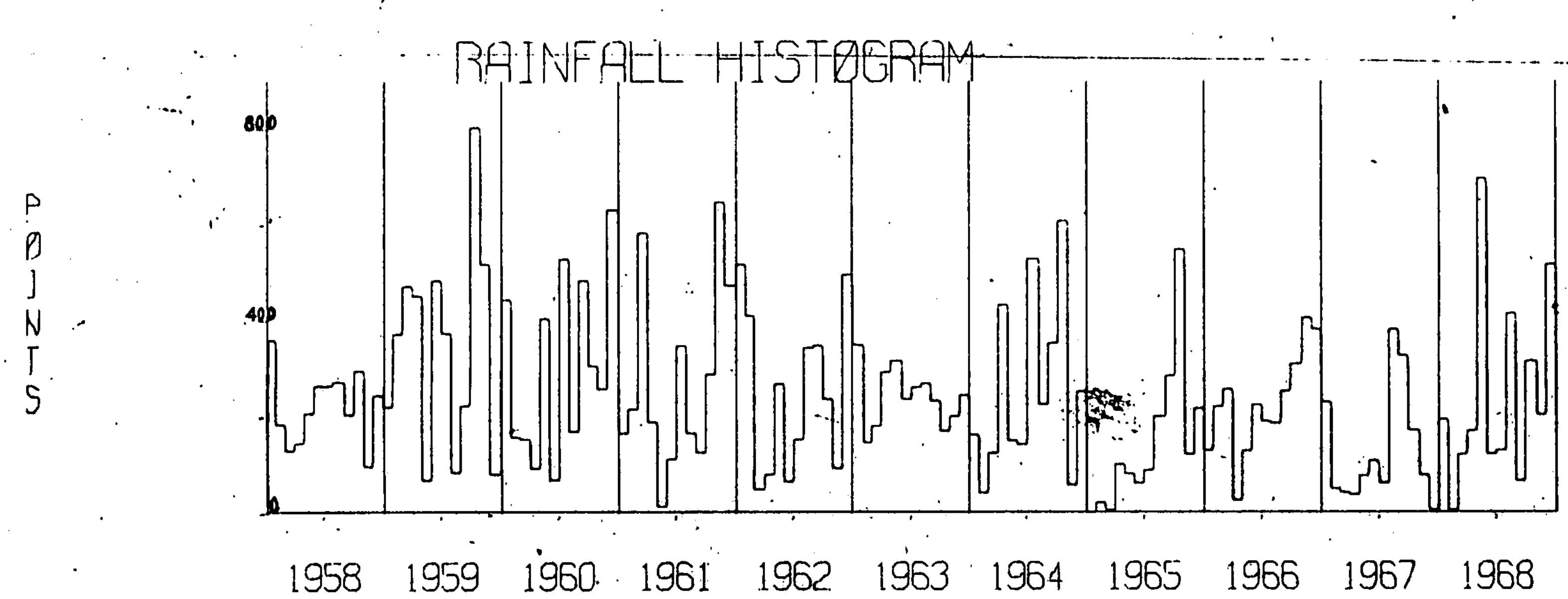

LAKE GEORGE
HYDROLOGICAL DATA 1958-1968

Fig 8

To accompany Record 1969/73

APPENDIX

PROGRAMME OF SYMPOSIUM

09.30 Opening Address - Minister for Interior, Mr Nixon

09.45 Meteorological aspects of the 1965-68 Drought in the A.C.T.
V.J. Bahr, M.E. McCawley and K.J. O'Loughlin, Met. Bureau

10.30 Morning Tea

11.00 Hydrology of Canberra's major water storages in the 1965-68 Drought.
B.J. Fitzgerald, Commonwealth Department of Works

11.30 Agriculture and Rural water supplies in the A.C.T. during the 1965-68 Drought.
T. Taylor, Commonwealth Department of Interior

12.00 Drought and the A.C.T. Forests.
A.J. McArthur and R. Thistlethwaite, Forestry Research Institute

12.30 Luncheon

14.00 Drought and Groundwater in the A.C.T.
G.M. Burton, Bureau of Mineral Resources

14.30 Rainfall analysis techniques and Drought
J. Maher, Bureau of Meteorology

15.00 Simulation techniques for the water balance in a drought situation
J. McAlpine, C.S.I.R.O. Division of Land Research

15.30 Afternoon tea

16.00 Open discussion on drought and symposium summary
Discussion Leader: A.I. McCutchan, Department of National Development.