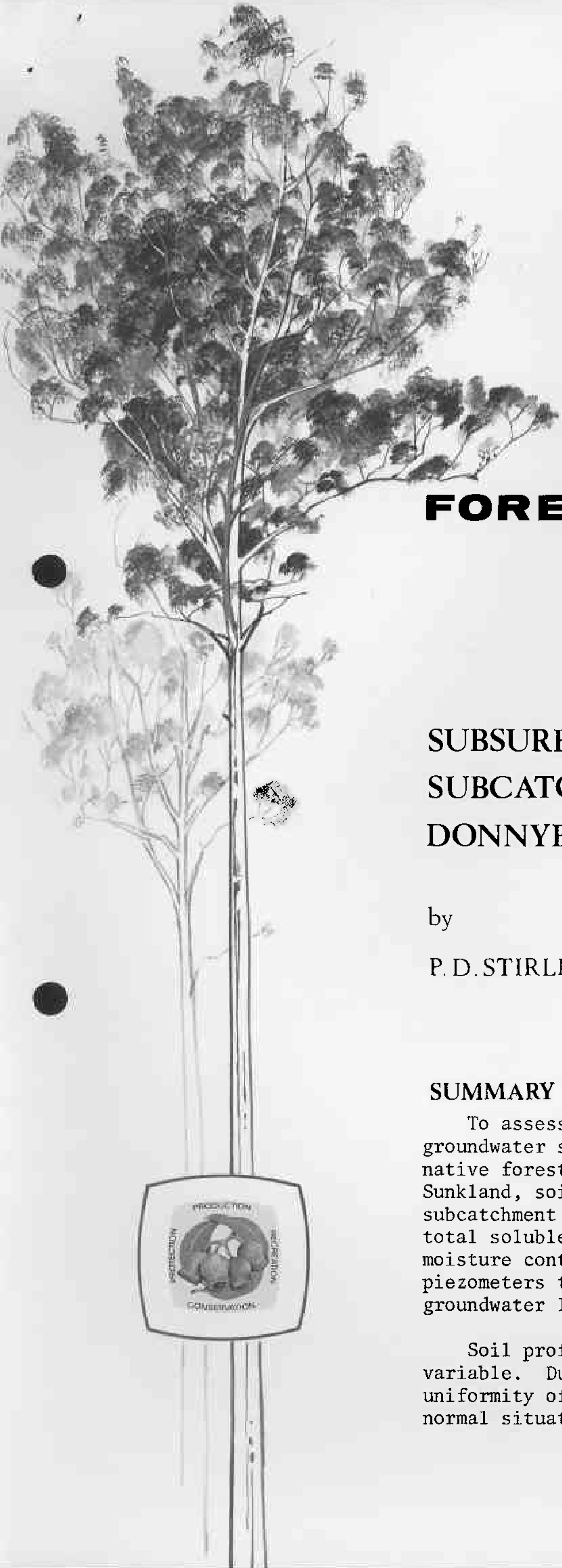

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FORESTS DEPARTMENT
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SUBSURFACE SAMPLING IN A SMALL SUBCATCHMENT IN THE DONNYBROOK SUNKLAND

by

P. D. STIRLING

SUMMARY

To assess the possible effects on the stream and groundwater salinity resulting from the replacement of native forest with exotic pines in the Donnybrook Sunkland, soil cores from 19 bores in a small subcatchment were analysed for electrical conductivity, total soluble salts, chlorides, pH, bulk density and moisture content. The bores were converted to piezometers to provide data on seasonal fluctuations in groundwater level and salinity.

Soil profiles in the area sampled were extremely variable. Due to the geological and topographic uniformity of the Sunkland this is likely to be the normal situation.

INTRODUCTION

The Donnybrook Sunkland pine plantation project (Forests Department of Western Australia, 1975) proposed the conversion of approximately 60 000 ha of native jarrah (*Eucalyptus marginata* Sm.) forest to intensively managed stands of *Pinus radiata* D. Don. The Sunkland contains significant surface water resources, some of which are likely to be used more intensively in the future, as well as very large sub-artesian water resources (Collet, 1973), and the environmental impact of the plantation project will probably be most evident in relation to the area's hydrology. Since 1974 the Forests Department has become increasingly involved in hydrological research associated with the project. Whilst broad-scale stream salinity surveys (McKinnell, 1976) indicated the likely effect of a change in land use on water quality, further information was required concerning subsurface soil properties and groundwater salt content.

Initial pine plantings in the Sunkland have been confined to a representative range of sites in the Apostles Brook Catchment near Jarrahwood (Fig. 1). The hydrology of this catchment can be compared with that of the adjacent St. Paul Brook Catchment, which currently supports native forest and is of comparable size and position in the landscape.

To assist interpretation of the runoff and salinity data collected from subcatchment gauging weirs on the Apostles Brook and to provide information on physical and chemical properties of the subsoil that might affect water quality,

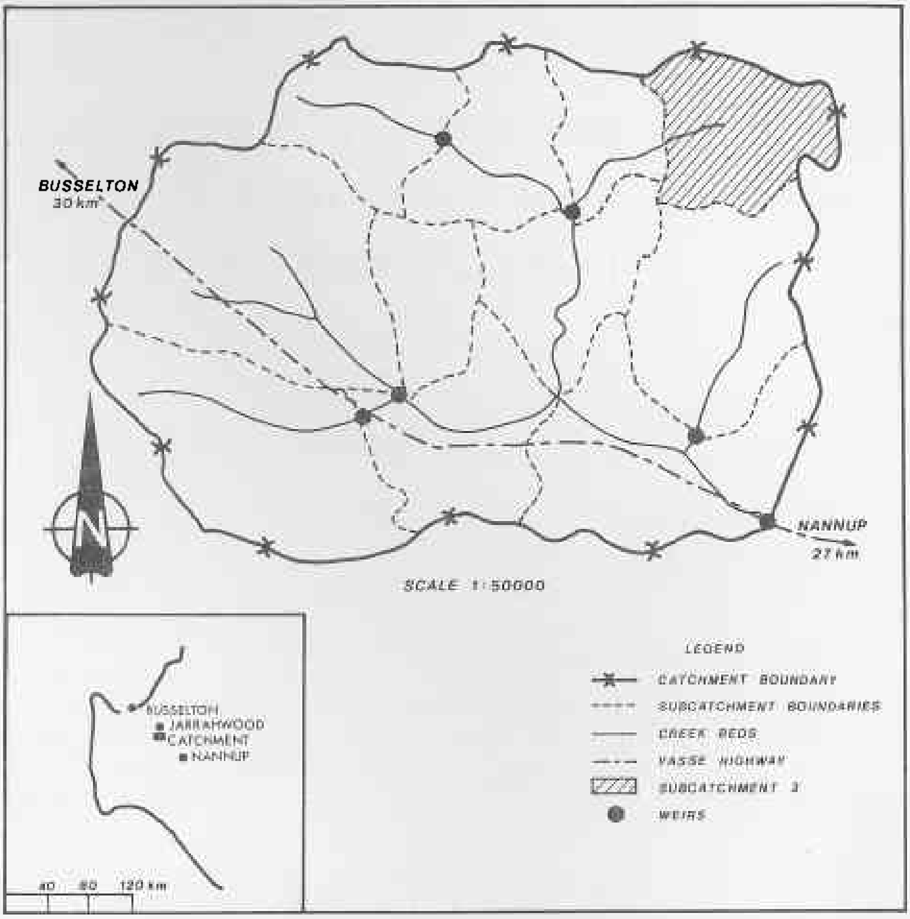


FIGURE 1: Apostles Brook Catchment, showing catchment and subcatchment boundaries and study area (Subcatchment 3).

Inset: location of catchment

a series of bores was sunk in Subcatchment 3 (Fig. 2), which covers an area of 207 ha on the upper Apostles Brook.

This paper reports the results of the subsurface sampling programme carried out during 1975 and 1976, and presents preliminary data collected during the monitoring of groundwater level and salinity.

METHOD

Nineteen sites in Subcatchment 3 were cored to depths varying from 6.08 to 19.76 m. The 1975 series of bores (Q1 to Q9) formed a ridge-to-ridge transect of a typical valley, covering as many different soil types as possible. Owing to the absence of bedrock, the depth of drilling was largely governed by position in the landscape and estimated depth to the water table, but a nominal depth of 8.36 m was specified. Preliminary analysis of the data indicated that deeper, more intensive sampling between the sites was required. Consequently, ten further bores (Q10 to Q19) were drilled in 1976 to a nominal depth of 19.76 m.

The drilling technique was similar to that described by Batini et al. (1976). From each bore a soil core was removed in lengths of 76 cm to the nominal depth if possible; however, because a cutting shoe was used in compacted strata, some of the cores recovered were not complete.

Soil samples were taken from the soil surface and at 76 cm intervals from the drill press shoe. One portion of each sample was placed in an air-tight tin so that moisture content and bulk density could be determined. The other portion was analysed for electrical conductivity (EC), total soluble salts (TSS), sodium chloride (NaCl) content and pH, using the techniques described by Hatch (1976).

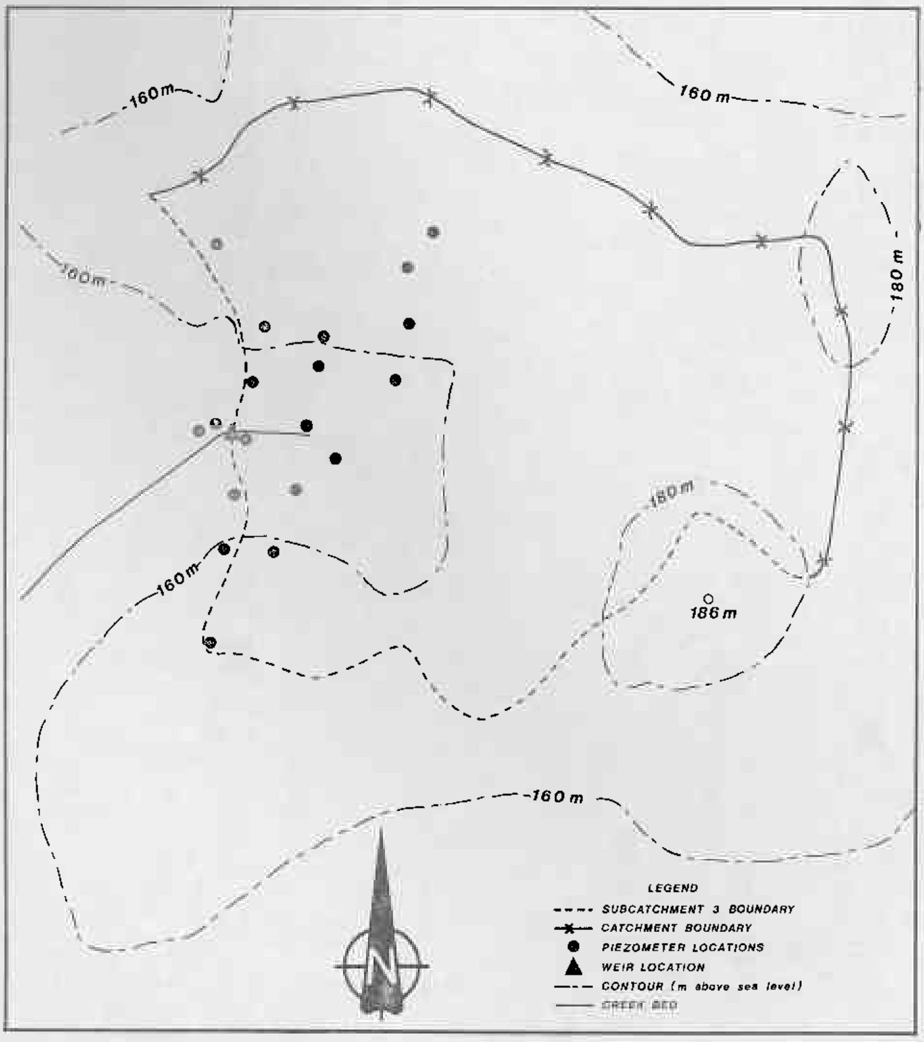


FIGURE 2: Bore and piezometer locations and contours in Subcatchment 3

A piezometer was installed in each bore hole, as described by Batini et al. (1976), and samples were taken at monthly intervals to monitor water level and salinity variations. Only the data for the nine 1975 bores are presented here. Total salt storage for each location was estimated using the Trapezoidal Rule.

RESULTS AND DISCUSSION

Soil profiles

The soil profiles at the different bore sites varied greatly (Fig. 3). However, the general pattern was as follows:

(1) At the surface there was usually a layer of sand 1 to 2 m in depth overlying a concretionary layer of lateritic boulders or gravel. On most ridge-top sites the sand layer was absent or very shallow.

(2) The concretionary layer was underlain by red and yellow mottled sandy clays, the sand component often being very coarse.

(3) The mottled clays phased into pale grey and white clay-zones alternating with layers of sandy clay loam or poorly sorted coarse sands. In coarse-textured layers there was usually a proliferation of fine plant roots (presumably jarrah).

(4) Below 10 m depth the profiles consisted mainly of grey to dark grey clays and sandy clays or poorly sorted sands containing much carbonaceous material, pyrite, mica and some thin bands of lignite. No live plant roots were encountered below a depth of 10 m.

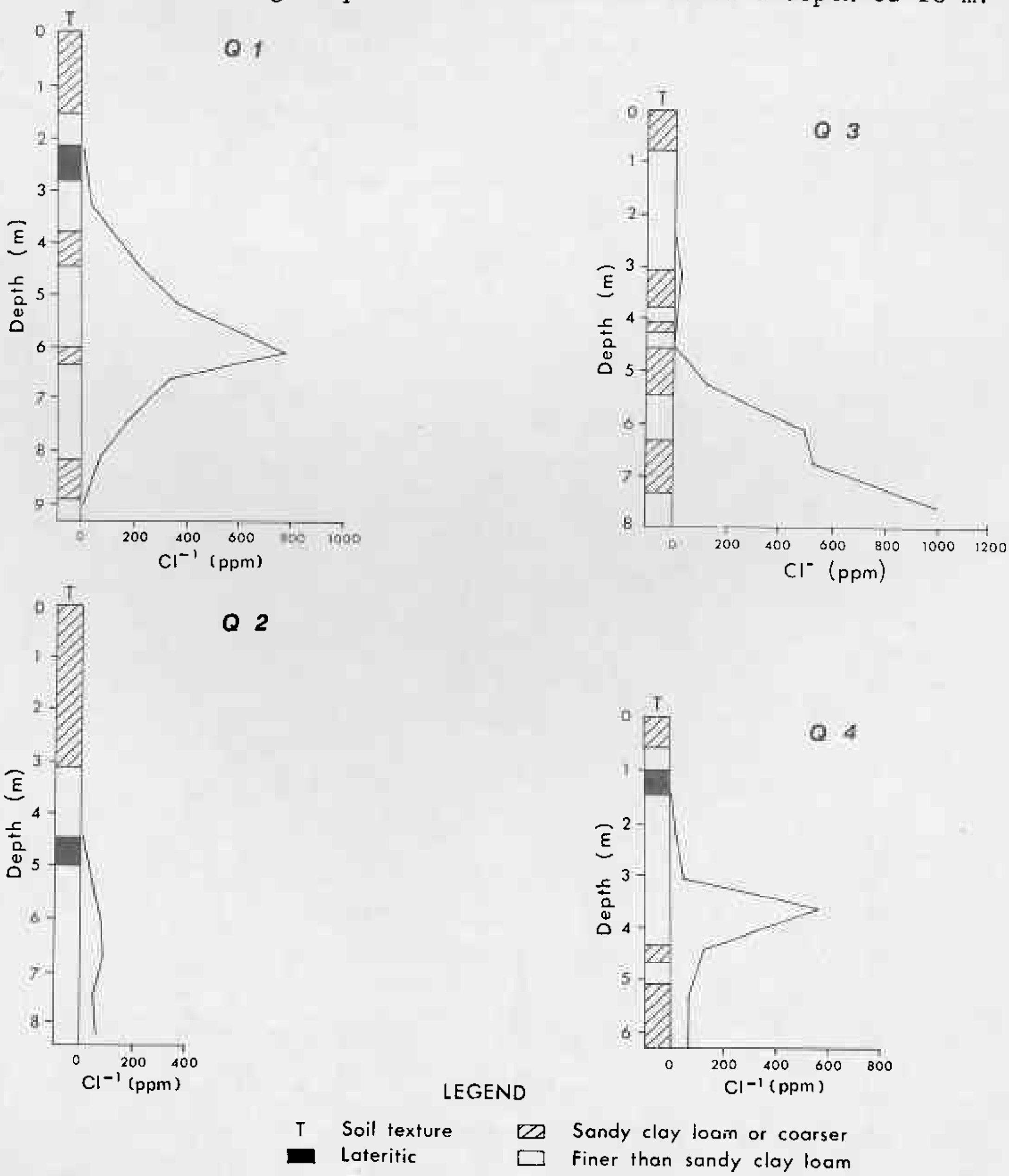
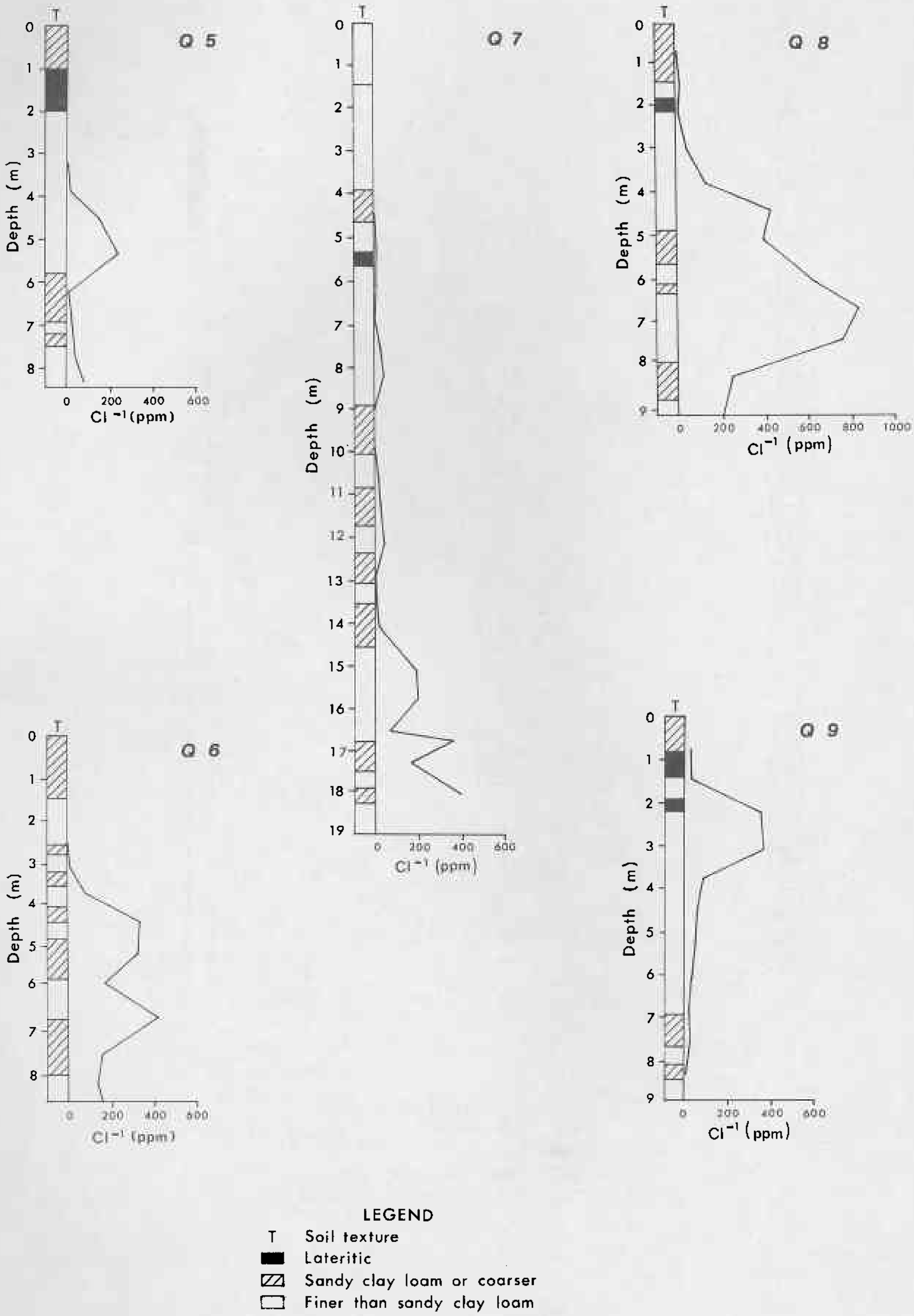


FIGURE 3: Texture and chloride (Cl^-) content of soil profiles, bores Q1 to Q19



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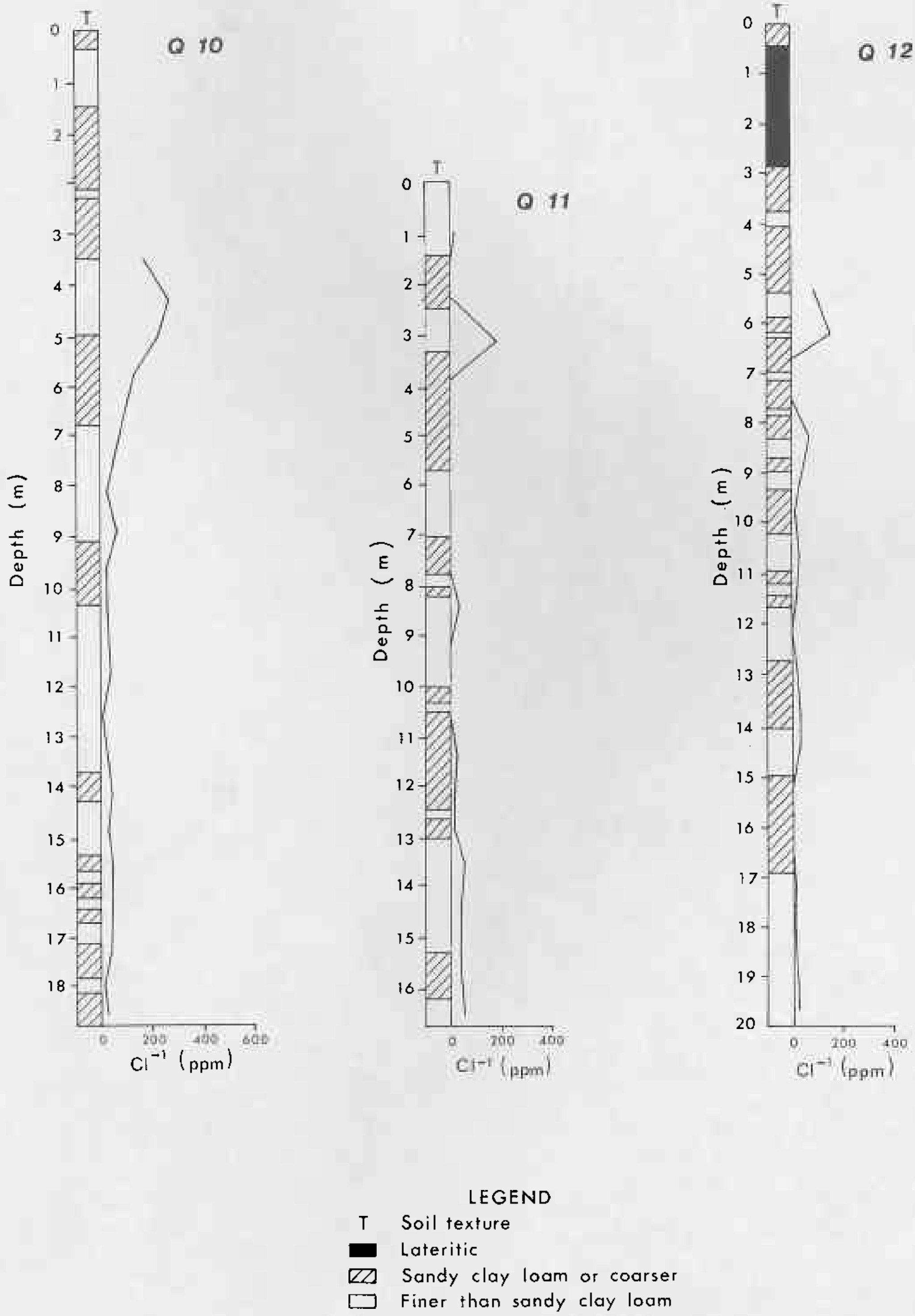

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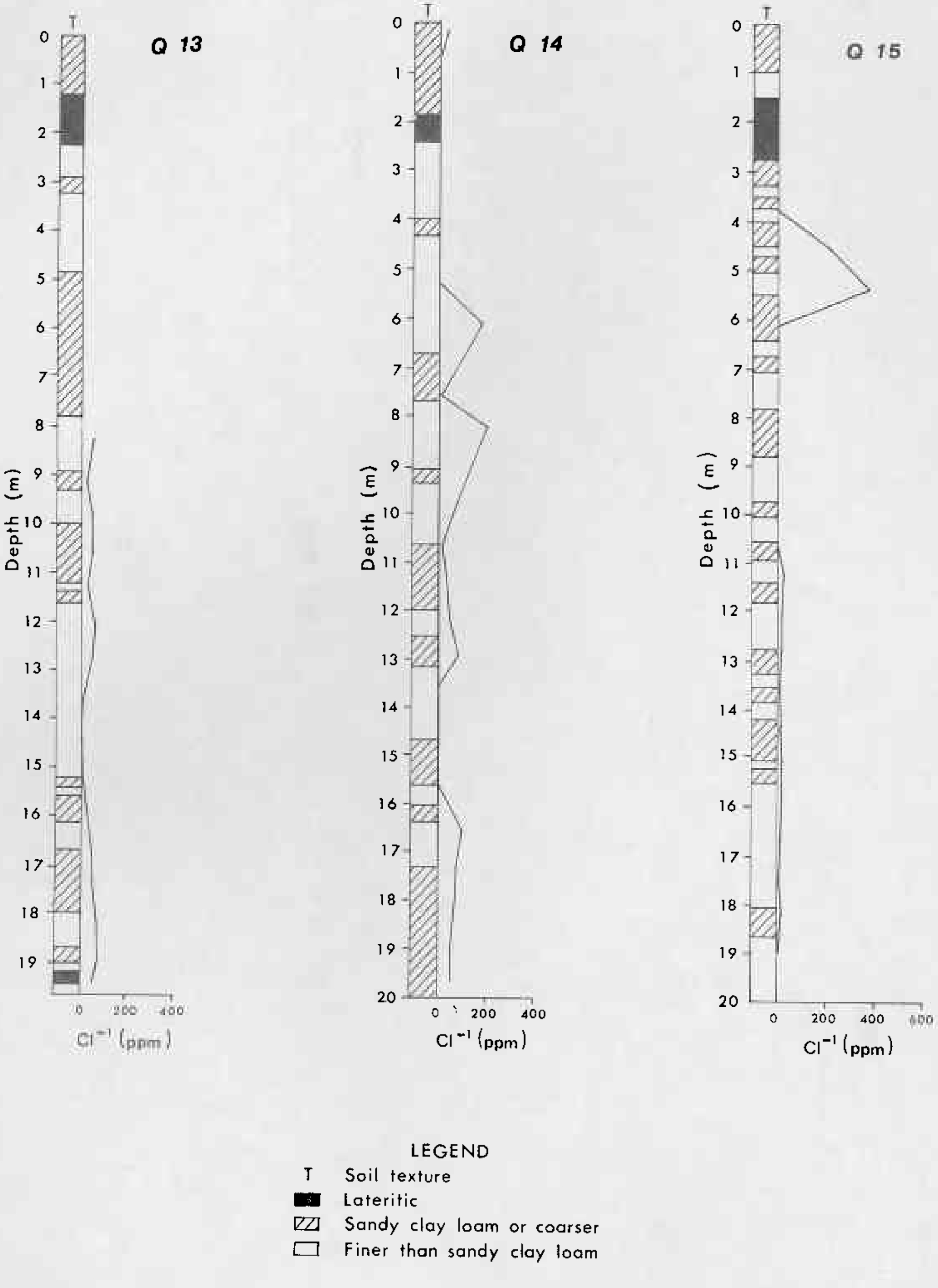

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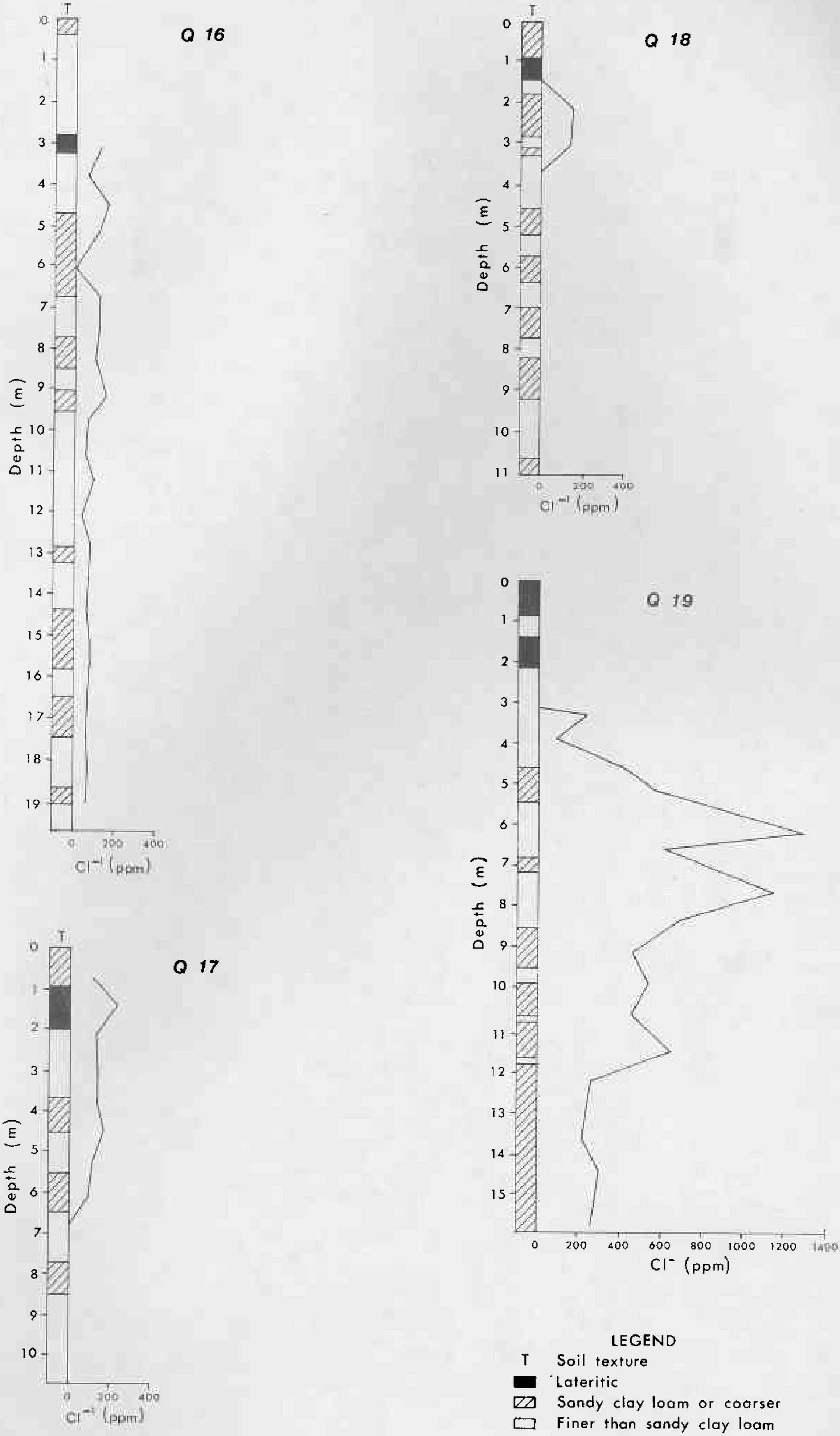

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All profiles were acidic, the pH decreasing from 5.5 to 6.0 at the surface to as low as 2.5 at 12.16 m depth (bore Q12). A deep zone of pallid kaolinitic clay down to bedrock, a feature of bore profiles on the Darling Plateau (Batini et al., 1976), was absent in the Jarrahwood bores; this is to be expected since these soils come from sedimentary parent material.

It was not possible to correlate the soil horizons of the different bores to establish a local pattern of soil strata. It appears that the strata are discontinuous and vary in thickness over quite short distances, forming an array of clay lenses within a sandy matrix. This is attributable to the alluvial or deltaic manner in which most of the upper sediments in the Sunkland are believed to have been deposited (Probert, 1967).

This variation in the soil profiles implies that the surface catchment area for a particular stream might not necessarily correspond with the subsurface catchment area, and that there may be subsurface flows out of the catchment and also underneath the walls of stream gauging weirs.

Nearly all the bores, except those on ridge-top sites, showed positive hydrostatic pressure; the water level in the piezometer rose above the confining cement plug, indicating that some aquifers are saturated and confined and that the sandy zones in the soil profiles tend to be laterally continuous. The great variation between the soil profiles of different bores suggests that a range of aquifer types exists in the area, including confined, semi-confined and unconfined, depending on the situation of the clay lenses. The configuration and extent of the clay lenses near the surface could play a major role in determining the characteristics of a particular subcatchment.

Soil chemical properties

An unusual feature of the Jarrahwood bores was the high concentration of soluble sulphates, particularly below 10 m (Table 1). The maximum concentration recorded was 23 000 ppm in bore Q16 at 19.76 m depth. Large quantities of sulphates rarely occur in Western Australian soils (A.B. Hatch, personal communication), although there are many reports from other countries of significant sulphate levels in surface waters. Sulphates are non-toxic to plant growth and are not considered to affect water quality adversely.

Chloride contents of the soil were relatively low (Table 1, Fig. 3) compared with those reported by other researchers in Western Australia (Table 2). However, isolated pockets of high salinity did occur. Chloride levels greater than 800 ppm, usually associated with saturated clay or sandy clay horizons, were recorded in mid-slope bores Q3, Q8 and Q19 at depths between 6 and 8 m, reaching an overall maximum of 1300 ppm in bore Q19 at 6.08 m depth (Fig. 3).

The data presented in Table 2 must be interpreted with caution. The nett storage data quoted by other workers come from bores which cover the complete soil profile from surface to bedrock and where the tree root system extends down through the kaolinitic layer to the water table, which is usually at considerable depth (Kimber, 1974). The total salt storage is therefore relevant to land-use problems, but this may not be so in the Sunkland where water tables are more shallow and rooting depth is much reduced, and where the subsoil conditions are different. Since no live plant roots were observed in the Apostles Brook bores at depths greater than 10 m, it is likely the salt storage to that level is all that could be influenced by land-use practices.

Groundwater properties

Groundwater salinity levels (Fig. 4) rarely exceeded 650 ppm, and most were less than 400 ppm. The overall patterns of salinity variation recorded during 1976 resembled those of the previous year, although the values themselves were generally lower. This may be associated with the unusually low rainfall during winter 1976 in the Jarrahwood area (Fig. 5). Water table level in most bores also reflected these rainfall variations.

The seasonal patterns of salinity change varied considerably from bore to bore. For example, the mid-slope bore Q8, which showed minor variations in bore water level throughout the 1975-76 year, showed a marked fluctuation in salinity (Fig. 4).

TABLE 1

Chloride and sulphate storage (kg·ha^{-1} x 10^{5})
at bore sites in Subcatchment 3

Bore	Depth (≤10.64 m)	Chloride	Sulphate	Bore	Depth (>10.64 m)	Chloride	Sulphate
Q1	9.12	0.20	-	Q10	19.76	0.14	7.96
Q2	8.36	0.04	-	Q11	16.72	0.07	6.46
Q3	7.60	0.21	-	Q12	19.76	0.07	6.23
Q4	6.08	0.16	-	Q13	19.76	0.06	7.00
Q5	8.36	0.06	-	Q14	19.76	0.15	4.10
Q6	8.36	0.02	-	Q15	19.76	0.09	6.03
Q8	9.12	0.44	-	Q16	19.76	0.30	5.43
Q9	8.36	0.13	-	Q19	15.96	1.01	1.31
Q17	10.64	0.12	0.21	Q7	19.00	0.19	-
Q18	10.64	0.04	0.15				
Mean	8.66	0.14	0.03		18.92	0.23	4.95
S.D.	-	0.12	-		-	0.30	2.52

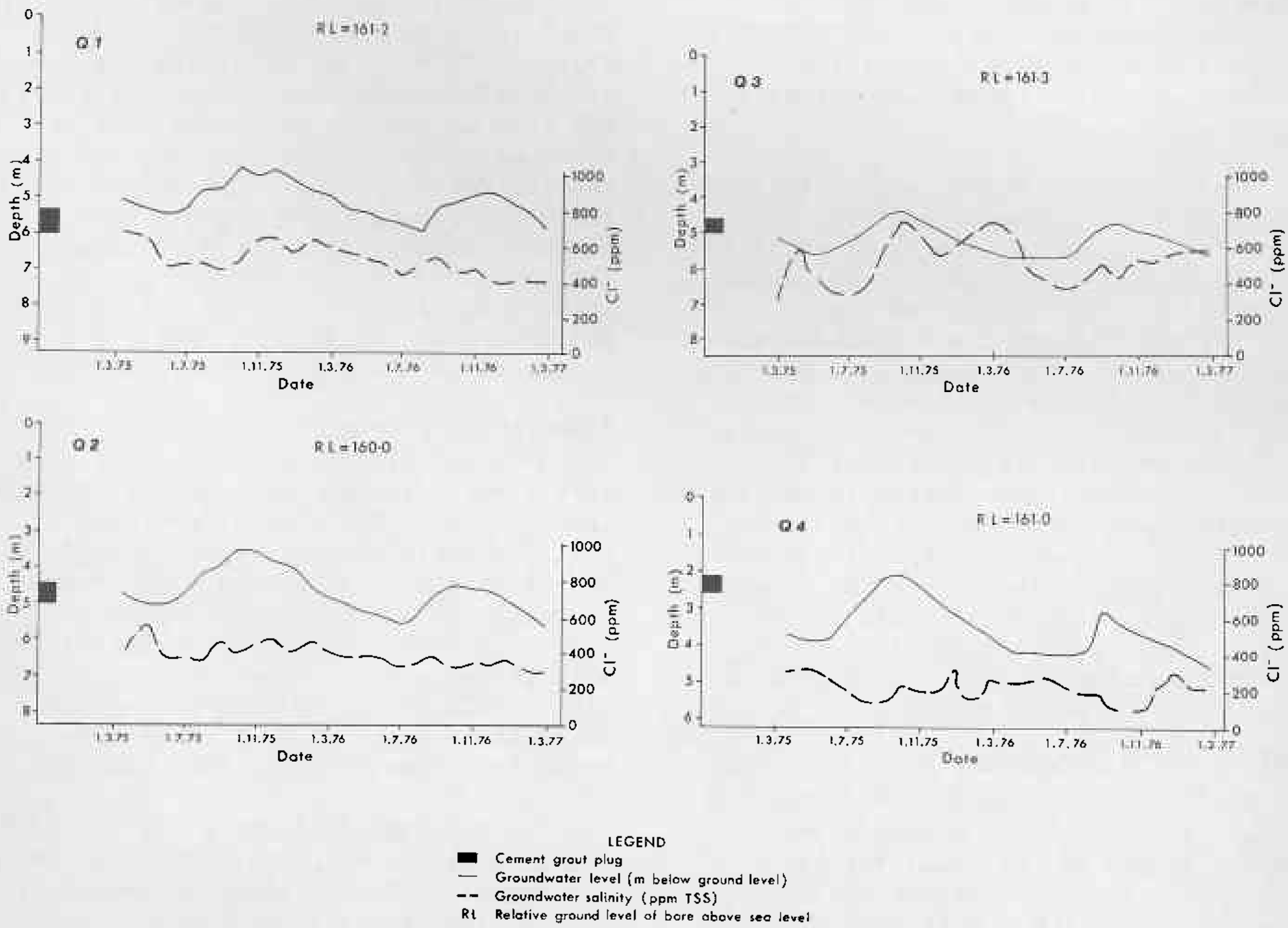

FIGURE 4: Groundwater level and salinity variations, bores Q1 to Q9

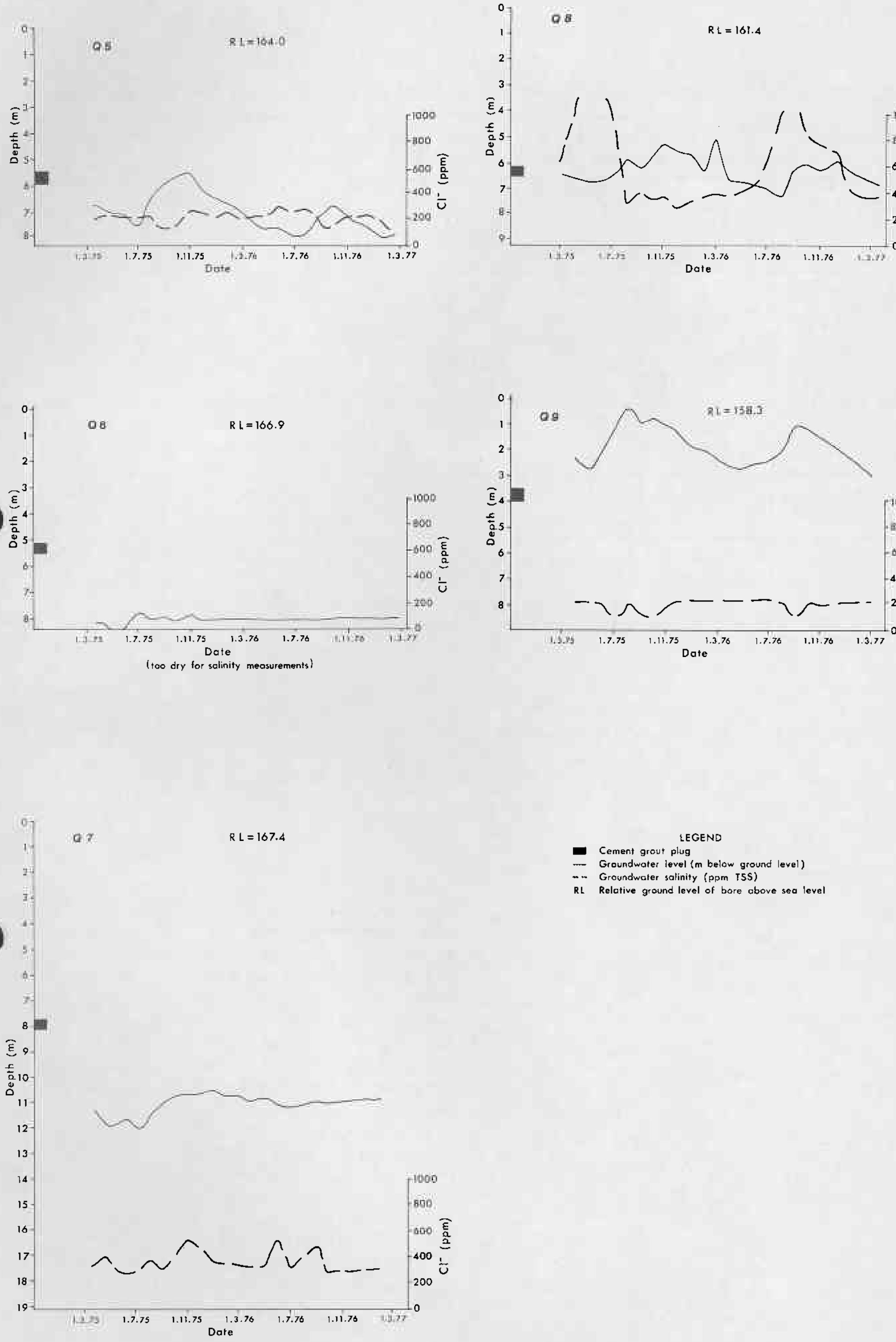

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TABLE 2

Comparison of Sunkland deep bore salinity data with those of other researchers

Authority	Location and annual rainfall (mm)	Depth to bedrock (m)*	No. of bores	Salt (Cl^-) storage ($\times 10^5$ $kg \cdot ha^{-1}$)*
Bettenay *et al.* (1964)	Belka Valley 340	> 50 Bores to 14 m	30	39.65 ± N.A. 7.32 to 141.29
Batini *et al.* (1976)	Helena Catchment 800-850	17.5 ± 5.3 8.4 to 29.3	20	1.27 ± 1.33 0.08 to 4.93
Dimmock *et al.* (1974)	Darling Range 800-1000	21.6 ± 11.3 7.1 to 33.6	4	1.76 ± 1.03 0.67 to 2.73
	Darling Range 800	20.6 ± 9.9 5.4 to 42.1	29	4.91 ± 3.21 0.3 to 11.64
Herbert *et al.* (1978)	Darling Range	Bores to 44 m	27	1.01 ± 0.79 0.18 to 2.68
Stirling	Sunkland > 900 (depth > 10.64 m)		9	0.23 ± 0.30 0.06 to 1.01
	(depth < 10.64 m)		10	0.14 ± 0.12 0.04 to 0.44

*Mean ± standard deviation, with range below

Where necessary, data for NaCl were converted to figures for Cl^- content by dividing by 1.65

N.A. data not available

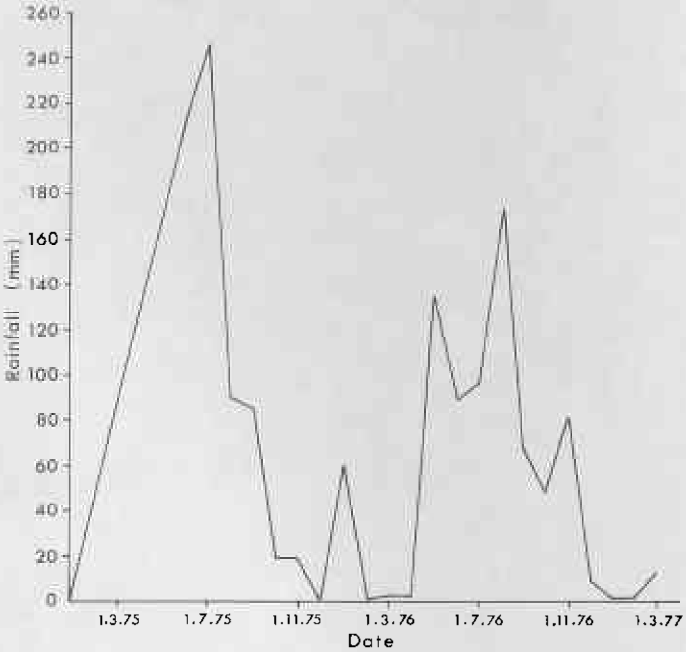

FIGURE 5: Rainfall data for Jarrahwood, March 1975 to March 1977

However, bore Q3, located 50 m away at the same contour level, did not show any significant change in water level or salinity. Water in bore Q19, on the opposite side of the valley to bore Q8, also varied in salinity during the year. The data suggest that in both bores Q8 and Q19 a pulse of water of higher salinity passes downslope, the timing of the pulse being related to seasonal rainfall patterns. This pulse, however, did not appear in the stream outflow, indicating that the particular aquifer either is discontinuous and is diluted downslope or is confined and is not intercepted by the stream bed. Since similar variations were not observed in any of the other 17 bores, it appears that this phenomenon is not characteristic of the area.

Since the stratigraphy of the Sunkland appears to be relatively uniform

(Cope, 1971), it seems reasonable to regard the results from one intensively studied area as applicable, in general terms, to the region as a whole.

The bore programme has shown that the soil profiles are extremely variable at the depth where tree roots could be expected to influence hydrological processes. However, since the soil contains comparatively low levels of chlorides, the potential for increases in stream salinity is low. This conclusion is supported by observations in areas elsewhere in the Sunkland where native forest was replaced with pasture over 20 years ago but which show no sign of increasing salinity (McKinnell, 1976).

REFERENCES

BATINI, F.E., SELKIRK, A.B. and HATCH, A.B. (1976). Salt content of soil profiles in the Helena Catchment, Western Australia. Research Paper 23, Forests Department of Western Australia.

BETTENAY, E., BLACKMORE, A.V. and HINGSTON, F.J. (1964). Aspects of the hydrologic cycle and related salinity in the Belka Valley, Western Australia. Australian Journal of Soil Research 2, 187-210.

COLLET, D.B. (1973). Water resources of the south west of Western Australia. (A paper presented to the 1973 Conference of the South West Shire Councils).

COPE, R.N. (1971). Tectonic style in the southern Perth Basin. Mines Department of Western Australia, Geological Survey, Annual Report, 46-50.

DIMMOCK, G.M., BETTENAY, E. and MULCAHY, M.J. (1974). Salt content of lateritic profiles in the Darling Range, Western Australia. Australian Journal of Soil Research 12, 63-69.

FORESTS DEPARTMENT OF WESTERN AUSTRALIA, (1975). Afforestation with pines in the Donnybrook Sunklands: Statement of Intent.

HATCH, A.B. (1976). The relationship between electrical conductivity of soil:water suspensions and soluble salts in some Western Australian forest soils. Research Paper 19 Forests Department of Western Australia.

HERBERT, E.J., SHEA, S.R. and HATCH, A.B. (1978). Salt content of lateritic profiles in the Yarragil Catchment, Western Australia. Research Paper 32, Forests Department of Western Australia.

KIMBER, P.C. (1974). The root system of jarrah (*Eucalyptus marginata*). Research Paper 10, Forests Department of Western Australia.

McKINNELL, F.H. (1976). Water quality in the Donnybrook Sunkland (Blackwood Plateau). Research Paper 24, Forests Department of Western Australia.

PROBERT, D.H. (1967). Groundwater in the Busselton area, progress report on exploratory drilling. Mines Department of Western Australia.