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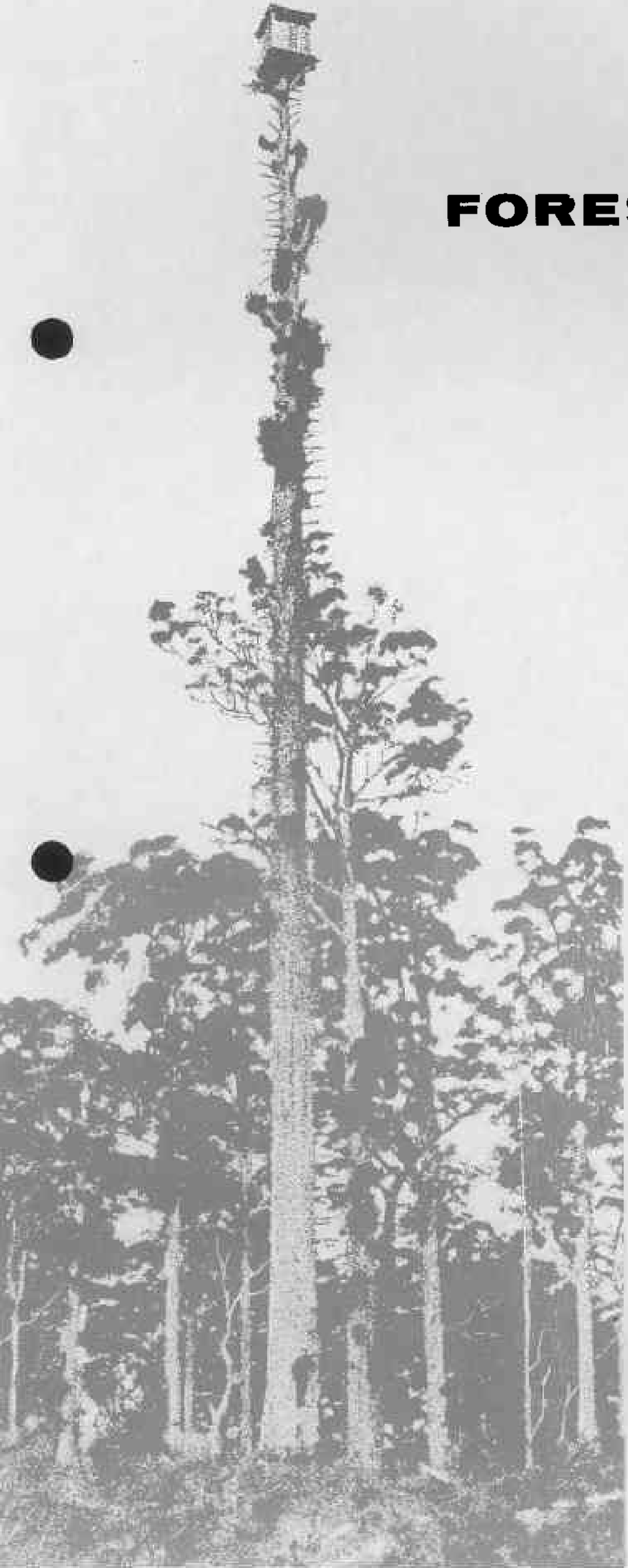

SALT CONTENT OF SOIL PROFILES IN THE HELENA CATCHMENT, WESTERN AUSTRALIA.

by

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SUMMARY

Soil cores from 20 deep bores in the Helena Catchment were examined for electrical conductivity, total soluble salts, sodium chloride, pH, bulk density and moisture content. Within an area of a few square kilometres, considerable differences in the store of soluble salts were observed. Bores less than 300 m apart differed by a factor of 40. The quantity of salt stored per unit of landscape appears to be related to site type. Types J, F/J and M/G were generally non-saline; Y types had a saline band between 3 and 11 metres, and H/G types tended to be saline at depth. The data for A types were inconclusive. In finer-textured soils, the store of salts was concentrated in the region above the water rest level and below the surface soil horizons.

INTRODUCTION

In the eastern portion of the Helena Catchment, there are large areas suitable for the establishment of pine plantations. A considerable store of soluble salts is present within lateritic profiles in the Darling Range (Dimmock, Bettenay and Mulcahy; 1974), especially in low rainfall areas (<800 mm per annum). Before a planting programme can be confidently undertaken, the possible effects of this change in land use on parameters of salt and water yield need to be assessed.

During 1973, two experimental catchments, each of about 500 ha, were selected. These were located 22 km east of Mundaring Weir and had an annual rainfall of approximately 820 mm. Using saltfall data provided by Hingston (pers. comm.), the annual salt input was calculated as 52 kg ha $^{-1}$. The landforms and soils for this portion of the Darling Range have been described (Mulcahy, Churchward and Dimmock; 1972), and the catchments included parts of the Laterite Mantled Upland and of the Goonaping Valley Unit. The experimental areas were mapped in detail for soil and site-vegetation types, according to the system of Havel (1975). Current measurements include estimates of rainfall and saltfall, and stream flow and salt flow. In addition to these, it was considered desirable to assess the quantity of salt stored in the profile and its distribution by site types. This was achieved by the drilling of bore holes and analysis of the core samples recovered.

METHOD

The locations of bore holes were selected on the basis of site-vegetation type. Twenty holes were fully cored, 17 within the two experimental catchments and 3 located 8 km to the east. The holes were drilled with a Gemcodril H13 mounted on a Bedford Truck (Plate 1) and fitted with hollow flight augers, wire-line, split barrel and press shoe. Where possible, drilling continued to bedrock and a complete core was recovered, wrapped in plastic, labelled and stored.

Samples for analysis were obtained from the soil surface and from the press shoe (the latter usually at 76 cm vertical intervals). The samples from the press shoe were immediately subdivided into two parts, one of which was used for the analysis of specific electrical conductivity (EC), total soluble salts (TSS), sodium chloride (NaCl) and pH. The other portion was obtained from a section of known volume, transferred to a moisture-content tin, sealed and subsequently processed for gravimetric moisture content and for bulk density. The occasional use of a cutting shoe in compacted strata resulted in some incomplete cores being recovered.

PLATE 1: Gemcodril H13 mounted on Bedford Truck at Site W11.

The concentration of soluble salts in the soil samples was estimated from the specific conductivity of a 1 : 5 soil:water suspension, which had been shaken for one hour. The relationship used was as follows:

$$(TSS\%) = 0.0000000483\,(EC)^2 + 0.0002175\,(EC) - 0.0014$$

(Where EC is measured in μS at 25°C (Hatch, 1976))

pH values were determined on the same soil:water suspension using a glass-calomel combined electrode. The percentage NaCl was obtained by titrating a 20 ml aliquot of the suspension against silver nitrate, using an electrometric method (Piper, 1947).

The estimate of total salt for each location was derived by integrating the data using the Trapezoidal Rule, and extrapolating curves to bedrock in the profiles where the data was incomplete.

After each hole had been drilled, a piezometer was installed. This consisted of a length of 48 mm internal diameter PVC piping, slit vertically below the water table (or for a minimum of 6 m), with an unslit portion above this. The lower section of the hole was backfilled with coarse sand to about 1 m above the slit section. A cement grout seal was added and the remainder was backfilled with drilling spoil. The part above ground was protected with a length of cement pipe and then capped. On the following day, the water rest level (WRL) was recorded.

TABLE 1

Location and Description of Deep Bore Holes

Hole No.	Map Reference	Depth (m)	Topographic Situation	Dominant Tree Species	Soil Types	Site Type
W1	AT8057	29.30	lower slope	wandoo (*Eucalyptus wandoo*)	loam (1 m) over clays	Y
W2	AT8064	19.76	mid slope	jarrah (*Eucalyptus marginata*) marri (*Eucalyptus calophylla*)	grey sands (1 m) over clays	J
W3	AU8093	17.48	lower slope	jarrah banksia (*Banksia attenuata*)	white sands (3 m) over clays	J
W4	AU8099	18.10	mid slope	wandoo, marri, jarrah powderbark wandoo (*Eucalyptus accedens*)	lateritic gravel (3 m) over clays	M/G
W5	AU8159	14.44	lower slope	jarrah, marri, banksia	grey sands (3 m) over clays	J
W6*	AT8152	31.40	mid slope	jarrah, marri	grey sands (3 m) over clays	J
W8	AT8059	23.56	lower slope	wandoo, marri	lateritic gravel (1.5 m) over clays	M/G
W9	AT8094	13.81	swamp	very open, occasional wandoo	grey sands (0.5 m) over clays	A
W11	AU8117	21.08	saddle	wandoo, marri	lateritic gravels (3 m) over clays	M
H13	AV8258	16.16	mid slope	jarrah, marri	yellow sands (3 m) over clays	F/J
H14	AV8227	9.12	swamp	open, occasional wandoo	sandy clay (0.5 m) over compact clays	A
H15	AV8255	15.16	lower slope	banksia, Christmas tree (*Nuytsia floribunda*), jarrah	white sands (3 m) over clays	J
H16	AV8214	15.96	lower slope	wandoo	grey sand (0.5 m) over clays	Y
H18	AW8299	13.68	saddle	jarrah, marri	yellow sands (3 m), white sand, then clays	F/J
H19	AV8354	19.76	upper slope	jarrah, marri	laterite (4 m) on mottled clays	H
H20	AV8340	8.36	upper slope	jarrah, marri	lateritic gravel (1 m) over clay	H/G
H21	AW8199	20.52	upper slope	jarrah, marri	lateritic gravel (0.5 m) over clay	H/G
H22	AV8294	17.39	mid slope	jarrah, marri	lateritic gravel (3 m) over clay	H/G
K1	AT8841	26.60	lower slope	jarrah, banksia	yellow sands (6 m) over clays	F/J
K2	AS8856	14.44	lower slope	banksia, Christmas tree, jarrah and blackbutt (*Eucalyptus patens*)	grey sands (1 m) over gravels and clay.	J
K3	AT8879	16.00	lower slope	wandoo, blackbutt	grey loam (0.5 m) over compact clay	Y

*This hole was not cored.

TABLE 2

Analysis of Cores from Deep Bore Holes W5 and H14

Core No.	Depth (m)	Bulk Density kg m⁻³	H_2O %	pH	E C μS	T S S %	NaCl %
			HOLE W5				
1	0.0	*	0.3	6.1	10	.001	.001
2	0.76	1790	4.5	6.2	17	.002	.001
3	1.52	1770	11.6	6.2	29	.005	.004
4	2.28	1830	9.2	6.2	30	.005	.002
5	3.04	1950	9.4	6.7	66	.013	.006
6	3.80	1800	13.5	6.2	27	.004	.003
7	4.56	2050	6.2	6.2	29	.005	.003
8	5.32	2080	8.3	6.4	42	.007	.005
9	6.08	1920	6.0	6.4	31	.005	.003
10	6.84	1750	18.2	6.1	88	.018	.016
11	7.60	*	1.3	6.3	13	.001	.001
12	8.36	1810	2.3	6.3	14	.002	.001
13	9.12	1690	3.4	6.2	23	.004	.003
14	9.88	1820	9.4	6.2	61	.012	.012
15	10.64	1600	4.6	6.2	32	.005	.005
16	11.40	1140	44.2	6.0	125	.026	.024
17	12.16	1180	43.3	6.2	72	.014	.009
18	12.92	1190	42.9	6.4	51	.010	.005
19	13.68	1220	42.0	6.6	52	.014	.008
20	14.44	1510	28.8	7.0	36	.006	.006
			Hole H14				
0	0	*	0.5	5.8	43	.008	.004
1	0.50	*	12.1	7.4	271	.061	.057
2	0.76	*	14.7	7.4	893	.231	.172
3	1.52	1710	17.1	7.0	1494	.431	.321
4	2.28	1780	15.0	6.2	1743	.524	.374
5	3.04	1860	10.6	6.2	1435	.410	.311
6	3.80	1880	11.8	6.3	1435	.410	.305
7	4.56	1670	15.6	6.4	1664	.494	.371
8	5.32	1580	17.2	6.4	1525	.443	.343
9	6.08	1640	17.5	6.4	1776	.537	.369
10	6.84	1720	17.0	6.8	1595	.468	.327
11	7.60	1750	15.7	6.6	1281	.356	.245
12	8.36	1700	16.8	6.4	1421	.405	.276
13	9.12	1910	9.8	6.7	965	.254	.181

* Incomplete core.

TABLE 3

Comparison of the Salinity Characteristics of Deep Bores with the Data of Dimmock *et al.* (Mean ± standard deviation, with range shown below).

	No. of Bores	Depth to Rock (m)	Salt Content (g/100 g)	Salt Storage ($\times 10^5$ kg ha⁻¹)
Helena Catchment (800-850 mm p.a.)	20	17.5 ± 5.3 8.4 − 29.3	0.07 ± 0.10 0.005 − 0.40	2.1 ± 2.2 A 0.14 − 8.13
Dimmock *et al* (800-1 000 mm p.a.)	4	21.6 ± 11.3 7.1 − 33.6	0.13 ± 0.15 0.03 − 0.19	2.9 ± 1.7 B 1.1 − 4.5
Dimmock *et al* (800 mm p.a.)	29	20.6 ± 9.9 5.4 − 42.1	0.22 ± 0.10 0.05 − 0.49	8.1 ± 5.3 B 0.5 − 19.2

A Assuming average bulk density of 1 750 kg m⁻³ for profile B Assuming average bulk density of 1 700 kg m⁻³ for profile

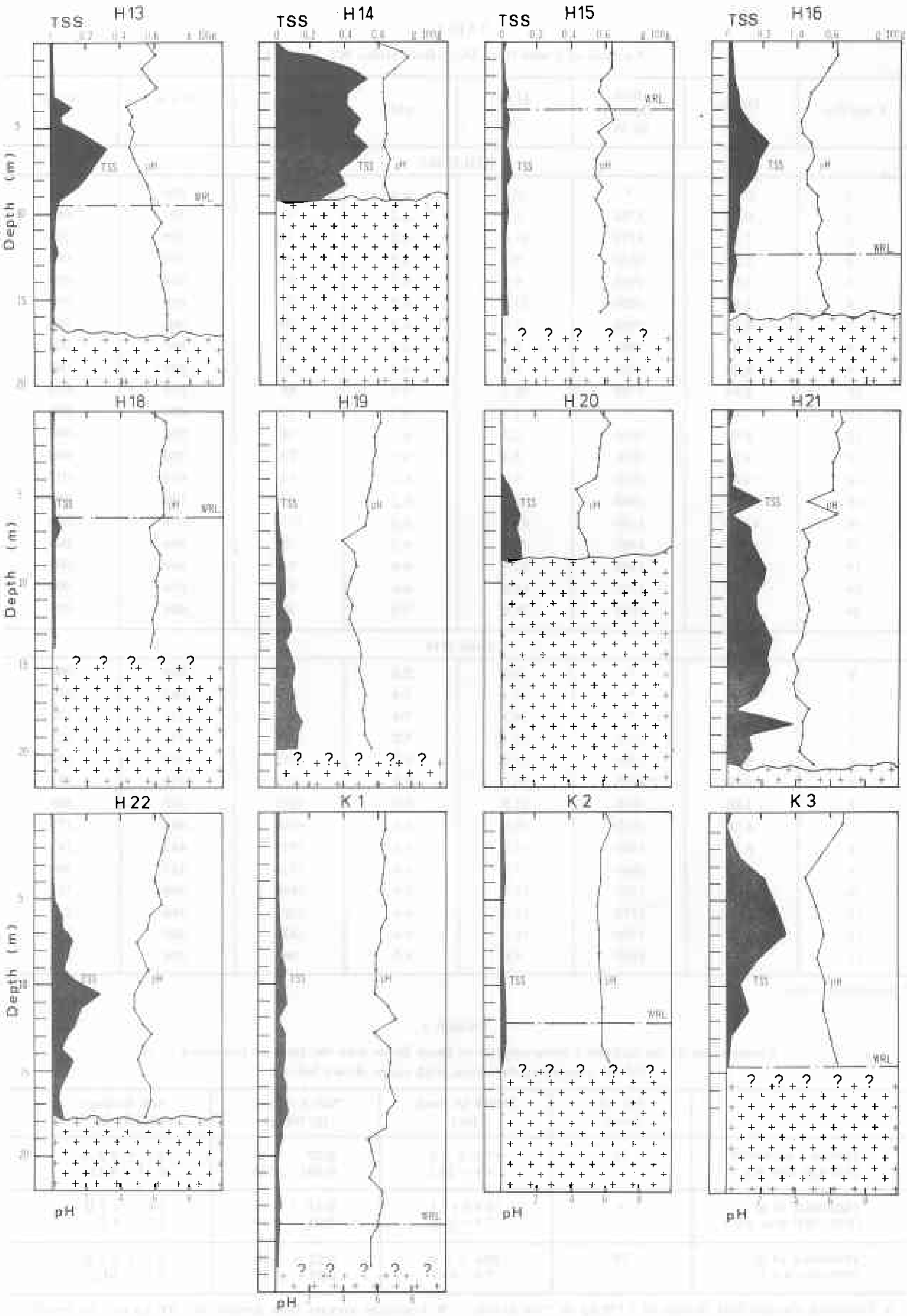

FIGURE 1: Vertical distribution of salt (g/100g) and pH for bores in the Hutt and Kent Catchments.
(WRL: Water rest level 24 hours after piezometer installation. + + +: Hard rock).

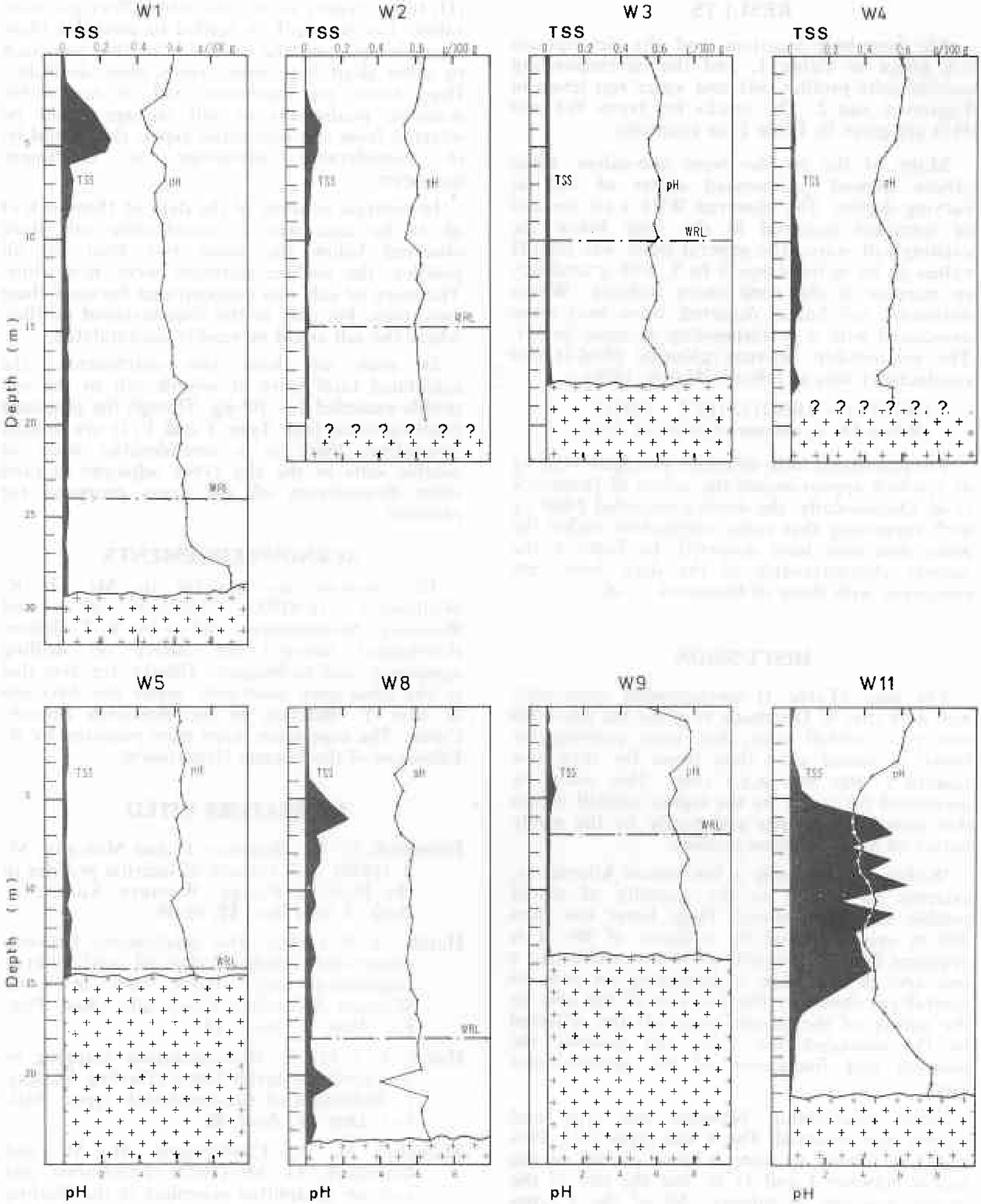

FIGURE 2: Vertical distribution of salt (g/100g) and pH for bores in the Wellbucket Catchment. (WRL: Water rest level 24 hours after piezometer installation. +++: Hard rock).

RESULTS

The bore-hole locations and site descriptions are given in Table 1, and the corresponding soluble salts profiles, pH and water rest levels in Figures 1 and 2. The results for bores W5 and H14 are given in Table 2, as examples.

Many of the profiles were non-saline, while others showed pronounced stores of salt at varying depths. The observed WRL's (at the end of summer) occurred in the zone below the existing salt store. The general trend was for pH values to be in the range 5 to 7, with a tendency to increase in the zone above bedrock. Where noticeable salt bulges occurred, these were often associated with a corresponding decrease in pH. The relationship between chloride (NaCl) and conductivity was as follows (Hatch, 1976):

(NaCl%) = 0.0002112 (EC) + 0.0017
(When EC is measured in μS at 25°C).

The calculated bulk densities averaged 1750 kg m^{-3}, which approximated the values of Dimmock *et al*. Occasionally, the density exceeded 2 000 kg m^{-3}, suggesting that some compaction within the press shoe may have occurred. In Table 3, the salinity characteristics of the deep bores are compared with those of Dimmock *et al*.

DISCUSSION

The data (Table 3) corresponded reasonably well with that of Dimmock *et al* for the 800-1 000 mm p.a. rainfall zone, but were considerably lower in stored salts than those for their low rainfall (< 800 mm p.a.) zone. This could be accounted for partly by the higher rainfall within this experimental area and partly by the sandy nature of many of these profiles.

Within areas of only a few square kilometres, extreme differences in the quantity of stored soluble salts were noted. Deep bores less than 300 m apart differed by a factor of 40. It is apparent that the quantity of salt stored under a unit area of landscape is dependent not only on rainfall (as shown by Dimmock *et al*) but also on the nature of the parent materials (as reflected by the site-vegetation type) and possibly the position and fluctuation of the ground-water table.

Some relationship between site type and salinity was observed. The Y site types (W1, H16 and K3) tended to have a store of salt in the region between 3 and 11 m, but the rest of the profile was low in salinity. All of the J types (W2, W3, W5, H15 and K2) were non-saline. Two of the F/J types (H18 and K1) were non-saline, but the other (H13, a marginal site) had a considerable store of salt between 5 and 9 m. Both of the M/G types (W4 and W8) were relatively non-saline, whereas the three H/G types (H20, H21 and H22) were saline at lower depths. A marked difference was observed between the two A types sampled. One of these (H14) was highly saline, the other (W9) was non-saline. Further work is needed to elucidate these relationships, and the extension of this approach to other deep bore sites seems most desirable. Deep bores are expensive, and, if reasonably accurate predictions of salt storage could be inferred from site-vegetation types, this would be of considerable advantage to catchment managers.

In contrast to some of the data of Dimmock *et al*, in no case was a considerable salt store observed below the water rest level. In all profiles, the surface horizons were non-saline. The store of salt was concentrated between these two zones, but only in the finer-textured profiles, where the salt could be readily accumulated.

In each of these two catchments, the calculated total store of soluble salt in the soil profile exceeded 1×10^8 kg. Though the proposed planting areas (site Type J and F/J) are usually non-saline, there is a considerable store of soluble salts in the site types adjacent to (and often downstream of) the areas proposed for planting.

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NOTE:

In the two equations relating TSS% and NaCl% to EC, EC is measured in μS per centimetre.

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