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The soils of South Carrabin Research Station -Light Land annex

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Disclaimer

The contents of this report were based on the best available information at the time of publication. It is based in part on various assumptions and predictions. Conditions may change over time and conclusions should be interpreted in the light of the latest information available.

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1. Summary

A soil survey was carried out for the South Carrabin Research Station (SCRS), a property of the W.A.D.A., Division of Plant Production.

Three categories of soil types were recognized. The first and most widely occurring yellow, pseudo-earthy soil type includes varying amounts of bleached mottles. Large amounts of bleached mottles distributed over the upper 100 cm of the soil profile result in low pH values (< 4.5) and hence high aluminium concentrations.

Some of the profiles have gravelly layers at depth which may result in better fertility and water holding capacity. Salt is found at a depth of 100 cm and deeper, the subsoil gravels are cemented by calcium carbonate.

Since all soils are vulnerable to wind erosion and the yellow, pseudo-earthy sands to water erosion it is recommended that reduced tillage and erosion control should have a high priority in managing the research station.

2. Introduction

The soils of the South Carrabin Research Station - formerly South Bodallin -were initially mapped in 1983 when the area was still in a virgin state. The mapping was carried out by J. Grasby and J. Carder (1983, advisors of the Department of Agriculture, Western Australia). J. Grasby and J. Carder recommended not to clear large areas with very shallow sand over indurated duricrust. The preliminary map by Grasby and Carder (1983) shows minimum and maximum depths of sand to laterite and indicates roughly the textures of the soil material. As the report shows, emphasis was placed on the wind erosion after clearing.

Five drillings were undertaken by the Hydrology Group of the Division of Resource Management to find an area which would best be suited for a possible dam site to store surface run-off water. Salinity was found at two bores whereas the three others did not show any salinity (Nulsen 1983).

The objectives of this paper are to provide a soil map and basic soil information for the new research station.

3. Materials and Methods

The Dryland Research Institute, Merredin, and the Division of Plant Production were assisted in selecting, developing and planning of 800 ha of uncleared land 20 km SSE of Carrabin by Grasby and Carder (1983). The developed land was to become a light land annex of the Merredin Research Station. Clearing (chaining, burning and raking), following an initial development plan, was undertaken in the period September 1983 - March 1984.

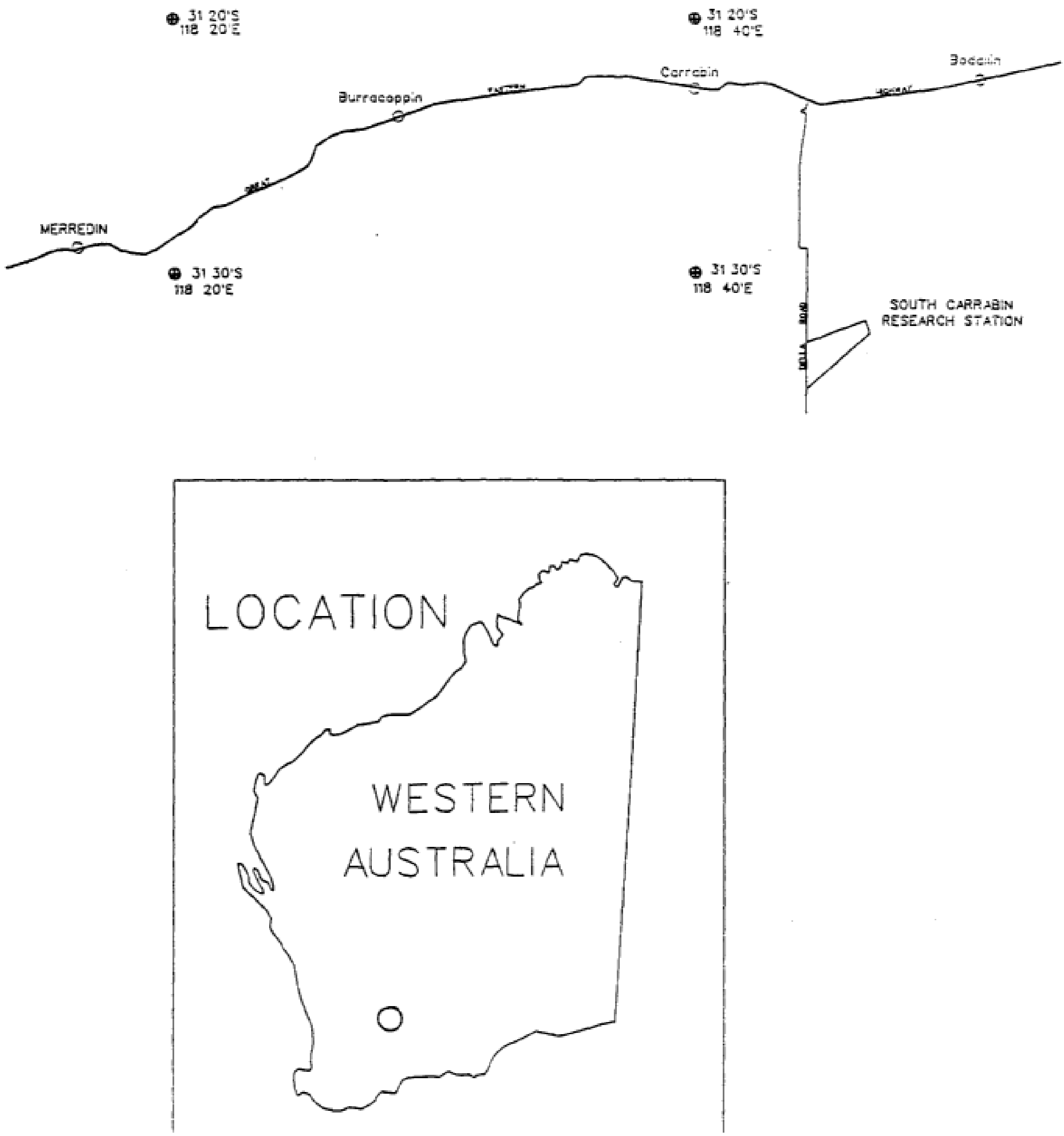
In spring 1984, when detailed soil mapping commenced, most of the block was cleared and the northern part which is more or less level was used for cropping and field trials.

3.1 Location and Topography

The SCRS is situated east of the junction of Della Road and Antonio Road, approximately 50 km ESE of Merredin (31° 31’ 30’ ‘S and 118° 45’ E) and 20 km SSW of Bodallin (Fig. 1). The highest elevation of 460 m is found near the homestead of the farm.

At the NW corner of the SCRS a broad ridge starts which runs towards the east. This ridge, dominates the block. It decreases slightly in elevation towards the E (less than 1%) but falls away more strongly (about 5%) to NE and W flowing valleys. The westward bound valley has a flat floor sloping very gently (less than 1%). The area south and SW of the ridge is characterized by a slightly dissected catchment which is covered by a mantle of sandy loam. A broad valley like a stagnant alluvial plain, but of a much smaller dimension, has cut into the plateau remnant. The lower slopes of the valley are waning, the middle and upper slopes are slightly waxing. The north eastward bound valley starts just at the southern fenceline with a well defined water course line.

Figure 1. Location of the South Carrabin Research Station



3.2 Geology and Hydrology

The mapping area is situated on the Yilgarn Block on a former gently undulating lateritised peneplain. The Yilgarn Block consists entirely of Archean granite and greenstone. The peneplain was dissected during Quaternary time and the laterite was eroded forming a rolling plateau. The erosion developed breakaways, which must have at first been nearly vertical. Today all steep slopes on the dissected plateau are levelled with colluvial debris of ferruginous gravel and fine to coarse sand forming a gently undulating landscape. The broad valleys are filled with colluvial sands and sandy barns and lack often clearly defined water courses. Gee (1982) says that the valleys' upper reaches tend to be fresh whereas the water quickly becomes highly saline downstream.

Five boreholes drilled to a maximum depth of 21 m found little water. At three sites there were hardpans at shallow depths (3 m to 8 m). At one site weathered soil material showed acid soil reaction trends and the other two sites were neutral to alkaline.

One site had considerable salt contents stores in the profile (6 metres) (Nulsen, 1983).

3.3 Climate

The small area inspected is situated at the SW-border of the Regional Planning District No. 8 — Marginal — of the Commonwealth Metereological Bureau (1962). Two recording stations lie 50 km WNW (Merredin) and 20 km SSW (Bodallin) of the investigated area. The climatic zone in which the SCRS is situated is called “Steppe climate” according to Koeppen (1979).

Table 1 gives the rainfall data for Merredin and Bodallin and the temperature and evaporation data of Merredin. The rainfall for Bodallin and for Merredin are similar (Table 1) and therefore the leaching intensity is nearly the same at both places.

According to Gentilli (1972) the yearly moisture balance at the SCRS station at South Carrabin is very close to the arid moisture regime, if the rainfall data of Bodallin and the highest temperatures of Southern Cross or those of Merredin are taken into account. With this it can be assumed that the present leaching of the soils reaches only to a shallow depth. The soils at the SCRS are very porous and have a very high infiltration rate when undisturbed.

Table 1. Climatic data for Merredin and Bodallin

Months	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	An
MERREDIN													
Av Max Temp ^{o}C**	15.9	16.4	19.3	23.9	28.4	31.9	33.2	32.8	29.5	24.5	20.2	16.9	24.4
P mm	54	39	26	19	13	12	11	13	22	22	41	55	327
PET mm*	54	68	103	167	244	307	270	270	235	150	92	59	2078
BODALLIN													
Av Max Temp ^{o}C**	16.3	18.1	22.1	25.3	30.1	33.3	34.7	33.8	30.7	25.8	20.6	17.1	25.7
P mm	47	33	23	16	10	12	12	16	23	20	34	42	288
PET mm*	54	68	103	167	244	307	329	270	235	150	92	59	2078

Aver. max. temp. = average maximum temperature; P = precipitation;

* PET = potential evapotranspiration; the same for both stations; (Hounamn, 1961).

** Maximum temperature data for Southern Cross (Bureau of Meterology, (1962).

3.4 Vegetation

The SCRS had been cleared prior to soil mapping. A vegetation list was compiled from observations made at uncleared clay and gravel ridges, contour strips and bordering road verges (Table 2 see Appendix 1). The area had experienced frequent fires so that the vegetation structure had to be based on descriptions of representative mature communities in the neighbourhood.

The vegetation of the research station can be characterized as shrubland, mallee heath, and woodland. The vegetation types can be correlated roughly to textural soil materials such as:

clay - woodland

gravel - Allocasuarina, Acacia and Melaleuca shrubland

deep sand - mallee heath or mallee shrub land.

It was not possible to distinguish between similar soil mapping units, such as unit 1 from unit 2 or unit 3 from 4 by the vegetation. The main vegetation types according to the classification by Muir (1977) are:

Map unit 1 and 2:	Scrub over low heath C* or Eucalyptus burracoppinensis. Open low scrub A* over low heath C*.
Map unit 3:	Low scrub A* over low heath C*.
Map unit 4:	Albocasuarina, Acacia, Mebaleuca thicket over open scrub D*.
Map unit 5:	Low woodland A* over low scrub B*.

* The abbreviations A, B, C and D stand for heights of the plant community:

A = 1.5—2 m; B = 1.0—1.5 m; C = 0.5—1.0 m; D = 0.0—0.5 m (Muir, 1977).

3.5 Methods of Soil Mapping

The area (800 ha) was mapped at a scale of 1:5 000 for a publication scale of 1:10 000. 330 auger holes were dug to a maximum depth of 200 cm. Profile examinations were made at a distance of 50 to 100 m apart. Toposequences revealed changes of various soil properties.

Soil horizons were designated and the colour (Munsell, 1975), mottling, texture, structure (where possible), consistency, ped fabric, pH-value, texture and colour boundaries, biotic activity, graveliness and presence of manganiferrous nodules in each horizon were described.

After the whole area was mapped, two soil profiles for each of the two dominant soil types were selected and 2 m deep pits were dug. Disturbed soil samples were collected from each horizon and a set of chemical and mechanical analyses carried out. The minor soil types were not sampled.

A soil map and four additional maps showing the most common pH-values (Raupach Indicator measurements) at four different depths (0-10 cm, 40—70 cm, 70—110 cm, and 150—200 cm; see Appendix 4) were produced.

3.6 Methods of Soil Analyses

Soil reaction:	1:5 soil water suspension.
Sodium chloride:	From the above suspension by tritration according to Richards (1954).
Exchange properties:	Silver-Thiourea method as proposed by Chhabra et al (1975).
Particle sizes:	Hydrometer method according to Head (1980).

3.7 Soil Classification

The soils of the SCRS have been classified according to Northcote (1975, 1979), the Great Soil Group scheme of the Handbook of Australian Soils (Stace et al 1968).

3.8 Northcote's key

Profiles showing at least 50% (up to 80%) pale coloured mottles — when dry -were named Uc2.2l, those with less Uc3.21. The mottles are seen only when the soil material is dry, in the moderately moist state the mottles have the same colour as their surrounding.

The pale coloured mottles rarely occur in well defined horizons with clear boundaries. They can be noticed throughout the whole soil profile.

Soils in the research area appear to have an "earthy" fabric when moderately moist and a "sandy" fabric when dry. This observation was made on most yellowish coloured soils. Sandy soils with an earthy appearance are called "Uc5" according to Northcote's Key (1979). Since the yellowish sandy soils have a massive structure, and a sandy fabric when dry but an earthy fabric when moderately moist, the soils were called 'Uc3.21 or Uc5.22".

In the profile descriptions, the term "pseudo-earthy" fabric was chosen to distinguish these soils from the Earthy Sands as described by Northcote et al (1975). All soils that show a pseudo-earthy fabric have the typical feature of a sandy fabric when dry and an earthy appearance when moderately moist to moist.

Great Soil Group classification — Stace et al. (1968).

According to the particle size analysis, the soils belong to the texture class sandy barns (clay content 18%). This ranks the soils into siliceous sands or earthy sands of the Great Soil Group scheme. The earthy sands are characterized by an "earthy" appearance of coherent sands, clayey sands, or light sandy loams. They are underlain by either ferruginous nodules or lateritic duricrust. The description according to Stace et al. (1968) does not mention that the earthy sands may have a sandy fabric when dry.

The sandy fabric of the soils when dry and earthy when moist does not allow the sands to be classified as Earthy Sands. Therefore an intergrade between Siliceous Sands and Earthy Sands would be more appropriate. The morphological appearance of a sandy and an earthy fabric was called "pseudo-earthy" fabric in this paper.

4. Soils

At the SCRS two major sandy soils, differing in their colour are found covering most of the area. These two different soils were grouped according to colour and the occurrence of gravel in their profiles into four map units. The first two map units contain yellow sand, which are called "yellow, pseudo—earthy sands" and the other two bleached sands which are called "siliceous sands" (map unit 3) and "lithosols" (map unit 4).

The yellow pseudo-earthy sands of map unit 1 have a continuous gravel layer deeper than 140 cm and the soils of map unit 2 have a continuous gravel layer below 50 cm depth. The siliceous sands contain abundant ferruginous gravel at 10 cm depth, hardpans occur at 15 cm depth in the lithosols.

Heavy clay soils occur sporadically throughout the SCRS (map unit 5) which are called "brown clays".

In the ploughed state, the sandy soils react strongly to the weight of vehicles. Deep furrows develop (up to 20 cm) which act during rainstorms as waterways in sloping areas and as water reservoirs on level ground. On sloping ground, water erosion occurs in the furrows whereas on level ground water infiltrates only slowly into the compacted soil. The puddles showed dispersed yellow soil material.

In the dry state, the cultivated sandy soil is highly erodible by wind whereas under natural vegetation the soils seem to be stable. The natural waterways, however, show gully erosion and on slopes slight rill - but mainly sheet erosion. Under natural vegetation, the surface of the yellow soils was covered by a 5 mm thick medium to coarse sand layer. In the drainage lines, sand has accumulated and fine material has settled in stillwater ponds.

The loose, siliceous sands and lithosols showed water repellent properties and were prone to wind erosion when unvegetated. Under natural vegetation no infiltration problems were observed.

The brown clays showed free water on the surface during heavy downpours. The infiltration was very slow and most of the water evaporated from the ground surface.

4.1 Yellow Pseudo-Earthy Sands

Most of the area is covered by the map unit 1 (see Appendix, soil map) a yellowish sandy loam with pseudo-earthy fabric. (Typical soil profiles are described and found in the Appendix 2, profiles I, II and III). The soil is normally more than 2 m deep, has a clay content less than 24% throughout the profile (Table 3), and very little gravel content. Gravel sometimes appears as a thin layer at 140 cm depth. On some occasions the profile is 200 cm deep, its base then being formed by a dense gravel layer. The soils are acid throughout especially in the top 100 cm. The yellow soils show a wide variety of different soil phases which or determined by the density of bleached mottles.

The bleached mottles are easily noticed when the soil is dry, however, if the soil is moist, the blotches are less obvious (see colour change at profiles). The soil has a conspicuously bleached A2—horizon. The soil material is slightly acid at the surface layers. Below the bleached layer a uniformly yellow coloured (1OYR 6/8) light sandy clay loam follows with a few bleached blotches around fine roots.

The Principal Profile Form Uc3.2l (map unit 2) has the same morphological features as map unit 1, but the gravel occurs below a depth of 50 cm. Typical profiles are described under profile IV in the Appendix 2. The map unit 2 occurs near duricrust outcrops. The duricrust which capped the old shield must have been dissected forming steep cliffs. The change from duricrust to deep sand over gravel was always abrupt. The foot of such free faces is filled with rubble and gravel sloping steeply toward the bottom of the valleys.

Table 2. Selected soil physical and chemical data; (Profile III)

a) Brief description and physical data

Horizon	**Depth (cm)**	**Description**	**Coarse sand (%)**	**Fine sand (%)**	**Silt (%)**	**Clay (%)**
A1	0 - 20	Yellowish brown (10YR 5/6) sandy loam; pseudo-earthy fabric; massive	34.5	42.6	10.8	12.1
B21	20 - 100	Brownish yellow (10YR 6/8) light sandy clay loam; with yellow (10YR 7/8) mottles; pseudo-earthy fabric; massive.	29.3	36.0	15.5	18.3
B22	100 - 200	Brownish yellow (10YR 6/8) light sandy clay loam; pseudo-earthy fabric; massive.	24.4	36.1	16.2	23.3

b) Chemical data

				Exchangeable cations mmol(+) kg-1						
Horizon	Depth cm	PH	NaCl (%)	Total	$1/2Ca^{2+}$	$1/2Mg^{2+}$	K^+	Na^+	$1/3A1^{3+}$	ESP* (%)
A1	0–20	5.0	tr	12.0	3.3	1.9	0.5	0.15	3.5	1.2
B21	20–100	4.5	tr	18.5	3.0	11.5	tr	0.79	7.4	4.3
B22	100-200	5.4	0.21	24.3	5.2	14.6	tr	19.20	1.4	79.0

* ESP = Exchangeable sodium percentage; tr = trace.

The clay content of the yellow pseudo-earthy sands is uniform below the surface layer.

The dominant particle size is silt and fine sand. At sampling time (October 1984) the soil was moist between a depth of 50 and 150 cm. Below this depth the moisture content decreased.

The yellow pseudo-earthy sands show very low cation exchange capacities; potassium and manganese occur only in traces in the soils. Exchangeable sodium is low in the surface layers but increases rapidly. The pH-values drop from 5.5 at the surface to 4.5 at 60 cm and increase slowly with depth. Aluminium shows toxic concentrations.

4.2 Siliceous Sands

The map unit 3 consist of greyish-brown sand with a large amount of lateritic gravel. Lateritic hardpans occur at a depth of 70 and 90 cms. The soils are strongly leached and a residual clay content can be found just above the hardpan. The map unit 3 occurs mainly on the ridge surrounding the lateritic duripan outcrops.

Table 3 Selected soil physical and chemical data. (Profile V)

a) Brief description and physical data

Horizon	**Depth (cm)**	**Description**	**Coarse sand (%)**	**Fine sand (%)**	**Silt (%)**	**Clay (%)**
A1	0 – 10	Dark greyish brown (10YR 5/2) loamy sand; sandy fabric; massive	46.0	47.0	4.5	1.6
A2cb	10 – 50	very pale brown (10YR 7/3) gravelly sand; conspicuously bleached; massive	47.3	46.4	3.0	3.3
B2nk	50—150	yellow (10YR 7/6) and red (2.5YR 4/8) mottled gravelly sand; massive	32.6	56.9	5.3	4.2

b) Chemical data

				Exchangeable cations mmol($^+$) kg^{-1}					
Horizon	Depth cm	PH	NaCl (%)	Total	1/2Ca^{2+}	1/2Mg^{2+}	K^+	Na^+	ESP* (%)
A1	0–10	5.6	tr	16.0	4.0	1.5	tr	0.30	1.2
A2cb	10–50	5.8	tr	19.0	4.0	3.4	tr	0.60	4.3
B2nk	50-150	8.0	0.30	23.0	11.0	12.4	0.85	8.00	79.0

* ESP = exchangeable sodium percentage; tr = trace.

Very low clay, high silt and fine sand contents are typical for these sands. The surface layers were at sampling time saturated (October 1984), whereas the following horizon containing thin layers of cemented gravel were dry.

The exchange capacities of the siliceous sands are very low. The soils are not as acid as the yellow pseudo-earthy sands. Aluminium, potassium and manganese are not present, but potassium is found in the gravelly subsoils. At many sites, ferruginous gravel is cemented by calcium carbonate. At such sites the pH-values can increase above 8.0. The ES? values increase with depth and similarly sodium chloride contents. When the gravel layer starts values higher than 0.3% NaCl can be measured (Table 4b).

4.3 Lithosols

The highest elevations are occupied by duricrust covered by lateritic boulders and shallow sandy soils of map unit 4 (KS—Uc2.12). The soils are greyish with plenty of bleached sand grains. Most of these soils have small amounts of clay. At most sites the organic matter is the only fine material next to the sand grains.

Cemented lateritic duricrust underlying the sand often hinders the free drainage into greater depth. Complete saturation at ground level can be expected during winter and a shortage of water in summer. At sites where the duricrust has deep cracks or is broken up in larger blocks the water reserve is high enough to support plant growth during the dry months.

No soil physical and chemical data were collected for this map unit. A typical soil profile is found in Appendix 2, profile VI.

4.4 Brown Clays

The soils of map unit 5 occur scattered throughout the area as isolated patches. The largest area is found on the ridge. It contains at some places soils with a neutral and at others with an alkaline reaction trend. The soils are cracking and may be either self-mulching or crusting. The soil profile VII (see Appendix 2) is a typical profile for map unit 5. It shows that the soil has an alkaline soil reaction trend in the upper 60 cm and segregations of calcium carbonate. Acid clays appear below a depth of 70 to 100 cm, which represent the mottled zone of the laterite profile.

In some small areas at the eastern boundary of the SCRS, the same material occurs under sand. At these sites the soils are far less alkaline and cracking is not as severe as at the other sites.

Infiltration of water into these soils is very slow. During rain the water enters the deeper subsoil through the open cracks which close after a short time by swelling of the clays. (No physical or chemical data were collected for this minor soil type.)

5. The Soil Map

The soil map shows the distribution of 3 soil types separated into 5 map units according to gravel content or clay content. The soil boundaries contain a broad band of intergrades between different soil types.

Yellow pseudo-earthy sands cover 80% of the mapped area. They contain about 5% siliceous sands, 2% of which are intergrades with lithosols. The boundary between these soils is irregular. The siliceous sands occur mainly along the lateritic duricrust outcrops on the ridge.

The soils in the two valleys are not classified differently to the yellow pseudo—earthy sands of the slopes and ridge. The valleys are filled, however, with a thicker mantle (2 to 5 cm thick) of fine to medium sandy loams.

In the gravel or kaolinitic clays underlying the sands calcium carbonate can be found at any relief position.

6. Value Maps

Four pH-value maps have been drawn to indicate the trend and the lateral extent of acid reactions within the mapped soils. The maps show fairly well the extent of lateritic gravel or crust formation in the subsoils (dotted lines on each map).

The pH—value map, 0—10 cm depth, shows that most surface soils are nearly neutral, only the level areas of the ridge zone are slightly acid.

The pH-value map, 40—70 cm depth, shows the ridge zone with an acid reaction and the valleys with a neutral reaction trend at the same depth. Some isolated areas have alkaline pH-values which correspond to the soil profiles where calcium carbonate was found in the gravel.

The pH-value map, 70—110 cm depth, shows only some small areas on the slopes of the north-eastward bound valley with pH-values lower than 5.0 but the same valley contains soils with pH-values up to 8.0. Most other areas are higher than pH 5.0.

The pH-value map, 200 cm depth, shows that most soils have higher pH-values than 6.0. Only soils occurring in two channels between two duricrust formations at the west and at the east of the research station have values lower than 6.0 and a small area west of the north-eastward bound valley has consistently low values.

7. Conclusions

The most common soils - yellow pseudo-earthy sands - show very acid profiles to a depth of 80 cm. Below this depth the soils increase in their pH-values. Aluminium toxicity and deficiencies of potassium, trace elements, nitrogen and phosphate are severe. The yellow pseudo-earthy and siliceous sands develop traffic pans when heavy machines are used. The siliceous sands are less acid and aluminium toxicity is not a problem. The soils have a high infiltration rate when not compacted, and a low capacity to hold nutrients.

In most areas salt is concentrated below a depth of 150 cm. It is very unlikely that the salt will rise to the ground surface because of the high infiltration rates of all soil horizons.

The following recommendations are made:

- Application of gypsum to exchange sodium and magnesium for calcium and to reduce water erosion. The acidity must be overcome with liming.
- The lime applications should be renewed yearly since the soils are very porous; lime and fertilizers are leached rapidly.
- The sands must be protected against wind erosion which can be severe when the soils are dry, unvegetated and ploughed.
- On all slopes - even at very gentle ones - contour ploughing is necessary to avoid sheet wash or rill erosion.
- The lithosols and brown clays should be left under natural vegetation as Grasby and Carder (1983) have suggested.

8. Acknowledgements

Thanks are expressed to Professors R. Gilkes and A. Robson (Department of Soil Science and Plant Nutrition of the University of Western Australia) who gave permission to use the facilities of the University to analyse the soils.

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Appendix 1

Table 2. Plant Species List

Species	Map unit				
	1	2	3	4	5
Acacia ligustrina					
Acpcip aff. merrallii					+
Acacia densiflorp			+	+	+
Acacia aff. uncinel].a	+	+			
Acacia signata	+	+			
Acacia beauverdiana	+	+	+	+	
Acacia longispinea	+	+			
Acacia rossei	+	+	+	+	
Acacia anfractuosa	+	+	+	+	
Acacia ixiophylla			+	+	
Acacia unifissilis			+	+	
Acacia spinosissima			+	+	
Acacia cohletioides			+	+	
Acacia anastryphylla			+	+	
Acacia fihifohia			+	+	
Acacia erinacea			+	+	
Acacia costata			+	+	
Allocasuariup campestris			+	+	
Allocasuarina corniculata			+	+	
Allocasuraina acutivalvis			÷	÷	
Balaustion pulcherrimum	+	+	+	+	
Baeckea carnosa	+	+			
Beaufortia orbifolia			+	+	
Beaufortia micrantha			+	+	
Boronia coerulesscens	+	+	+	+	
Calothaninus qilesii					

Species	**Map unit**				
	1	**2**	**3**	**4**	**5**
Calytrix plumulosa	+				
Calytris sapphirina	+	+			
Chanielaucium megalopetalum	+	+			+
Choretrum pritzehii					
Condonocarpus cotinifolius		÷			
Conospermum brownii				+	
Conostylis bealiana	+	+			
Cryptandra myriantha				+	
Cyanostegia angustifohia				+	
Dampiera lavandulacea	÷	+			
Dampiera fasciculate	+	+			
Dampiera stenophylla			+	+	
Danipiera eriocephala			+	+	
Daviesia nematophylla					
Daviesia nudiflora			+	+	
Daviesia croniniana			+	÷	
Daviesia hakeoides	+	+	+	+	
Eremophila drummondii					+
Eremophila compacta				+	
Eucalyptus wandop					+
Eucalyptus eremophila					+
Eucalyptus sheathiana					+
Eucalyptus platycorys	+	+		+	+
Eucalyptus rigidula		+	+		+
Eucalyptus transcontinentalis				+	+
Eucalyptus calycogona					+
Eucalyptus erythronema					+
Eucalyptus redunca				+	+
Eucalyptus burracoppinensis	+	+	+		
Eucalyptus leptopoda	+	+	+		

Species	**Map unit**				
	1	**2**	**3**	**4**	**5**
Exocarpus aphyllus					+
Exocarpus cupressiformis	+	+	+	+	÷
Gastrolobium spinosum					
Greyillep dielsiana					+
Grevillea excelsior	+	+			
Grevillea eryngioides	+	+			
Grevillea ceratocarpa	+	+			
Grevillea hookeriana	+	+			
Grevillea integrifolia	+	+	+	+	
Grevillea didymobotrya		+			
Grevillea concinnp		+	+	+	
Grevillea teretifolia			+	+	
Grevillea apiciloba		+			
Grevillea paradoxa			+	+	
Grevillea yorkrakinensis					+
Gyrostemon ramulosus	+	+			
Hakea subsulcata			+	÷	+
Hakea coriacea	+	+			+
Hakea platysperma	+	+	+		
Hakea ambigua	+	+	+		
Halgania viscosa				+	
Hibbertia eatonipe	+	+			
Hibbertia exasperata	+	+			
Hibbertip stricta	+	+			
Hybanthus floribundus			+	+	
Lechenauhtip formosa	+	+	+	+	
E.ysinema ciliatum			+	+	
Melaleuca uncinpta	+	+	+	+	+
Melpleucp aff. uncinata					+
Melaleuca subfalcata					÷

Species	**Map unit**				
	1	**2**	**3**	**4**	**5**
Melaleuca laxiflora					+
Melaleuca spicigera					
Meipleuca acumninata					f
Melaleuca eleuterostachya		+	+	+	
Melaleuca pungens					
Melaleuca holosericea	+	+	+	+	
Melaleuca conothamnoides			+	+	
Melaleuca platycalyx					
Persponia coriacea	+	+	+	+	+
Persognip saundersiana	+	+			
Persognip angustiflora	+	+			
Petrophile ericifolia			+	+	
Petrophile serruriae			+	+	
Phebalium tuberculuosumn					+
Phebalium microphyllun					+
Phebalium filifolium	+	+	÷	+	+
Philotheca hassellii	+	+	+		
Pimelea sylvestris					+
Pimelep suaveolens					+
Pmelea brachyphylla			+	+	
Podotheca gnaphalioides	+	+			
Pultenaea dasyphylla			+	+	
Santalwn acuminatum				+	+
Synaphea polymorpha		+	÷	+	
Tetrathecp efoliata				+	
Xpnthprrhpep nana			+	+	

Appendix 2

Soil profile descriptions

Map unit 1	Soil profile: I (exact location see soil map)	
Location:	South Carrabin, W.A.	Latitude 310 3l'30" S Longitude 118° 45'00" E Altitude 460 m.
Topography:	Ridge with a westerly aspect, sloping < 1%.	
Parent Material:	Tertiary sands (?) over laterite and/or cemented ferruginous gravel.	
Profile Drainage:	Free, possibly impeded at greater depth.	
Native Vegetation:	<u>Eucalyptus</u> <u>burracoppinensis</u> scrub over low heath C.	
Land Use:	Cleared for cropping.	
Classification:	Northcote (1979): Uc2.21 -— Bleached Sands with colour B horizon. Stacey et al. (1968): Siliceous sands — Earthy sands. Abbreviated soil name: Yellow pseudo-earthy sands.	

Horizon	**Depth**	**Description**
A1	15 cm	Yellowish brown (1OYR 5/6 moist, *6/6* dry); sandy loam; massive; weak consistence; pseudo-earthy fabric; pH-value 5.5; abundant roots; diffuse boundary to
A2(cb)	45 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry); sporadically to conspicuously bleached, mottles of yellow (1OYR 7/8 moist, 8/4 dry; 50-80%) sporadically to; sandy loam; massive; weak consistence; pseudo—earthy fabric; pH—value 4.5; frequent roots, abundant fine roots; diffuse boundary to
B2	100 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry); mottles of yellow (1OYR 7/8 moist, 8/4 dry); gravelly, light sandy clay loam; massive; weak consistence; pseudo—earthy fabric; pH—value 4, then increases to 4.5 at 100 cm; soft ferruginous nodules between 75 cm and 80 cm; abundant fine roots to 80 cm, frequent fine roots; diffuse boundary to
Cl	160 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry); light sandy clay loam; massive; weak consistence; pseudo-earthy fabric; pH—value 5; some ferruginous gravel at 140 cm; rare fine roots, diffuse boundary to

C2	200 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry) mottled yellowish red (5YR 4/6 moist, 5/8 dry); gravelly, sandy clay loam; massive weak consistence; pseudo-earthy fabric; pH—value 5.5; rare fine roots; abrupt boundary to
D	250 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry, matrix) yellowish red (5YR 4/6 moist, 5/8 dry, hard pan); gravelly sandy clay loam (matrix); massive; pH-value 5.5; no roots.

Map unit 1	Soil Profile: II (exact location **see** soil map)
Location:	South Carrabin, W.A. Latitude3l°31'30" S Longitude 118°45'30" E Altitude 460 m.
Topography:	Ridge with an easterly aspect, sloping < 2%.
Parent Material:	Tertiary sands (7) over laterite and/or cemented ferruginous gravel.
Profile Drainage:	Free, possibly impeded at depth.
Native Vegetation:	eucalyptus burracoppinesis scrub over low heath C.
Land Use:	Cleared for cropping.
Classification:	Northcote (1979): Uc3.21 - Bleached to pale sands with a colour B horizon. Stacey et al. (1968): Siliceous sands — Earthy sands. Abbreviated soil name: Yellow pseudo-earthy sands.

Horizon	**Depth**	**Description**
A1	15 cm	yellowish brown (10YR 5/6 moist, 6/6 dry); sandy loam; massive; weak consistence; pseudo-earthy fabric; pH-value 6.0; abundant roots; many white single sand grains partly in small patches; diffuse boundary to
A2sb	50 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry), mottles yellow (10YR 7/8 moist, 8/4 dry, 30—50%); light sandy clay loam; massive; weak consistence; pseudo—earthy fabric; pH-value 4.0; abundant white single sand grains; abundant roots; diffuse boundary to
B2	100 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry), some mottles, yellow (1OYR 6/8 moist, 8/4 dry); light sandy clay loam; massive; weak consistence; pseudo—earthy fabric; pH—value 5.0 at 70 cm and 6.0 at 100 cm; frequent roots; diffuse boundary to
Cl	210 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry); gravelly light sandy clay loam; massive; weak consistence; pseudo-earthy fabric; pH—value 6.0; frequent roots to 140 cm, rare roots to 170 cm; ferruginous gravel at 140 cm increasing in density with depth, at 170 cm slightly cemented; abrupt and wavy boundary to
D	220+ cm	red (2.5YR 2.5/4 moist and dry) hard pan, brownish yellow (1OYR 6/8 moist, 7/8 dry) soft matrix; coarse sand (soft matrix); strongly cemented.

Map unit 1	Soil Profile: III (exact location see soil map)
Location:	South Carrabin, W.A. Latitude 31°32'00" S Longitude 118°45'00" E Altitude 460 m.
Topography:	Ridge with a southwesterly aspect, sloping < 5%.
Parent Material:	Tertiary sands (?) over laterite and/or cemented ferruginous gravel.
Profile Drainage:	Free, possibly impeded at depth.
Native Vegetation:	Eucalyptus burracoppinesis scrub and low heath C.
Land Use:	Cleared for cropping.
Classification:	Northcote (1979): Uc3.2l or Uc5.22 - Bleached to pale sands with a colour B horizon or Earthy sands. Stace et al. (1968): Siliceous sands — Earthy sands. Abbreviated soil name: Yellow pseudo-earthy sands.

Horizon	**Depth**	**Description**
Al	20 cm	yellowish brown (1OYR 5/6 moist, 7/6 dry); fine sandy loam; massive; weak consistence; pseudo—earthy fabric; pH-value 5.5; abundant roots; diffuse boundary to
B2l	100 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry), mottles yellow to brownish yellow (1OYR 7/8 to 6/8 moist, 8/6 dry, less than 30%); light sandy clay loam; massive; weak consistence; pseudo—earthy fabric; pH—value 4.5 increasing with depth to 5.0; frequent roots; diffuse boundary to
B22	200 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry); light sandy clay loam; massive; weak consistence; pseudo—earthy fabric; pH-value 5.0; frequent roots.

Map unit 2	Soil Profile: IV (exact location see soil map)
Location:	South Carrabin, W.A. Latitude 3l°3l'15" S Longitude1l8°45'00" E Altitude 460 m.
Topography:	Ridge with a southwesterly aspect, sloping < 2%.
Parent Material:	Tertiary sands (?) over laterite and/or cemented ferruginous gravel.
Profile Drainage:	Free, possibly impeded at depth.
Native Vegetation:	Eucalyptus burracoppinensis scrub over low heath C.
Land Use:	Cleared for cropping.
Classification:	Northcote (1979): Uc3.2l - Bleached to pale sands with colour B horizon. Stace et al. (1968): Siliceous sands — Earthy sands. Abbreviated soil name: Yellow pseudo-earthy sands.

Horizon	**Depth**	**Description**
Al	20 cm	yellowish brown (10YR 5/6 moist, 7/6 dry); sandy loam; massive; weak consistence; pseudo-earthy fabric; pH- value 6.0; abundant roots; gradual boundary to
A2sb	50 cm	brownish yellow (10YR 6/8 moist, 7/8 dry), mottles brownish yellow (10YR 6/8 moist, 8/4 dry) sporadically bleached (50%); clayey sand to sandy loam; massiv; weak consistence; sandy to pseudo—earthy fabric; pH—value 4.5; frequent roots; diffuse boundary to
B2l	70 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry) sporadically bleached at A2sb but less than 50%, many ferruginous gravel yellowish red (5YR 5/8 moist, 6/8 dry); gravelly sandy loam; massive; weak consistence; pseudo-earthy fabric; pH—value 4.5; frequent roots; diffuse boundary to
B22	100 cm	brownish yellow (1OYR 6/8 moist, 7/8 dry), reddish mottled (2.5YR 4/8 moist and dry); strong gravelly, light sandy clay loam, massive; weak consistence; pseudo-earthy fabric; pH—value 5.0; frequent roots; clear boundary to
D	200 cm	brownish yellow (10YR 6/8 moist, 7/8 dry, soft matrix), red (2.5YR 4/8 moist and dry, 70% of colour, gravel); soft matrix: light sandy clay loam; massive; pseudo earthy fabric; pH—value 6.0; dry to 175 cm depth, becoming moist at 195 cm; large roots penetrating into moister zone; abrupt boundary to
Dm	210 cm	brownish yellow (10YR 6/8 moist, 7/8 dry), hardpan.

Map unit 3	Soil Profile: V	(exact location see soil map)
Location:	South Carrabin, W.A.	Latitude 31°31’30” S
		Longitude 118°46’00” E
		Altitude 460 m.
Topography:	Ridge with an easterly aspect, sloping <1%.	
Parent Material:	Tertiary sands (7) over laterite and/or cemented ferruginous gravel.	
Profile Drainage:	free, impeded at depth.	
Native Vegetation:	Low scrub A over low scrub C.	
Land Use:	cleared for cropping.	
Classification:	Northcote (1979): KS-Uc2.11 - Bleached sands.	
	Stace et al. (1968): Siliceous sands.	

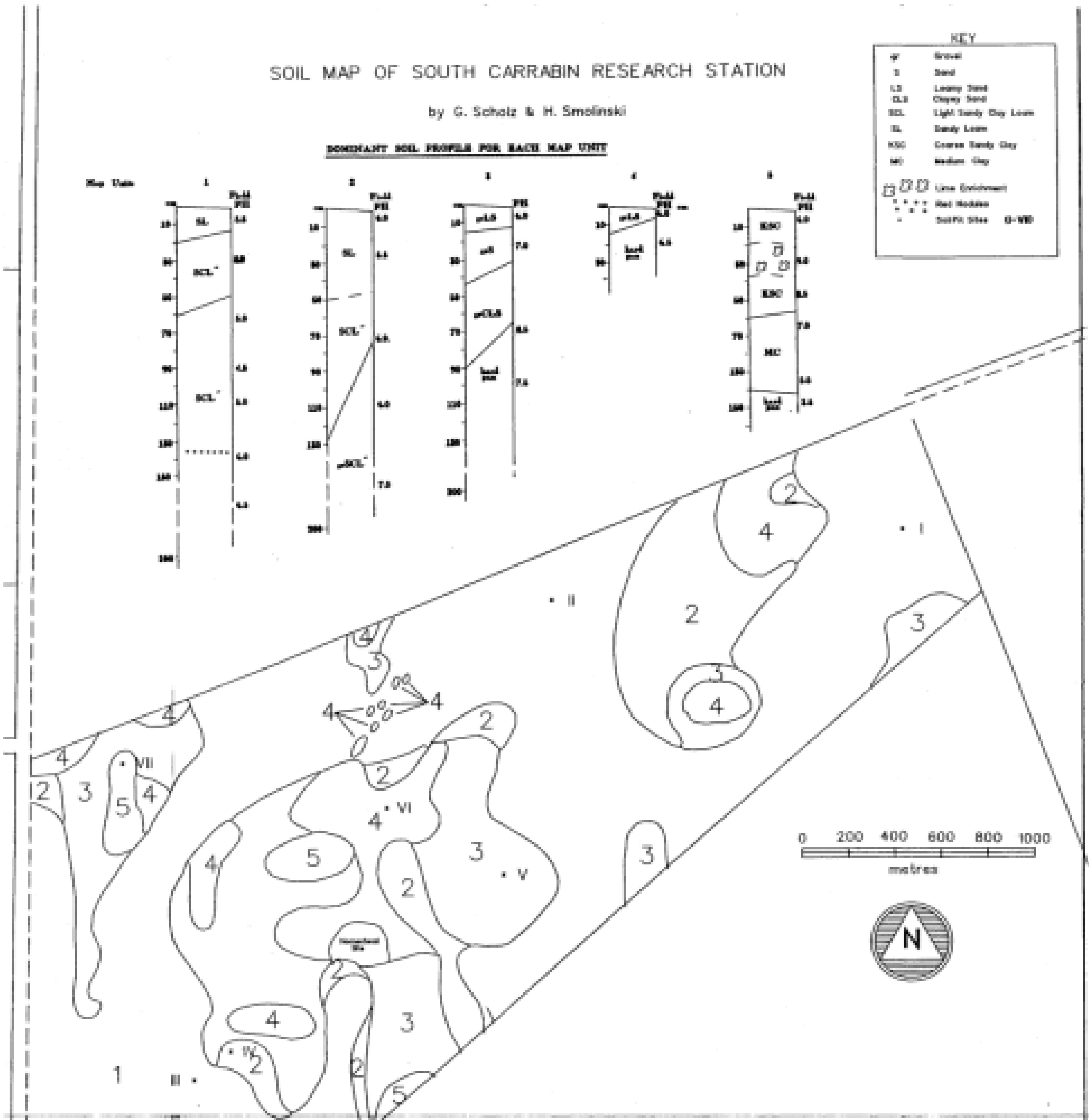
Horizon	**Depth**	**Description**
Al	10 cm	dark greyish brown (1OYR 5/2 moist, 6/2 dry); loamy sand; massive; weak consistence; sandy fabric; pH-value 6.0; many white sand grains; abundant roots; gradual boundary to
A2cb	50 cm	very pale brown (1OYR 7/3 moist, 8/2 dry); conspicuously bleached; gravelly sand, gravel 60%; massive; weak consistence; sandy fabric; pH-value 6.5; frequent roots; clear boundary to
B2nk	200 cm	yellow (1OYR 7/6 moist and dry), mottled, red (2.5YR 4/8 moist and dry, 10%), yellow colour decreasing with depth to less than 10%; gravelly sand with depth changing to gravelly sandy clay loam; massive at 100 cm, changing into slight platy structure at 150 cm and coarse to medium blocky peds at 180 cm; weak coherent; sandy fabric changing into smooth ped fabric; at 100 cm white thin layers of calcium carbonate and white blotches of kaolinitic clay (medium clay), slightly calcareous; pH—value 8.5; rare roots; several layers of ferruginous thin hardpans cemented by calcium carbonate (50 to 100 cm depth), softening at 120 to 200 cm; clear boundary to
C	220 cm	white (10YR 8/1 moist and dry), mottled, dark red, 20% (2.5YR 3/6 moist, 4/8 dry); coarse sandy medium clay; platy structure, smooth ped fabric; slickensides; pH—value 7.0 decreasing to 4.5 with depth.

Map unit 4	Soil Profile: VI	(exact location see soil map)
Location:	South Carrabin, W.A. Latitude31^{0}31'30" 5 Longitude118°45'00" E Altitude 460 m.	
Topography:	Ridge, level.	
Parent Material:	Tertiary sands (?) over laterite and/or cemented ferruginous gravel.	
Profile Drainage:	Free, impeded at depth.	
Native Vegetation:	Allocasaurina, Acacia, Melaleuca uncinata Thicket over open scrub D.	
Land Use:	Cleared for cropping.	
Classification:	Northcote (1979): KS—Uc2.12 - Bleached sands. Stace et al. (1968): Lithosols.	

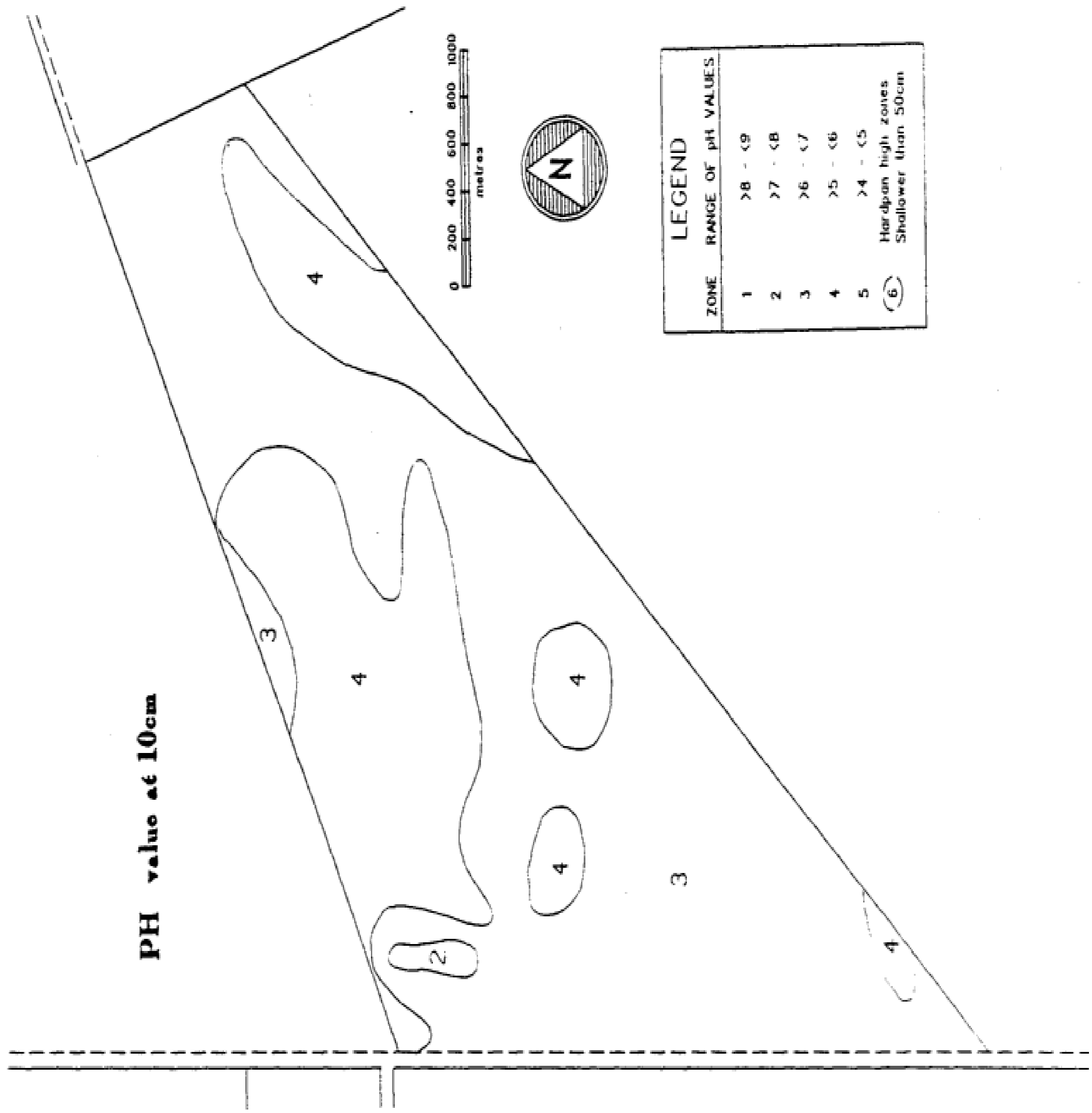
Horizon	**Depth**	**Description**
A1	10 cm	light brownish grey (10YR 6/2 moist, 7/2 dry), strongly gravelly, loamy sand; massive; weak consistence; sandy fabric; pH-value 6.0; gravel more than 60%; abundant roots; gradual boundary to
A2cb	15 cm	light grey (10YR 7/2 moist, 8/2 dry), strongly gravelly clayey sand; massive; sandy fabric; pH-value 6.0; gravel more than 60%; abundant roots; abrupt boundary to
Cm	17 cm	manganiferrous duricrust.

Map unit 5	Soil Profile: VII (exact location see soil map)
Location:	South Carrabin, W.A. Latitude 31°31'30" S Longitude 118°44'30" E Altitude 460 m.
Topography:	Ridge, level.
Parent Material:	Tertiary clays.
Profile Drainage:	Impeded.
Native Vegetation:	Open low woodland over open low scrub B.
Land Use:	Uncleared.
Classification:	Northcote (1979): Ug5.31 - Brown selfmulching cracking clays. Stace et al. (1968): Brown clays.

Horizon	**Depth**	**Description**
Al	20 cm	dark greyish brown (1OYR 3/2 moist, 5/2 dry); coarse sandy clay; subangular blocky; weak consistence; rough fabric; pH-value 6.0; abundant roots; gradual boundary to
Bk	40 cm	yellow (10YR 7/6 moist, 8/3 dry), mottled, reddish yellow (7.5YR 6/6 moist and dry) and reddish yellow (7.5YR 7/6 moist, 8/4 dry); coarse sandy clay; medium polyhedral; moderate weak consistence; smooth to rough fabric; pH-value 9.0; calcium carbonate accumulation in the fine earth and as soft nodules; abundant roots; abrupt boundary to
Dl	60 cm	red (2.5YR 4/6 moist, 4/8 dry), mottled, light reddish brown (5YR 6/4 moist, 8/3 dry); coarse sandy clay; coarse blocky; weak consistence; smooth fabric; pH—value 8.5; no visible calcium carbonate; frequent roots along cracks and structural peds; abrupt boundary to
D2	140 cm	brown (7,5YR 5/2 moist and dry), mottled, red (2.5YR 4/6 moist, 4/8 dry); light coarse sandy medium clay; coarse blocky with platy segregation; moderate weak to firm consistence; smooth fabric; pH—value 7.0 at 70 cm depth decreasing to pH-value 3.5 at 140 cm; frequent roots along cracks; slickensides; abrupt boundary to
D3m	145 cm	hardpan; similarly coloured as D2.



MAP UNITS	NORTHCOTE'S NOTATION	DESCRIPTION	STRUCTURE OF HORIZON A-	B-	HAZARDS OF TOP SOIL
1	Uc5.21	Yellow pseudo-earthy sands (deep phase)	Structureless		Wind erosion, compaction
2		Yellow pseudo-earthy sands (moderately deep phase)			
3	KS-Uc2.11	Siliceous sands (with pan)		pan	
4	KS-Uc2.12	Lithosols (with pan)	Structureless	Pan	Wind erosion perched watertable
5	Ug5.31	Brown Clays	Subangular blocky	Polyhedral	Perched watertable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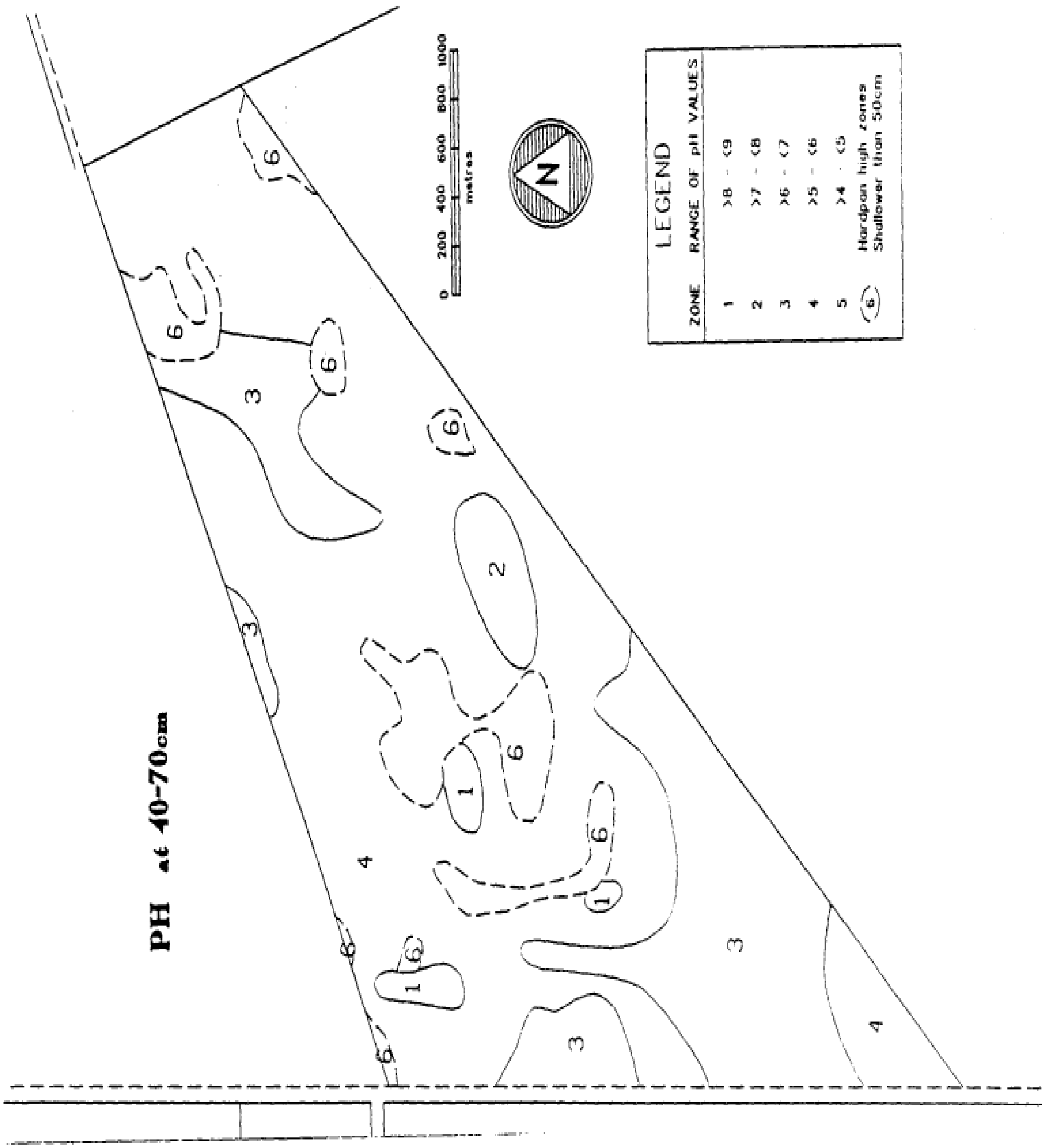
metres
N
LEGEND
ZONE
RANGE OF pH VALUES
1 >8 - <9
2 >7 - <8
3 >6 - <7
4 >5 - <6
5 >4 - <5
6 Hardpan high zones Shallower than 50cm
4
3
4
4
4
3
2
4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metres
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LEGEND
ZONE RANGE OF pH VALUES
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2 >7 - <8
3 >6 - <7
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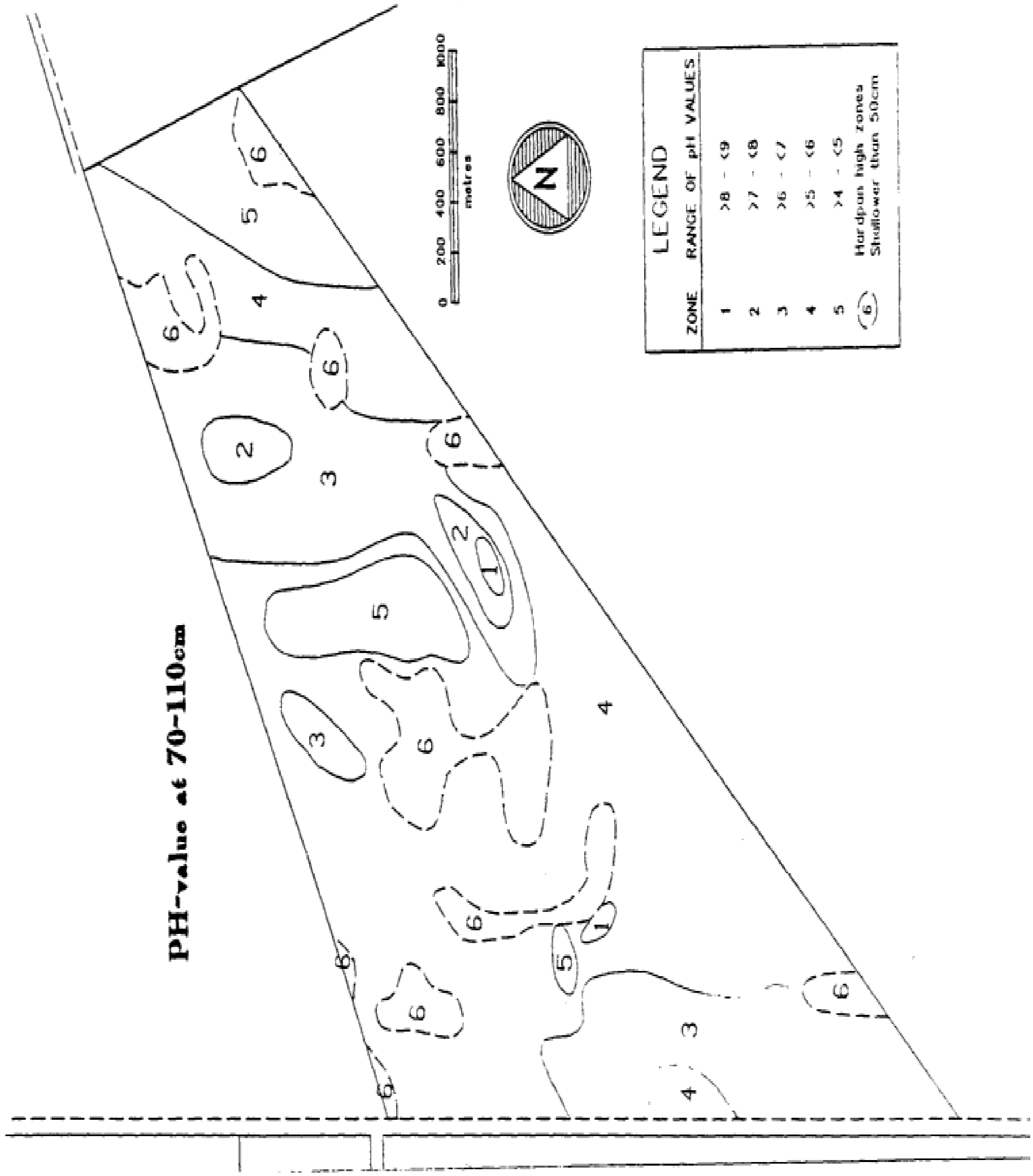
5 >4 - <5
6 Hardpan high zones Shallower than 50cm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metres
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LEGEND
ZONE RANGE OF pH VALUES
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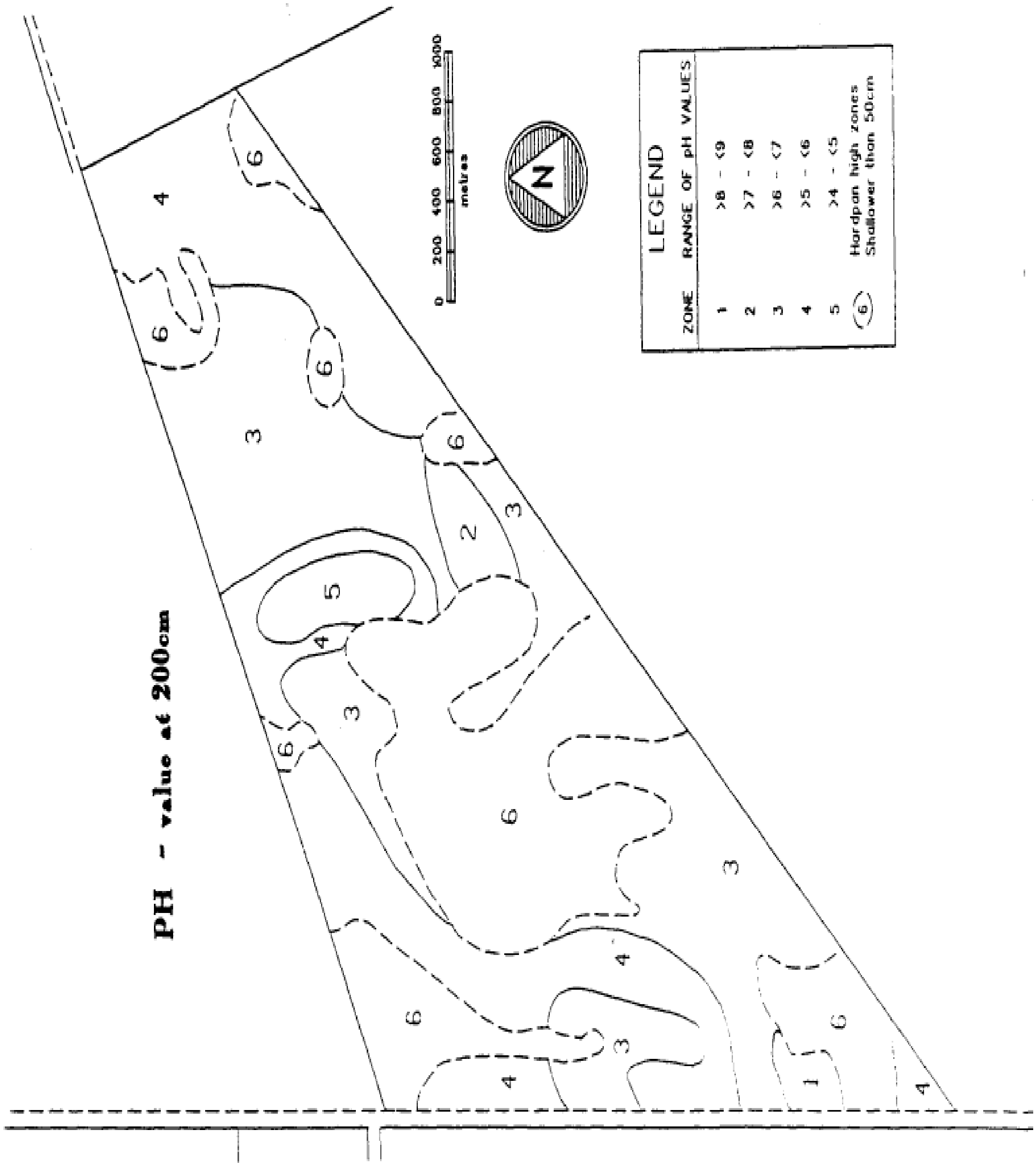
2 >7 - <8
3 >6 - <7
4 >5 - <6
5 >4 - <5
6 Hardpan high zones Shallower than 50cm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metres
N
LEGEND
ZONE
RANGE OF pH VALUES
1 >8 - <9
2 >7 - <8
3 >6 - <7
4 >5 - <6
5 >4 - <5
6 Hardpan high zones Shallower than 50cm