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The soils of the Salmon Gums district, Western Australia

George Henry Burvill

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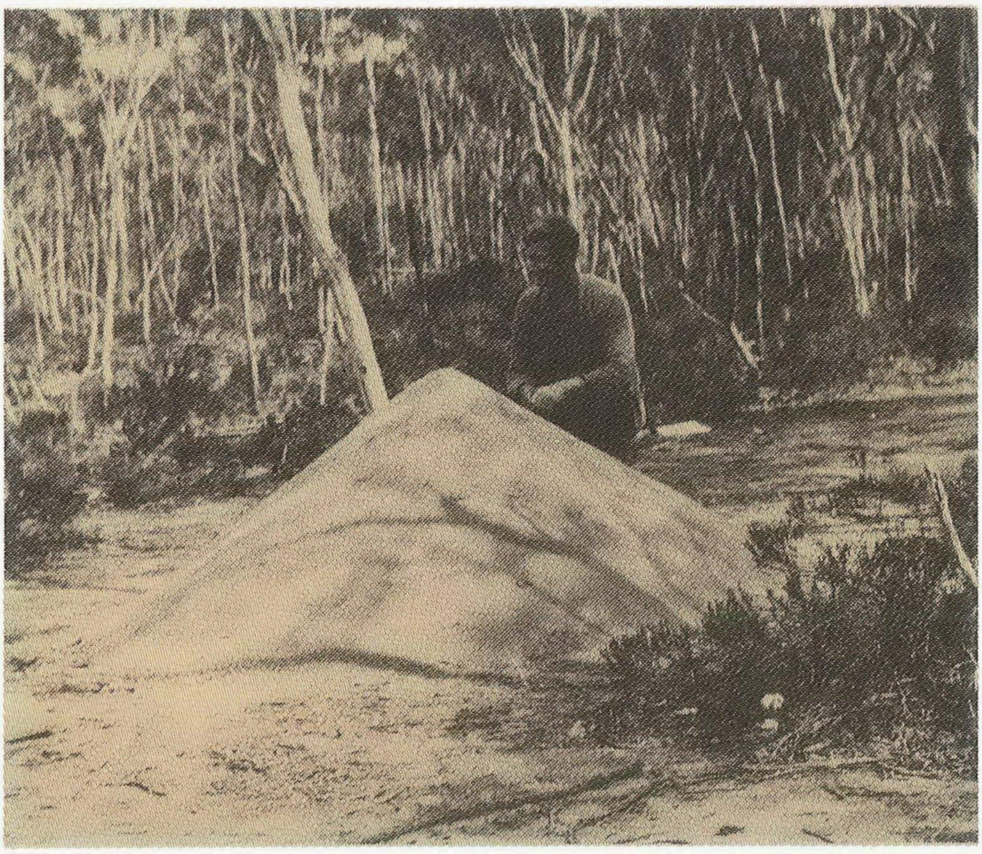

G.H. Burvill

ERRATA

Western Australian Department of Agriculture
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'The soils of the Salmon Gums district, Western Australia'

page 30
Reaction (pH). Line 4 should read Appendix 4, not Appendix 3.

page 31
Calcium. Line 11 should read Appendix 4, not Appendix 3.

The soils of the Salmon Gums district — Western Australia

By: G.H. Burvill
Editor: D.A.W. Johnston

Foreword

The purpose of this publication is to give permanent record to scientific and practical information obtained from a soil survey of 235,717 ha (582,018 acres) of farming land centred on Salmon Gums, Western Australia, about halfway between Esperance and Norseman. The field work of the survey took three years (August 1932 to August 1935). The survey was undertaken because earlier work and experience had shown that soil salinity was a major factor in reducing wheat yields. The aim was to determine the extent and distribution of these saline soils. Some 70,000 soil samples from 33,000 sites were analysed for salt in a field tent laboratory. Type samples from 64 sites, many to depths of 5-8 m, were examined in laboratories in Perth and, by 1939, writing a permanent record was commenced. Because of the outbreak of the World War on September 3, 1939, the writing was set aside. The 42 map sheets of the survey were, however, used by the Agricultural Bank as the basis for farm reconstruction.

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The Author:

Mr George H. Burvill, Agricultural Adviser during the survey. Became Assistant Director of Agriculture.

G.H. Burvill, Assistant Director of Agriculture (retired),
Department of Agriculture, Western Australia.

George Henry Burvill was born at Cottesloe Beach (Mosman Park) Western Australia on August 23, 1908. In 1920, while attending Perth Boys' School, he won a scholarship to Perth Modern School and completed the Leaving Certificate in 1925 with four distinctions. This won him the first General Exhibition, but he relinquished this to accept the Henry Seeligson Senior Scholarship which tied him to agriculture and provided an extra £20 per year. He enrolled at the University of Western Australia in 1926 and graduated B.Sc.(Agric) with First Class Honours in 1931. He joined the Western Australian Department of Agriculture as a cadet in 1927 and was appointed an Agricultural Adviser in 1930. He was closely associated with Dr L.J.H. Teakle from 1928 until 1947 when Teakle left Western Australia to become Professor of Agriculture in the University of Queensland.

Burvill was associated with most of the Department's soil surveys in the years 1931 to 1936, but more particularly with the Lake Brown Survey in 1931 and 1932, and the Salmon Gums Survey from 1932 to 1935. He spent some summer months of 1934/1935 on the Denmark Survey.

From 1937 to 1947 he was Assistant Plant Nutrition Officer under Teakle, but spent 14 months in 1937 to 1938 with the C.S.I.R. Division of Soils in Adelaide. He gained his Master of Agricultural Science degree from the University of Adelaide. In 1944 he worked on the Ord River Soil Survey from April to September and identified and named the major soil Cununurra clay — hence the name Kununurra adopted later for the town and locality.
Burvill was Commissioner of Soil Conservation from 1947 to 1956, then Chief of the Division of Plant Research, 1956 to 1969. He was Assistant Director till his retirement in 1971. He was responsible for the drought relief programmes of 1969 to 1971.

When the research emphasis of the Plant Nutrition Branch changed from soil salinity to plant nutrition in the 1940s, Burvill recognized in 1946 that zinc deficiency of oats resulted from the use of "war-time super" on new land. The source of phosphate rock had changed when Nauru fell into enemy hands and the superphosphate had much less zinc. While he was Commissioner of Soil Conservation a large programme of work by other officers with copper, zinc and molybdenum showed the need for these in the great new land development programme from 1949 to 1969. Burvill and his officers in the Division of Plant Research had a major part in this work. He had a major role in selecting the site for Esperance Downs Research Station in 1949 and Badgingarra Research Station in 1955 — both in major light land areas. The Kimberley Research Station site on the Ord River had been located by Burvill in 1944. This was renamed "The Frank Wise Institute of Tropical Agricultural Research" in 1986.

After his retirement in 1971 he was appointed as Chairman of the Western Australian Barley Marketing Board (1972 to 1974), and began work on the

unpublished data from the soil surveys of the 1930s. In 1976 interest in the State's Sesquicentenary (1979) developed and he was asked to write and edit a book on agriculture in Western Australia embracing 150 years of progress and achievement. His long and varied experience equipped him for this task and the book was released early in 1980. Again he took up the Salmon Gums Soil Survey and this publication is the product of his work. For 50 years he had preserved the original data much of which now appears for the first time.

Meticulous care and attention to detail were hallmarks of Burvill's professional career. He was made a Fellow of the Australian Institute of Agricultural Science in 1961 and was Western Australian President and later Federal President of that body. He joined the Royal Society of Western Australia in 1927 and became its President in 1947. He is now an Honorary Member. The Australian Society of Soil Science has named him as an Honorary Member for Life. He is also a fellow of ANZAAS.

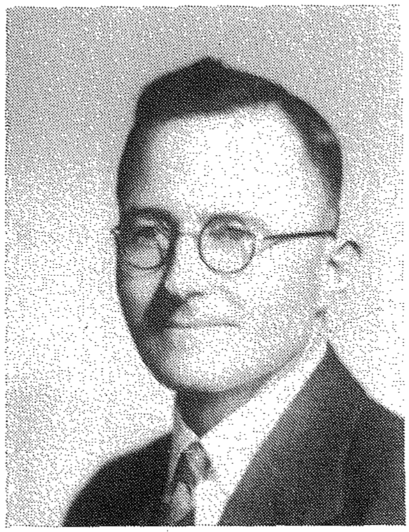
Editor's Note:

In 1976, the then Director of Agriculture, Mr E.N. Fitzpatrick, commissioned Mr G.H. Burvill to write and edit a book on Western Australian agriculture. This was to become part of the Sesquicentenary Celebrations Series and was entitled, "Agriculture in Western Australia — 150 years of development and achievement, 1829–1979".

Upon its successful completion in 1979, Mr Burvill was prevailed upon to write up the now historic Salmon Gums soil survey of the 1930s. The preparation of this work was finally completed in 1987, some 52 years after the completion of the survey in which Burvill was so intimately involved.

D.A. Johnston
Editor

Burvill, G.H. (George Henry), 1908 -
The soils of the Salmon Gums district, Western Australia



Dr L.J. Hartley Teakle, Plant Nutrition Officer in charge of the survey. Became Professor of Agriculture at the University of Queensland in 1947.

Bibliography.
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Contents

Abstract

The Salmon Gums district is about 80 km by 40 km and lies inland about 50 km from Esperance on the south coast of Western Australia. It is an area of low relief and few watercourses, 150 to 250 m above sea level, and is now known to be underlain by Eocene and more recent sediments with occasional outcrops of pre-Cambrian granites and greenstones. The native vegetation dominated by mallee and sapling forms of *Eucalyptus*, gave the name "Esperance Mallee lands" to the area. The scrub covered sandy soils nearer the coast have long been known as the "Esperance Sandplain".

The finding of gold in 1892 and 1893 at Coolgardie and Kalgoorlie, 400 km north of Esperance, led to the opening of tracks to the "diggings". Farming to produce hay for horse transport — coaches and wagons — started around Grass Patch, 70 km inland, in 1896. Salmon Gums, 100 km from Esperance, was one of the stopping places on the coach route.

Around 1910, expansion of farming for wheat was attempted, but various problems led to a Royal Commission being established in 1916 to investigate the situation. There was emphasis on salt in the soils, but the Commission discounted this and so, after The Great War of 1914–18, soldier settlers and migrants were allotted blocks of 450 hectares. Before the Great Depression which started in 1929 there were 500 farmers in the area.

In 1929, L.J.H. Teakle investigated the poor wheat yields on many farms and pointed to soil salinity and powdery calcareous soils (locally called "kopi") as two major soil problems. By the early 1930s hundreds of farms had been abandoned. This led to a programme of reconnaissance and detailed soil survey from 1929–1936. This included the Salmon Gums Soil Survey — the field work in the three years 1932–1935 embraced 235,717 ha. Some 70,000 soil samples from 33,000 sites were analysed for salt (NaCl) in a field laboratory (a canvas tent).

Most of the soils are grey and brown solonized soils originally called 'mallee' soils by J.A. Prescott in 1931. The subsoils, to about 2 m, are calcareous sandy clays with limestone rubble, but there are three main surface variations.

1. Sandy surfaced, 5–30 cm deep, passing abruptly to the sandy clay subsoil with lime nodules. The Circle Valley sand and Scaddan sand are major types. Scaddan sand has a domed subsoil clay.

2. Powdery calcareous sandy loam ("kopi") with much soft lime and calcareous rubble in the subsoil. The Beete calcareous sandy loam is the major type.

3. Clay loam and clay with some lime in the subsoil, but less than in 1 and 2. Gilgais (crabholes) are a common surface feature. Kumarl clay loam (brown to red-brown) and Dowak clay loam (grey) are the major types.

The occurrence of siliceous boulders and gravels, sometimes conglomerates or breccias, and ironstone gravels on the surface of the heavier soils may link them with laterites, but laterite residuals otherwise do not occur in this area.

Below about 2 m all the major soil types have grey and brown or red brown mottled sandy clays that are very acid (pH ca 4) and, by contrast with the calcareous

layers above, are almost free of calcium. The origin of the acid horizons, and of the lime in the upper layers remains obscure; explanatory hypotheses are discussed in the text.
In the detailed survey, 16 soil types in 13 named series were identified and mapped. Twenty-four per cent of the total area surveyed had to be mapped as complexes because of the patchy occurrence of the soils. A map of soil associations is presented (map 3). The amount and distribution of soluble salts, especially chloride (expressed as NaCl) was of major interest, hence the large number of samples collected and analysed. All the major soil types contained amounts up to 1% NaCl in the subsoils; maximum figures in virgin soils often occurred within 1 m of the surface. Graphs of NaCl in representative profiles sampled to 5 or 6 m are included (figures 1, 2, 3).

After removing the natural vegetation to farm the land with cereals and annual pasture plants, salt distribution changes. Leaching occurs in sandy surfaced soils (Circle Valley and Scaddan), but surface concentration producing sterile bare patches is common on powdery calcareous soils (Beete) and heavy soils (Kumarl and Dowak). The soluble salts are dominantly chloride as in sea water and are believed to be mainly atmospheric accessions. The area averages less than 5 mm of rain per wet day and there is no run-off to the ocean. Rainwater analyses have shown annual accessions of NaCl of 22–30 kg/ha at Salmon Gums which has an annual rainfall average of 337 mm.

Mechanical analyses of the <2 mm fractions of most soil types are presented as well as data for calcium carbonate (calculated from CO_2). Up to 57% $CaCO_3$ was recorded in Beete series subsoils. Most surface soils have a pH of 6–7 and calcareous subsoils pH 8-9. The deep subsoils — below 2 m — have a pH 3.5–4.5. Total nitrogen ranges from 0.03% in sandy surfaces, 0.05–0.10% in more loamy types and 0.07–0.20% in powdery calcareous surfaces. Organic carbon is <1% in surface sands and up to 3% in calcareous powdery types. Other soils are intermediate. Phosphorus in most surface and subsoil samples is below 0.005% expressed as P_2O_5.

Magnesium, sodium and potassium are abundant in all horizons with more than 20% clay. Calcium is abundant in the upper 2 m, but the very acid layers at depth are almost without calcium, either acid soluble or exchangeable. Magnesium and sodium are the major exchangeable metal cations of the subsoils; calcium is more common in the surfaces.

The water soluble fractions are dominated by Na and Cl but the leaching of calcareous subsoils after clearing the natural vegetation reduces the proportion of these and increases the bicarbonate. The possibility that the salts in the deep layers are from marine submersion is discussed.

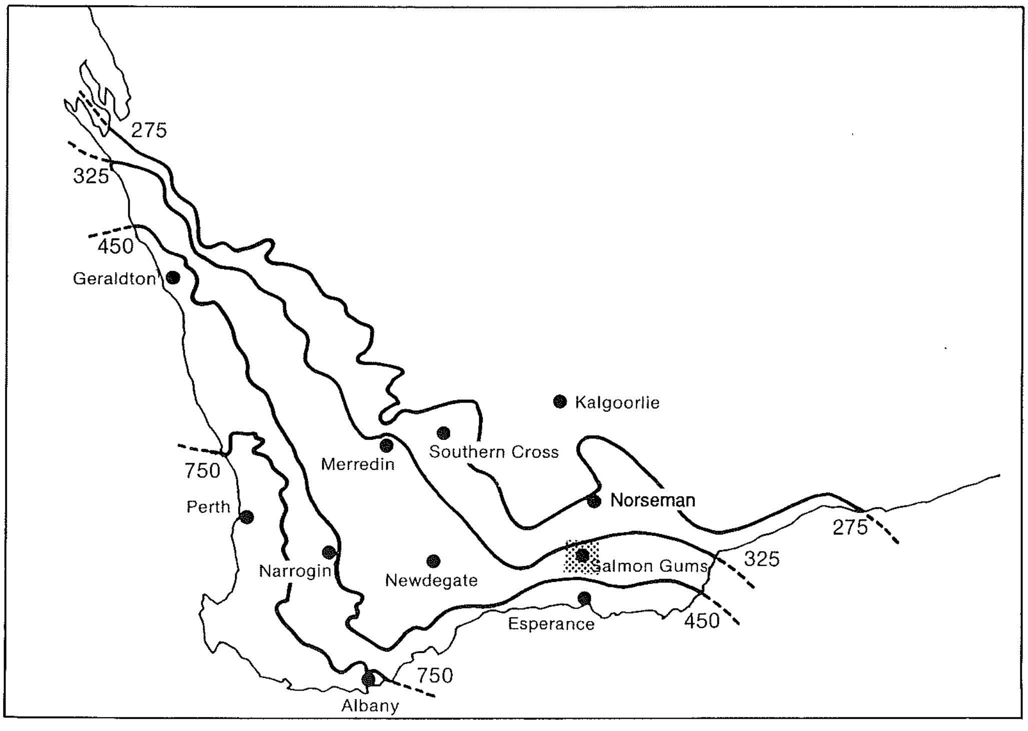
Attention is drawn to the chemical and physical similarities of the Salmon Gums soils and some of the so-called solonetz soils of southern California in the United States of America.

The soil survey maps and data were used as a basis for farm reconstruction in the late 1930s and 1940s. Mixed farming — cereals and sheep — continues on much larger properties and avoids the worst problem areas.

Introduction

Historical review

Salmon Gums (32°59'S, 121°36'E) is a small township 100 km north of Esperance on the railway and road leading to the mining centres of Norseman, Kambalda and Kalgoorlie **(map 1).** When gold was discovered at Coolgardie in 1892 and at Kalgoorlie in 1893 Esperance was the nearest port some 400 km to the south. It rapidly expanded from a pastoral and telegraph station outpost to a town of about 2000 people. Tracks north to the goldfields were developed for the coaches and wagons taking people and goods to the "diggings." Salmon Gums was one of the stopping places. Chaff and hay for horses were in great demand and led to the sowing of cereals on cleared land near Grass Patch and Red Lake 70–80 km north of Esperance. Natural open areas with few trees occurred in both localities, hence the names Grass Patch and North Patch (east of Red Lake). The Esperance hinterland is mainly a plain with low scrub and sandy soil extending inland about 50 km; it remained largely undeveloped till research from 1950 onwards showed its potential for pastures and cereals and led to extensive development (see Shier, Dunne and Fitzpatrick 1963).



Map 1. The South-West Province of Western Australia. Area of predominantly winter rainfall above an average of 275 mm per year after Johnston (1983), showing the location of the survey area.

The low scrubby natural vegetation of the Esperance sandplain changes near Scaddan to taller *Eucalyptus* species with a mallee habit of growth, i.e. no main trunk, but several growths from a bulbous root base. The mallee form is most common as far as Salmon Gums. Further north, although rainfall decreases, the general height of the natural eucalypts increases and sapling and tree forms of many species dominate. Around Beete, and north to Norseman and Kalgoorlie, eucalypt woodlands with trees 5–20 m tall are common and have provided mine timber and firewood since the 1890s.

The mallee belt north of the Esperance plain became known as the Esperance Mallee Lands. When land settlement in Western Australia for wheat farming was being extended around 1910, due to the decline in goldmining, the mallee lands around Scaddan, Grass Patch, Red Lake and Circle Valley were surveyed into farms. Cereal yields were generally poor and in 1916/17 there was a Royal Commission on the Esperance Mallee Lands. Soil salinity was one of the problems aired before the Royal Commission, but, in spite of unfavourable reports by several professional witnesses, the Commission concluded that the mallee lands were suitable for further settlement. Consequently, in the 1920s after The Great War, there was extensive settlement east, west and north of Salmon Gums by ex-servicemen and civilians, some of whom were British migrants. Each farm was originally about 450 ha (1100 ac). A railway was built from Esperance to Salmon Gums by 1925; the link to Norseman and thus to Coolgardie was completed in 1927.

The Depression of the 1930s, compounded with isolation, soil salinity and stock-water supply problems caused hundreds of farms to be abandoned. The number of farmers dropped from about 500 to little more than 100 and when reconstruction of the area took place in the late 1930s, losses of public money were estimated at about $1,000,000 (£500,000).

Salmon Gums takes its name from the patch of salmon gum trees (*Eucalyptus salmonophloia*) about 2 km south of the present town. It was one of the stopping places on the old coach road to the goldfields in the 1890s. A gully and an earth tank provided water and a hotel was located there till the present town hotel was built in the mid 1920s. The salmon gum is a common tree of the eastern wheatbelt and eastern goldfields areas, but is not extensive in the Salmon Gums district. The main occurrence, other than the old Salmon Gums stopping place, is around and south-west of Circle Valley, 10–15 km south of the town of Salmon Gums.

North of the Esperance sandplain, underground water, when located, is usually strongly saline and in the gold rush days condensers were established to provide potable water for man and beast. One of these was at Swan Lagoon, 8 km south-west of Grass Patch. The author saw the remains of the old well and the iron boiling pot in 1935 and again in 1962.

A site for a State Experiment Farm was selected in 1925 by Isaac Thomas, then Superintendent of Wheat Farms in the Department of Agriculture. The farm, now the Salmon Gums Research Station, is centred 2 km west of the present township. There was no railway connected to Norseman and Perth in 1925 so Thomas travelled by train to Newdegate and from there rode his Government belt-driven Triumph motor cycle along the roads and tracks to Ravensthorpe and from there via Peter's Soak and Peak Charles to Salmon Gums. He returned by riding to Norseman and thence by train to Coolgardie and Perth. A beer bottle full of petrol drained from the tank of the motor cycle before loading it on to a goods or passenger train, went (illegally) with Isaac Thomas when he travelled so that when the machine reached its destination there was fuel to reach the nearest petrol supply. He was Deputy Director of Agriculture when he retired in 1956 and died aged 87 in 1978.

Soil salinity investigations 1917 to 1931

The Salmon Gums district first became the subject of soil salinity studies when the 1917 Royal Commission on the Esperance Mallee Lands took evidence from numerous witnesses. The Royal Commission report on the suitability of the Esperance mallee lands for farming, deals at length with the evidence and opinions. Appendix 1 gives a review of the Commission's findings prepared by L.J.H. Teakle in 1939.

In 1928 attention was again focused on the area because it adjoined a large tract of country extending west to Lake King and north-west to Southern Cross that was proposed in 1927 to be a major part of the 3500 Farms Scheme. It was suggested to the Development and Migration Commission that this scheme be financed under the $68,000,000 (£34,000,000) Development and Migration Agreement between Australia and Great Britain — an arrangement for settling ex-servicemen and civilians who would emigrate

from Great Britain. The Commission drew attention in 1928 to the inferior average wheat yields in the Salmon Gums district compared with the State average. The figures are set out in Table 1.

Table 1. Wheat yields in the Salmon Gums district compared with State averages, 1912 to 1933.

	Salmon Gums district		State average
Year	Total yield tonnes	Yield kg/ha	Yield kg/ha
1912	200	213	767
1913	467	280	813
1914	333	167	130
1915	867	353	700
1916	800	640	687
1917	867	673	493
1918	200	260	513
1919	333	413	720
1920	933	720	640
1921	800	553	693
1922	733	440	593
1923	1,000	207	760
1924	3,200	267	853
1925	5,733	280	647
1926	12,733	460	806
1927	21,266	520	806
1928	14,000	240	673
1929	20,267	480	733
1930	43,000	633	900
1931	40,867	687	873
1932	39,933	700	820
1933	22,800	433	787

The Development and Migration Commission asked why wheat yields in the Salmon Gums district were inferior to the rest of the State, and were these the levels of wheat yields to be expected if the 3500 Farms Scheme went ahead.

In May 1929, Dr L.J.H. Teakle of the Western Australian Department of Agriculture was requested to go to Salmon Gums and examine the areas used for wheat growing. H.F. Rodgers, manager of the local branch of the Agricultural Bank, co-operated. Many new farms had been developed since 1922 as reflected in the total wheat yield from the district. Teakle identified three major classes of soil:-

1. Sandy surfaced types with a calcareous clay subsoil.

2. Heavy textured or clay types usually with crabholes or gilgais.

3. "Kopi" types related to the powdery calcareous soils of the morrel country in other wheatbelt districts. Strictly, "kopi" is whitish floury gypsum (calcium sulphate), but at Salmon Gums the name is applied to grey powdery soils with much calcium carbonate, not gypsum.

Soil analyses showed that crop failures or poor returns were associated with excessive salinity, especially in the upper 15 cm of soil. The heavy soils and the "kopi" types were the worst affected. Sandy surfaced soils had little salt trouble.

Teakle concluded that, if saline and 'kopi' soils could be avoided, wheat yields at Salmon Gums would be much better. Several years later, analyses of yields at the Salmon Gums Experiment Farm confirmed the superiority of yields on sandy surfaced soils which, by contrast with the heavy soils and kopi, were not prone to surface concentration of salt.

In 1931, the author made a detailed soil survey of the Salmon Gums Experiment Farm (now Research Station) to provide a basis for locating field experiments on the various soil types. It is fortunate that all three of the major soil groups defined by Teakle in 1929 are well represented on the Research Station and, as indicated above, the relationships between soil type, soil salinity and cereal yields were confirmed (see appendix 2).

Professor J.A. Prescott (1931) introduced to Australia the concepts of modern soil description and classification about 1927. He named and described "Mallee Soils" as a very important group within the zone of winter rainfall and the influence of the ocean south of the continent. The Salmon Gums district soils were mapped in the mallee category. The main characters of these soils are: alkaline subsoils containing much free calcium carbonate in powdery or nodular form; brown and grey brown surface soil, and soluble salts accumulated from atmospheric accessions, but not fully leached because of the low amount and light nature of the rainfall (<5 mm/wet day). The mallee soils occur in Western Australia, South Australia, Victoria and New South Wales. Many similar soils in Western Australia grow tree forms of *Eucalyptus* (salmon gum, gimlet, morrel, merrit, redwood, yorrel) and constitute "first class" land in the wheatbelt, whereas the mallee areas have traditionally been judged "second class."

Prescott's "Mallee Soils" contain soluble salts, especially NaCl, and this has influenced the chemical nature of the clay subsoils as well as the movement of $CaCO_3$ and clay in the soil profile. Thus the soils are "solonized" and the name grey and brown solonized soils is used. Teakle (1938), described a zone of grey and brown calcareous solonized soils of the low rainfall *Eucalyptus* woodlands. Stephens (1961), mapped the Salmon Gums district as a

complex of solonized brown soils, solonetz and solodized solonetz. The Handbook of Australian Soils (1968), uses a similar description on its soil map. The presence and influence of soluble salts, especially NaCl, in these soils and in many other areas of Western Australia has long been recognized.

Topography, geology and soil parent materials

The Salmon Gums district is a gently undulating area with its highest parts (292 m) around Dowak about 10 km north of Salmon Gums. From Dowak it falls imperceptibly north (Beete 249 m), east and west for 20-30 km to extensive salt lake systems (usually dry) which are a common feature of the inland parts of the southern half of Western Australia.

Railway levels indicate a gentle general fall from 249 m at Salmon Gums to 182 m at Scaddan. Red Lake (240 m) is an elevated area between Circle Valley (232 m) and Grass Patch (217 m). Most of the area east of the railway from Circle Valley south to Scaddan has numerous salt lakes with dunes of orange brown or white sand in the form of lunettes on the east-south-east sides and small rocky slopes of more or less horizontally bedded sandstone on the west and north-west sides. The upper parts of these slopes have calcareous rubble like the soil subsoils. These saltpans do not form continuous drainage lines of old river systems as do the salt lakes in many areas of the State such as the Lakes District, the Lake Brown area, and the country east of Morawa, Perenjori and Dalwallinu. They were probably blown out in an arid period which produced similar lunettes near many of the salt lake systems of the main Western Australian wheatbelt. Bowler (1976) from radio-carbon dating from some of them (e.g. Lake King) suggests 18,000–15,000 B.P. as the probable period of lunette building by west-north-westerly winds.

The Salmon Gums district has very few watercourses except west and south-west of Scaddan. This area is the source of the Dalyup River crossing the Esperance sandplain to the south coast. Near the old Salmon Gums stopping place and hotel there is a gully leading to a large depression about 1 km west of the present township. After very heavy falls of rain, 1–2 m of water has been known to collect in this depression which has trees of flat-topped yate (*Eucalyptus occidentalis*) around its edges and a grey clay bed. In the 1930s it was, when dry, used as a showground and sporting venue.

There are few rock outcrops other than those in salt lakes, but between Salmon Gums and Dowak and at Kumarl, outcrops of a granitic character occur and are also found at Styles Rock east of Red Lake. East of Beete and Dowak there are small occurrences of greenstones associated with the auriferous rocks of the Dundas and Norseman goldfields. Boulders of magnesite are scattered on the surface. What appears to be gneissic granite occurs in the beds of some of the salt lakes east of Grass Patch.

When the Salmon Gums soil survey was done in the 1930s it had been recorded that sediments and fossils, possibly of Miocene age, were found at Norseman (100 km north of Salmon Gums and about 280 m above sea level). The possibility was therefore envisaged that marine sediments had covered the Salmon Gums district. Sedimentary rocks, now referred to as the Plantagenet Group (Cockbain 1968) have since been studied in the Denmark, Albany and Esperance areas in many places and belong to the Eocene. The Eocene sea apparently extended inland at least to Norseman, and the Salmon Gums district must be underlain by Eocene and more recent sediments resting on a pre-Cambrian basement. Since 1977, when peat was found in Main Roads Department water bores at Kumarl (Loxton 1977) intense exploration by Western Collieries Ltd has defined lignite deposits of about 600 million tonnes beneath about 30 m of overburden in a strip about 40 km long east of Circle Valley, Grass Patch and Scaddan. Some of this is within the area of the soil survey. Geologically it is in the Werillup Formation of the Eocene Plantagenet Group and is recorded by Elms, Matthews and Chapman, (1982).

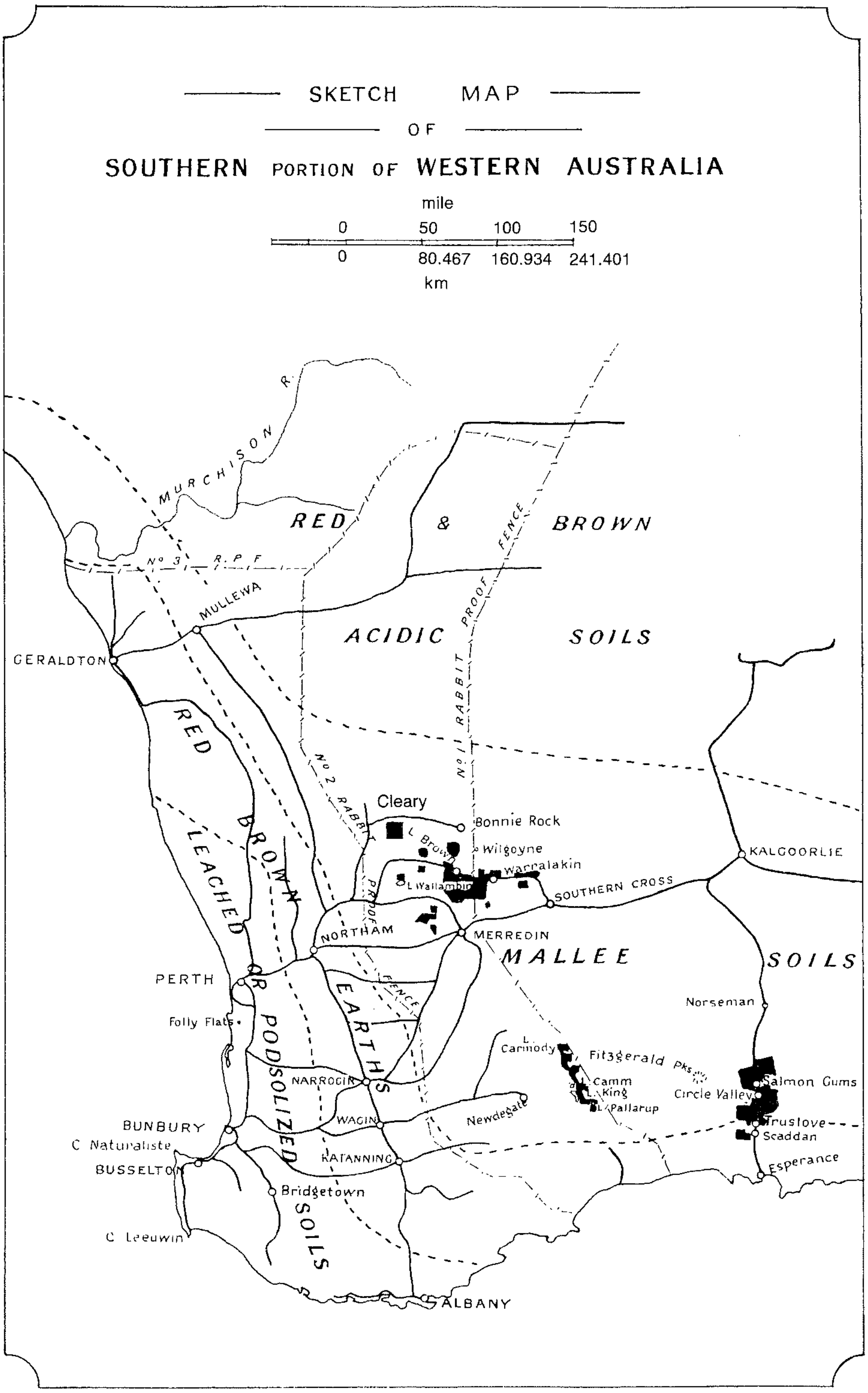
In 1934, the author, while taking a soil type sample in low lying salt lake country 20 km east of Salmon Gums and about 20 km north of the now defined lignite deposit, was puzzled by a layer of black sandy peat 3.5 – 4 m below the surface and below sand and calcareous clay. The ground water at about 2 m contained 6% NaCl almost twice the salinity of sea water. The sandy peat had 8.2% organic carbon and its pH was 3.9. The soil had a shallow sandy surface and a calcareous sandy clay subsoil (pH 8.3) from 1 to 3 m (appendix 3, Fitzgerald location 613, samples 1147 to 1155). This may have been originally a calcareous marine clay, as may many of the calcareous subsoils of the major soil types at Salmon Gums. The black sandy peat must be related to the lignite occurrences described above.

On the basement of ancient pre-Cambrian rocks, Tertiary and Recent sediments have apparently formed a thin overlay which is exposed in the many salt lakes. A ferruginous sandstone was found many times at depths of 5–7 m in type sample soil borings. But a feature of nearly all the soil profiles is that 2-3 m below the surface grey and red-brown mottled sandy clay occurs. This is strongly acid (pH 4), contains 0.5–1.0% NaCl, and Na, K and Mg in acid soluble and exchangeable forms, but has almost no calcium. The upper 2–3 m of the major soil groups, belonging to Prescott's mallee soils, have much free $CaCO_3$, soluble salts up to 1.0%, and exchangeable Ca, though Mg and Na are the dominant exchangeable ions in the subsoils. The question arises whether the deep very acid sandy clay is of marine origin and whether it has been modified by atmospheric accessions of calcium carbonate and soluble salts?

Crocker (1946, 1946a) postulated that much of the calcium carbonate in South Australian mallee soils was aeolianite from an exposed continental shelf. Teakle (1946) was unable to accept this hypothesis for Salmon Gums, nor for most of the large area of solonized soils in Western Australia. There are vast tracts of yellow sandplains of lateritic origin occurring throughout the solonized soil zone. Soils are acid and have no free lime, but would have received the same atmospheric accessions as the present calcareous solonized soils. The author has pondered these issues for 50 years without reaching a satisfactory answer. It may be that the upper 2–3 m of the major soils containing 20–50% calcareous rubble belong to one marine deposit and the lower strongly acid calcium free clay at 3–6 m is another deposit. Both layers, and the ferruginous sandstone below, would be younger than the Werillup formation of Eocene age described by Cockbain (1968) and discussed by Morgan and Peers (1973).

Marshall and Hooper (1935) reported acid clays (pH 5) at depths of 3–5 m below calcareous subsoils (pH 9) at 1–2 m in South Australian mallee soils of the irrigation areas at Berri, Cobdogla, Kingston and Moorook in the Murray Valley. Also, in the 1931–32 Lake Brown Soil Survey in Western Australia embracing the broad valleys around Gabbin, Mukinbudin, Lake Brown, Campion, Boodarockin, and south to Hines Hill, Nungarin, Goomarin and Westonia, the subsoils at 2–5 m were strongly acid (pH 4) as well as saline, while there was abundant $CaCO_3$ in the upper 2 m (see map 2). Bettenay and Hingston (1961) reported similar findings at Merredin. The Eocene sea may have reached these valleys which are now 250 – 300 m above sea level.

Climatic and sea level changes since Eocene times, and especially atmospheric accessions of NaCl, have been factors in determining present soil profile characters. In the higher parts, the occurrence on the surface of hard siliceous pebbles and rocks, some of which are conglomerates or breccias including water rounded quartz stones, and also, scattered ferruginous pisolites, add to the complexity of the soil features. They may be remnants of laterite profiles. There are however, no extensive laterite or ferruginous cappings as in most of the southern half of Western Australia. Ironstone gravel (used for road making) occurs in shallow deposits between Grass Patch and Scaddan and in pockets among the heavy soils west of Salmon Gums. There is a small hill of ironstone gravel on the Salmon Gums Research Station. In the gravel pits opened in this hillock for road work, water rounded quartz pebbles 2–3 cm in diameter were found by the author in the 1960s.



Map 2. Locations of soil surveys in southern Western Australia, 1930–1936. Map prepared c. 1936 by Burvill and Teakle.

Climate

Like most of the areas of Western Australia developed for agriculture, the Salmon Gums district receives more rain in winter than summer, but the preponderance is less marked than in most other agricultural areas. The average falls for January, February and March are higher than for most parts of the 300–400 mm rainfall zone. This is due to occasional heavy falls as cyclones bring rain from the north-west to the south-east of the State, but miss the south-west. May to August rains are generally lower than for areas of similar annual rainfall. Table 2 gives the monthly averages of rainfall for Esperance, Scaddan, Grass Patch, Salmon Gums, Salmon Gums Research Station and Norseman. North of Salmon Gums the rainfall decreases further and the reliability declines in the goldfields centres of Norseman and Kalgoorlie.

The rainfall is mostly in light falls so that the mean per wet day is < 5 mm. Run-off from virgin areas seldom occurs and salts arriving with the rain or as aerosols accumulate in the soil. Evapotranspiration is a powerful influence and, after clearing the natural vegetation to use the land for agriculture, more of the rain reaches the ground surface and leaching of salts occurs in sandy surfaced soils.

Winter and spring temperatures at Salmon Gums are comparable with those of higher rainfall areas of similar latitude to the west, but are lower than in much of the 300–400 mm annual rainfall areas. Winter frosts are common and cool southerly breezes in summer sometimes delay cereal harvesting.

The natural vegetation

It was on the Salmon Gums Research Station that the author was, in 1931, introduced to the vegetation and soils of the Salmon Gums district.

At the time of the main soil survey, 1932–1935, nearly all farms had areas of virgin land so that in traversing to map and sample the soil the natural vegetation was observed, and some notes of its major and minor elements were usually made in the field books. A large number of *Eucalyptus* species were recorded. In the northern part of the district (Beete and Kumarl) some of the eucalypts had the mallee form, but most were saplings or trees 4–10 m tall. Quite large trees to 20 m were also common, especially the morrels (*E. oleosa* and *E. melanoxylon*) the Dundas blackbutt (*E. dundasii*) and in a few places the salmon gum (*E. salmonophloia*). Except in a few areas south of Salmon Gums and near Circle Valley the salmon gum is not of major occurrence in the district.

The morrels were associated with the grey powdery Beete calcareous sandy loam. *E. conglobata* a smaller white smooth barked tree occurred among the morrels, along with two small tree species of *Melaleuca* — *M. quadrifaria* and *M. pauperiflora*. These are called "boree" in this district and have supplied most of the termite resistant posts for farm fencing. *M. quadrifaria*, because of the distinctive arrangement of its leaflets in four rows, was colloquially termed "fourbor". Saltbushes (*Atriplex* spp.) bluebush (*Maireana* sp.) and sagebush (*Cratystylis conocephala*) were common in the understorey, especially around Beete.

The Dundas blackbutt is an attractive tree up to 20 m tall with dark grey or black tessellated bark on the trunk and bronze smooth bark on the limbs. It occurred east of Kumarl and Beete on the Beete calcareous sandy loam and also on the Dundas calcareous loam. The Dundas soil is formed over greenstone, a common rock in the Dundas Goldfield, centred on Norseman about 80 km north of Salmon Gums.

Table 2. Rainfall distribution at five locations

Location	No. of records	Mean monthly rainfall mm												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Esperance	86	18	21	28	45	83	101	107	96	71	56	29	23	678
Scaddan	77	17	20	24	32	48	52	50	49	41	36	26	19	414
Grass Patch	87	16	21	23	24	38	44	38	40	33	31	22	18	348
Salmon Gums	58	21	24	24	26	34	42	36	34	31	27	20	18	338
Salmon Gums R.S.	54	21	24	24	25	34	42	36	34	30	28	22	18	338
Norseman	86	17	24	21	23	30	31	26	25	20	21	20	18	276

R.S. = Research Station

The sandy surfaced Circle Valley sand had merrit (*E. flocktoniae*) and *E. eremophila* (tall sand mallee or eastern goldfields horned mallee) as the most common eucalypts. In the northern parts, redwood (*E. transcontinentalis*) occurs, also forms with fruit shapes between the typical urn shaped *E. flocktoniae* fruit and the hemispherical *E. transcontinentalis* fruit. The latter species has typically glaucous leaves while *E. flocktoniae* has dark green shiny leaves. Both are white barked trees 8–10 m tall.

Less frequently noted on Circle Valley sand were salmon gum, gimlet (*E. diptera*), yorrel mallee (*E. gracilis*), mirret (*E. celastroides*) and sand salmon gum (*E. foecunda*).

The undergrowth on the sandy surfaced soils was mostly dense ti-trees (*Melaleuca* spp.) with one called blue ti-tree (because of the smooth leaves covered with silvery hairs) an almost infallible indicator of the Circle Valley series. In the field, other ti-trees were called black ti-tree, yellow-leaved ti-tree, pseudo-fourbor, flat-leaved ti-tree, umbrella bush and flat-leaved fourbor, but positive botanical identification was not achieved. At the time of the survey, blue ti-tree was called *Melaleuca pentagona*, but in 1985 was identified as *M. cuneata*. Also present was the rather prickly umbrella bush *Melaleuca cardiophylla*. Traversing such undergrowth required duck reinforcing on trousers from waist to below the knee and leather leggings were usually worn.

A number of species of *Eremophila*, *Acacia*, *Grevillea*, *Daviesia* and many small plants were also common; a very diversified flora, but notable for the absence of grasses. The absence of streams or natural occurrences of potable water makes these areas in their virgin state of very little value for grazing domestic livestock. Native animals were uncommon; even rabbits were seldom seen and rabbit-proof fences on farms were rare. Remains of mallee hen incubating mounds were common, but live mallee fowl were rare. Flying birds were numerous.

Moving south into the Dowak-Salmon Gums area the heavy soils of the Kumarl and Dowak series dominate (map 3). The mallee and sapling eucalypts most commonly found were *E. diptera*, *E. dielsii* and *E. annulata* all with rather similar bronze smooth bark; *E. grossa* of straggling habit, light grey rough bark and broad thick bright green leaves; *E. oleosa* mallee and *E. calycogona* mallee. Species of *Melaleuca*, *Daviesia*, *Dodonaea*, and many smaller plants made a very diversified understorey. A species of the grass *Danthonia* was a minor element in virgin country, but flourished on such heavy soils when cleared for farming and then abandoned. This was common in the 1930s when salt and the depression made cereal growing unprofitable.

The Kumarl-Dowak soil association, centred on Dowak, occupies the highest part of the district where the most salty soils occur and where farm abandonment in the 1930s was most intense. If growing in soil with high salt concentrations is taken as a guide to salt tolerance or salt resistance then most of the eucalypts, melaleucas and smaller plants of the Salmon Gums district must be rated as salt tolerant. Salt levels in the top 10 cm of soil are, however, not great under virgin conditions especially in sands and lighter textured areas. Waterlogging and concentration of salt into this layer is usually followed by death of native species (and agricultural plants). The salt problems adjacent to the drainage lines in the farming areas of Western Australia illustrate this phenomenon and follow the evapotranspiration changes when land is cleared to use for annual crops and pastures. This type of salt problem is rare at Salmon Gums where low and light rainfall and absence of stream lines are general features. The native vegetation apparently tolerates the salt, but surface concentration of salt on cleared land produces areas sterile for the common agricultural plants.

Surrounding the townsite of Salmon Gums, there are areas of the principal soil series, Kumarl, Beete and Circle Valley. There are also gritty soils associated with granite outcrops north of the town and patches of ironstone gravel to the south-west. There are various vegetation associations on the different soils. *E. grossa* and broombush (*Melaleuca uncinata*) are common around the granite outcrops. Morrels, large black mallee (a variety of *E. oleosa*) and *E. conglobata* grow on the Beete soils and *E. eremophila* on Circle Valley sand.

The flat topped yate (*E. occidentalis*) grows around the edges of a depression west of Salmon Gums. From here southwards and on the Esperance plain this eucalypt occurs only in local depressions subject to periodic flooding, but it also occurs on the slopes of the dissected upper reaches of the Gairdner River at Jerramungup between Ravensthorpe and Ongerup.

The heavy soils of the Kumarl series to the west and north-west of Salmon Gums carry *E.*

diptera, *E. dielsii*, *E. annulata*, *E. oleosa*, *E. calycogona* and *E. grossa* as major elements of the vegetation.

The soil survey

The Salmon Gums soil survey (1932–1935) was carried out by a team of professional officers from the Departments of Agriculture and Lands and Surveys, supported by survey hands, a motor driver and cook. Dr L.J.H. Teakle had overall control of the survey.

Those involved were:

* Department of Agriculture	Period involved
Teakle L.J.H.	1932–1935
Burvill G.H.	1932–1935
Samuel L.W.	1932
Roberts R.P.	1932
Lightfoot L.C.	1933–1935
Greaves G.A.	1933–1934
Snook L.C.	1935
Paul R.A.	1935

* Department of Lands and Surveys	
Stokes S.J. (surveyor)	1932–1935

The survey hands employed during the survey were Hugh O'Shaughnessy, Ben Scrivener, Jack Ralph, Ted Boyle and George Denne. The driver was Cecil Hancock and the cook Percy Coulson.

Salt problems for wheat growing were known to occur mainly on the heavy loams and clay loams and the calcareous powdery surfaced 'kopi' country. It was important therefore to map the soil types and subtypes as well as to sample the surface and subsoil for salt analyses. Techniques had been developed in the (1930/31) Lakes District Survey, reported by Teakle, Southern and Stokes (1940), and in the (1931/32) Lake Brown Soil Survey of 133,546 ha (330,000 ac) (unpublished), and these were applied at Salmon Gums (map 2).

Salinity tests were done at up to 224 a day. In three years (about 32 months field work) 70,000 soil samples from 33,000 sites were analysed and chloride assessed from conductimetric measurements on 1:5 soil:water extracts. Some 22,000 check titrations with silver nitrate and a silver-silver chloride electrode were done. The techniques were developed and described by Samuel and Teakle (1931).

Soil mapping and sampling in the field was done by teams comprising a graduate and a survey hand. They ran compass traverses 300–400 m apart through bush or across cleared land and sampled at 200 m intervals at representative sites. Joint work and discussion defined soil types and subtypes. The major elements of the vegetation were noted, especially on virgin areas, and some useful associations of vegetation and soil type were recorded. Soil sampling was done with a 10 cm (4 inch) 'Iwan' posthole digger, aided by a crowbar to penetrate subsoil clays especially where there was hard limestone rubble. Representative samples of the first 30 cm (one foot) and the second 30 cm were taken. Sometimes the third 30 cm was sampled. Surface sand, which rarely contained salt, was discarded. A day's traversing and sampling yielded 50–100 samples per team and usually two teams were operating while a third graduate and a survey hand operated the field laboratory and organized the numbered calico sample bags for the subsequent day's work.

Samples from the various horizons were collected for chemical studies other than salt. Also, special detailed salt samplings were made in layers 2.5 cm thick to 30 cm, 7.5 cm layers to 90 cm, then 30 cm layers (sometimes 60 or 90 cm) to the full depth of boring — often 5–7 m. Eight to 9 m is near the limit of boring with hand augers with no mechanical equipment to lift and support the auger while samples are removed from the cutting head. Where a tree grew nearby it was a useful support after two men had lifted the auger without uncoupling the stem which was in 90 cm sections. Pits were seldom dug more than 2 m; the bore hole was made in the bottom of the stepped pit after sampling the pit face.

Stokes organized the traverses and field books, from which he mapped the soil type boundaries and the salt status which had been transferred from the laboratory records to the field books. Maps on a scale of 20 chains to an inch (1:15,840) were produced. The whole survey required 42 such sheets. Later, a one mile to an inch (1:63,360) map of the whole area was prepared and in 1982 this was reduced to a 1:100,000 scale. Teakle's appreciation of Stokes' contribution is recorded in appendix 3.

From August to December 1932, the field laboratory was operated by Samuel who developed the laboratory techniques for the earlier Lake King and Lake Brown Soil Surveys (Samuel and Teakle 1931). In 1933 the author assumed control of the laboratory and later undertook some of the mapping. Other graduates spent one day each week in the laboratory while Samuel and the author

undertook field traverses. Teakle spent periods of two or three weeks at intervals in the camp.

The cook (Percy Coulson) was an important part of the operations and the motor driver (Cecil Hancock) serviced the two Chevrolet four cylinder motor trucks (WAG 66 and WAG 69). He collected stores and mail from Salmon Gums and kept up supplies of firewood and water for the camp. The camp was shifted from time to time. Ten different locations were used. Some representative scenes are shown in the photographs.

The survey hand, Ben Scrivener, who became laboratory assistant, had been a sleeper cutter and broad axe exponent in his younger days and was still a splendid axeman. He developed techniques for grinding soil samples (about 150/d) with hardened finger tips through a 10 mesh (2 mm approximately) sieve. He organized the drying of samples in a hot air oven, weighed out the 10 g lots in batches of 56, added the 50 mL of rain water from semi automatic burettes, corked and shook the bottles ready for conductimetric measurement by the graduate officer. Later he pipetted the required amounts for titration and when the analyses were complete, washed and racked the bottles. The remnants of completed samples were discarded and the bags grouped for re-use. At each camp site the soil remnants were built into a small cone.

Principal soils

On the basis of colour, texture and structure of the layers forming the soil profile, 16 soil types in 13 named series were identified and mapped. Four minor groups of miscellaneous soils were also mapped (table 3).

The principal soils of the area fall into three groups:-

(1) Soils with grey or grey brown sandy surfaces, 2.5 to 30 cm deep overlying yellow or greenish sandy clay loam and sandy clay subsoils including much lime rubble. The sand above the subsoil is usually bleached. This group includes the Circle Valley, Scaddan and Truslove series. The change from surface to subsoil is abrupt and in the southern areas around Truslove and Scaddan where the rainfall is higher, the sandy clay subsoil has domes 8 to 30 cm across in the upper part. These soils are related to the alkaline soils known as solonetz and have been discussed by Burvill and Teakle (1938). Teakle, Southern and Stokes (1940) drew attention to the similarity of the Circle Valley series at Salmon Gums and the Pallarup series in the Lakes District 200 km west (Lake King). Northcote (1967) ranks these soils in his duplex group Dy 5.43 and Northcote . (1967) mapped them Ya 29 and Ya 30 on Sheet 5 of the Atlas of Australian Soils.

(2) Soils with powdery calcareous surfaces — usually grey — and fawn to light brown or brown subsoils of very calcareous soft clay. These are classed Gc 1.12 in the Northcote system and are mapped Lb 10 on Sheet 5 of the Atlas of Australian Soils. This group is known locally as "kopi" and includes the Beete, Dundas and Geordie series. These are associated in the virgin state with vegetation associations including *Eucalyptus oleosa*, (as morrel trees in the north and as giant and smaller mallees further south); Dundas blackbutt and *E. conglobata*. It is thought that these species may have been a factor in the accumulation of the lime in the surface layers of these soils. Magnesium carbonate sometimes forms a considerable proportion of the total carbonates which, expressed as $CaCO_3$, may exceed 50% in the fine earth of the subsoil layers. The carbonate occurs in finely divided and nodular forms and is believed to be responsible for the powdery nature of these soils when dry. These soils are related to the Milarup series described by Teakle, Southern and Stokes (1940) in the Lakes District and the Hines Hill and Juterin series described by Bettenay and Hingston (1967) in the Merredin area. In the 1931–32 Lake Brown soil survey (unpublished) the name Campion had been given to similar grey snuffy morrel soil.

(3) Red, brown or grey clay soils often with gilgai micro relief. These show little movement of clay from the surface to subsoil and have less lime in the subsoil than the other groups. The group includes the Kumarl and Dowak series. Small amounts of gypsum sometimes occur in the subsoils. They are grouped with brown calcareous earths (Gc 1.22) in the Northcote system and mapped DD 12 on Sheet 5 of the Atlas of Australian Soils. These soils appear to be related to the grey and brown soils described by Prescott (1931). Similar soils are common in the zone of grey and brown calcareous solonized soils in Western Australia, but their distribution does not allow zonal segregation as in eastern Australia.

A soil with characters related to groups (1) and (2) was defined and mapped as Salmon Gums sandy loam. It occurs south of Salmon Gums around Circle Valley and originally carried salmon gum trees.

A minor group of deep sandy soils showing evidence of former wind action includes the Doust, Red Lake and Heart Echo sands. Sandy soils associated with laterite gravel are not common, but are represented by the Grass Patch gravelly sand.

Soil complexes

A common feature of many areas is an intermingling of soil types which could only be mapped as soil complexes. Several changes of soil type are located within 50 m in any direction from a given point and sometimes three or four series or distinct types are represented. The areas mapped in this way total 24% of the total area surveyed. The most important complexes include:-

- the Circle Valley and Beete series; and
- those involving two or more of the Kumarl, Dowak, Circle Valley and Beete soils (see table 3).

In these cases, the vegetation associations are likewise complex, but geological differences are seldom apparent. The formation of such soil and vegetation complexes offers a fascinating field for further study of the nature and operation of soil forming processes.

The general distribution of the main soil groups within the district has several points of interest. Intimate mixtures of soils of the three main groups are quite common, but some general segregations are apparent. The higher country the railway crosses between Salmon Gums and Dowak runs in a general north-east/south-west direction and its soils are principally the heavy crabholey (gilgai) types of the Kumarl and Dowak series. East and west of this belt, soils of the other two groups — principally the Circle Valley and Beete series — predominate. Heavy gilgai soils are again important on the high level country east and west of the railway in the Red Lake-Grass Patch section and are also known to be of extensive occurrence in the area west of the Swan Lagoon road (west of the railway) between Circle Valley and Red Lake. (A detailed soil survey was not made on account of low agricultural value in 1932–1935). The areas south and east of both Salmon Gums and Grass Patch, in which salt lakes are numerous, the Circle Valley sand soil type occurs extensively. The deep sandy types, Doust sand and Red Lake sand are also common in these areas.

Table 3. Summary of soil type characteristics and areas mapped

Soil type and map symbol	General characters of the profile: Surface and subsurface	Subsoil	Deep subsoil	Remarks	Area ha	mapped %
Circle Valley sand CVs	0—10cm. Light grey brown to brown sand. 10—15cm. White sand.	15—25cm. Dull brown and yellow grey mottled sandy clay. 25—152cm. Yellow, grey and light brown mottled sandy clay. Many calcareous nodules and soft lime.	152—244cm. Light brown stiff sandy clay sometimes calcareous and mottled. 244—305 cm. Mottled brown, red brown, yellow and grey stiff sandy clay — very acid. (pH ca. 4) Rests on sandstone	Occurs generally throughout the district. Frequently forms a complex or composite CV/B with Beete calcareous sandy loam. Surface and subsurface sands range from 8—31cm in depth. Immediately below the sand, the sandy clay subsoil frequently exhibits an undulating surface, possibly incipient dome or columnar structure. Brown shades in surface and subsoil more common round Beete and Kumarl. Olive shades common in freshly exposed subsoils. Rainfall 275—375 mm. Vegetation somewhat variable. Includes mallees and medium eucalypt trees (6—11 m) with ti-tree undergrowth. Most satisfactory wheat growing soil in the district.	73 361	31.1
Circle Valley sandy loam CVsl	0—3cm. Light grey brown sand. 3—5cm. Light grey sand.	As above, but sandy clay starts at 5cm.	As above	Total depth of surface and subsurface sands does not exceed 8cm. Hence there is a tendency with clearing and cultivation to produce a sandy loam surface. A sprinkling of ferruginous gravel on the surface is common particularly where associated with Kumarl and Dowak series.	18 131	7.6
Scaddan sand Ss	0—8cm. Light grey brown sand. 8—13cm. Light grey sand — extends down to about 31cm between domes of subsoil clay.	13—31cm. Dull brown and yellow mottled sandy clay in irregular domes or columns 15—31cm across. Outer layer of domes shows dark brown organic staining. 31—91cm. Yellow, green (olive) & light brown mottled sandy clay pockets of calcareous nodules and soft lime.	91—274cm. Mottled greenish and yellowish grey & brown or red brown stiff sandy clay, non-calcareous Acid reaction below 122cm.	The dome like nature of the upper part of the subsoil is related to the columnar structure of the solonetz. Probably is the counterpart of the Circle Valley sand under more effective leaching conditions as it only occurs in the southern parts of the district where the rainfall is higher (about 400 mm per annum).	2 713	1.2

				Decomposing gneissic rock has been found below 61 cm in some areas S.W. of Scaddan. The natural vegetation is usually stunted — Eucalypts range from 91—305cm. Most suitable soil for agriculture around Scaddan.		
Scaddan sandy loam Ssl	0—3cm. Light grey brown sand. 3—5cm. Light grey sand also fills spaces between subsoil domes.	As for Scaddan sand but tops of domes are within 8cm.	As for Scaddan sand.	This type stands in the same relation to the Scaddan sand as does the Circle Valley sandy loam to the Circle Valley sand.	3 489	1.5
Truslove sand Ts	0—23cm. Light grey sand. Often pale grey brown 0—8cm.	23—46cm. Pale yellowish and greenish grey sandy clay loam with orange mottling, usually somewhat cemented. 46—152cm. As 23—46cm, but calcareous and not cemented.	152—244cm. Grey calcareous sandy clay with pale greenish, yellowish and orange mottlings. 244—366cm. Grey and orange mottled sandy clay — non-calcareous-acid reaction.	Occurs around Truslove and Scaddan. Stunted vegetation of mallees and shrubs include many psamophilous species as *Eucalyptus tetragona* (tallerack) *E. angulosa. Banksia spp., Hakea spp.,* and *Grevillea spp.* Sand generally somewhat coarser than in Circle Valley and Scaddan series.	750	0.3
Beete calcareous sandy loam Bsl	0—23cm. Light grey or greyish brown calcareous powdery sandy loam.	23—76cm. Greyish white to very pale brown very calcareous and soft clay loam to light clay. Calcareous nodules common. 76—152cm. Pale brown to brown firm sandy clay. Nodules and soft lime decrease with depth.	155—244cm. Brown and grey mottled sandy clay sometimes calcareous. 244—366cm. Brown grey and red brown mottled sandy clay acid reaction.	Occurs throughout district but most extensive in north. Known locally as "kopi". Characteristic vegetation includes morrels, (principally *Eucalyptus oleosa)* and *Eucalyptus conglobata* in north, with mallee forms of *E. oleosa* further south. Frequently forms a complex or composite CV/B with the Circle Valley series. Generally unsatisfactory for wheat, but Wimmera rye grass does well except on very saline patches. Rye grows best of the cereals on this soil.	24 014	10.2

Georgie sandy loam Gsl	0—23cm. Dull brown or pale grey brown light sandy loam — powdery and usually calcareous.	23—61cm. Rounded calcareous nodules in loose matrix of pale brown calcareous sandy loam. 61—213cm. Light brown very calcareous & rubbly sandy clay loam	213—457cm. Light brown to red stiff sandy clay, acid reaction.	A minor type related to the Beete calcareous sandy loam and most common in northern parts of area. Vegetation includes *Eucalyptus oleosa and E.conglobata.* Intermediate in character between Circle Valley and Beete series.	2 273	1.0
Dundas calcareous loam D1	0—8cm. Brownish grey powdery calcareous sandy loam to loam. 8—23cm. White or pale brown powdery marl frequently with small nutty structure.	23—91cm. Brown or dark-red brown clay. Carbonates ($CaCO_3$ and $MgCO_3$) decrease with depth.	91—152cm. Dark red brown clay with decomposing greenstone. 152cm. Brown or greenish grey clay and decomposing greenstone.	Restricted occurrence in northern parts of the district where associated with basic rocks (greenstone). Surface appearance generally very similar to Beete calcareous sandy loam. Large Dundas blackbutt *(Eucalyptus Dundasii* 12—18 m) typically grows on this soil. Magnesite boulders sometimes found on surface and large proportion of magnesium carbonate in the soil.	1 177	0.5
Salmon Gums sandy loam SGs1	0—15cm. Brown loamy sand to sandy loam. 15—31cm. Light brown sandy clay loam. Slight grey mottling.	31—51cm. Light brown sandy clay loam with calcareous nodules. 51—114cm. Mostly limestone nodules and boulders in matrix of light brown calcareous sandy clay loam	114—152cm. Light brown sandy clay with grey and greenish grey mottlings. Many nodules and soft lime, but <51—114cm layer.	Restricted occurrence in the vicinity of, and south of Circle Valley where it originally carried an open salmon gum *(Eucalyptus salmonophloia* up to 18 m) woodland. Profile characters merge with those of Geordie sandy loam. A satisfactory type for general agriculture.	776	0.3
Kumarl clay loam Kcl	0—5cm. brown to red brown clay loam — sometimes calcareous. 5—13cm. Brown light clay — small to medium nutty structure.	13—31cm. Brown to red brown clay with streaks of soft lime. 31—76cm. Brown to red brown stiff clay with soft lime and sometimes small pockets of gypsum.	76—152cm. Red brown stiff clay. 152—305cm. Red brown and grey mottled stiff clay with odd red brown ferruginous pebbles. Very acid reaction.	Occurs mainly on high level country throughout the district. Surface generally crabholey, (gilgai), and frequently strewn with gravel and stones of a siliceous breccia. Important in areas mapped as complexes or composites (see below). Vegetation of mallee and sapling eucalypts with a ti-tree and *Acacia* undergrowth. Generally unsuitable for wheat under low rainfall conditions on account of salinity but Wimmera rye grass, trailing salt bush, *(Atriplex semibaccatum)* and *Bassia hyssopifolia* (American Burr) do well.	11 993	5.1

Kumarl sandy loam Ksl	0—8cm. Brown to red brown sandy loam.	As for Kumarl clay, but often shows more lime.	As for Kumarl clay loam.	Occurs in complexes associated with Kumarl clay loam and also in larger areas. Surface shows few or no crabholes (gilgai).	6 708	2.9
Dowak clay loam Docl	0—5cm. Grey to dark grey clay loam, sometimes calcareous and powdery. 5—15cm. Grey sandy clay loam or sandy clay. May be calcareous or have nut structure.	15—61cm. Grey or greenish grey sandy clay with streaks of soft lime. 61—122cm. Dull brown and grey mottled stiff clay or sandy clay sometimes slightly calcareous.	122—305cm. Grey and brown mottled stiff clay more red brown with depth. Very acid below. 183cm. Ferruginous sandstone pebbles usually occur scattered through deep subsoil.	Occurs associated with Kumarl clay loam especially in complexes or composites K/Do, also in important complexes with Circle Valley and Beete series Do/CV around Red Lake and Grass Patch. Surface crabholey, (gilgai) and frequently strewn with gravel and stones of a siliceous breccia. Vegetation associations similar to those of Kumarl clay loam. Generally unsatisfactory for wheat under low rainfall conditions on account of salinity.	5 699	2.4
Doust sand Dts	0—61cm. Light grey to white sand slightly brownish near surface.	15—76cm. Cemented light brown grey and yellow mottled sandy loam. 76—152cm. Yellowish grey and light brown mottled sandy loam to sandy clay loam.	152—305cm. Mottled light brown, greenish and yellowish grey sandy clay loam with soft lime.	Sandy surface varies from 31—91cm. Related to Circle Valley sand, but is less mature. It occurs usually on dunes or in depressions so that depth of sand is probably partly the result of wind action. Low agricultural value and liable to drift if cleared.	9 663	4.1
Red Lake sand RLs	0—61cm. Greyish yellow to light yellow or orange sand.	15—152cm. Light yellow to orange brown loamy sand.	152—381cm. Yellow or orange brown sandy loam to sandy clay loam — may be slightly calcareous. 381cm. Variable colours and textures. White yellow and red coarse sands and gritty clays.	Occurs chiefly as dune formations on east sides of salt lakes. Of low agricultural value. Liable to drift if cleared.	2 318	1.0
Heart Echo sand HEs	0—61cm. Greyish yellow to pale yellow sand.	61—122cm. Yellow sand.	122—600cm. Yellow to brownish yellow clayey sand sometimes cemented. Traces of lime. 180—460cm. in one hole. Acid reaction below 460cm.	Occurs in large dune formations and shows similarities to Red Lake sand. Individual areas are however much larger and not adjacent to lakes. Includes a few areas with ferruginous gravel about 122cm and probably related to Grass Patch sand.	1 555	0.7

Grass Patch sand GPs	0—10cm. Yellow or brownish yellow sand with more or less laterite gravel. 10—36cm. Yellow sand with much laterite gravel.	36—61cm. Cemented laterite gravel and white and yellow sand.	Occurs mostly in small areas, chiefly forming complexes with the Circle Valley sand and Circle Valley sandy loam. Scrubby vegetation includes stunted eucalypts, broombush, *(Melaleuca incinata)* and various *Proteaceae.* Of low agricultural value. Related to the lateritic sand plain soils of the main wheatbelt of Western Australia, and the ironstone gravelly soils of the Esperance plain.	1 187	0.5

	ha	%
Soil complexes or composites		
The soils of many areas are so patchy that the invidiual types recognized cannot be separately mapped.		
Composites of two or more series have been mapped to cover these complex areas and the soil series included are as follows:—		
(a) Circle Valley and Beete CV/B	30 175	12.8
(b) Kumarl and Dowak with smaller amounts of Beete and Circle Valley K/Do	11 919	5.1
(c) Dowak and Circle Valley with smaller amounts of Beete and Kumarl Do/CV	4 502	1.9
(d) Circle Valley and Grass Patch CV/GP	3 033	1.3
(e) Scaddan and Beete S/B	5 180	2.2
(f) Dowak and Scaddan, smaller amounts of Beete and Kumarl Do/S	1 008	0.4
(g) Scaddan and Grass Patch S/GP	700	0.3
Miscellanous minor types and areas		
Lakes, samphire, claypans	7 834	3.3
Lowlying soils adjacent to salt lakes, usually grey sand over grey sandy clay 5C	2 831	1.2
Unnamed sands — grey to brown sands or sandy loams with cemented non calcareous subsoils often in minor depressions, also brown sands on travertine at about 30.5 cm Us	1 287	0.5
Shallow stony and gritty soils associated with outcrops of granitic rocks 2C	705	0.3
Lowlying soils liable to flooding, usually grey and crabholey and characterized by growth of swamp yate *(Eucalyptus occidentalis)* and sometimes lignum *(Muehlenbeckia Cunninghamii)* D	739	0.3
Total area, ha	235 717	100.0

Soil associations

A detailed map of the soil types has not been produced for publication, but a map of soil associations in the surveyed area is included (map 3). They are named from the names of the principal soil series occurring in their defined areas. Five soil associations are delineated.

Beete — Circle Valley association

Beete calcareous sandy loam, Circle Valley sand and Circle Valley sandy loam are the dominant soil types. Lesser areas of Geordie sandy loam, Dundas calcareous loam, Kumarl sandy loam and the deep sands, Doust sand, Red Lake sand and Heart Echo sand are included. There are a few isolated granite outcrops and, with the Dundas soil, some greenstone outcrops.

Circle Valley — Red Lake association

Circle Valley sand is the major soil type and there are numerous salt pans with associated lunettes of Red Lake sand on their east south-east borders. Doust sand and Heart Echo sand also occur. There are some patches of Beete calcareous sandy loam and some low lying un-named sands adjoining the salt pans. The Salmon Gums sandy loam around and south-west of Circle Valley is included in this association.

Kumarl — Dowak association

This is dominated by Kumarl clay loam and Dowak clay loam and occurs in the highest parts of the district. Kumarl sandy loam, Circle Valley sandy loam, Beete calcareous sandy loam and patches of deep sand especially the yellow Heart Echo sand are lesser elements. Ironstone gravel and boulders of siliceous sandstone and sometimes breccias are common on the surface of these heavy soils. Some gravelly patches are mapped as Grass Patch sand. The ironstone gravels and siliceous boulders may be remnants of laterite. Some granite outcrops occur especially between Salmon Gums and Dowak.

Circle Valley — Beete — Dowak association

This occurs in another relatively high level area east and west of Red Lake and Grass Patch. Circle Valley sand, Circle Valley sandy loam, Beete calcareous sandy loam and Dowak clay loam are the major soils with a very complex distribution. Kumarl clay loam is a lesser element in the complex. The deep Doust sand, Heart Echo sand and the ironstone gravelly soil Grass Patch sand are elements occurring south-west of Grass Patch. A few granite outcrops were noted east of Red Lake (Styles Rock) and west of Grass Patch. Salt lakes and pans are few in this belt of country.

The vegetation at west Truslove where domed subsoils exist. L-R. Messrs L.C. Lightfoot and C. Hancock.

Scaddan association

The Scaddan association has the Scaddan sand and Scaddan sandy loam with their domed sandy clay subsoils as major features. The Truslove sand is also common. This association occurs south of Swan Lagoon and Truslove and west of Scaddan. The areas surveyed and mapped include complexes of Beete, Dowak and Kumarl series with the Scaddan series. There are some areas of the deep sands — Doust sand and Heart Echo sand. Some small salt pans occur and there are depressions subject to flooding in rainy periods. The flat topped yate (*Eucalyptus occidentalis*) grows in these grey clay depressions.

The Scaddan sand and the Circle Valley sand do not have clearly marked divisions. The sandy clay subsoil of Circle Valley sand shows some irregularity from north to south in the district. The domed subsoils of the named Scaddan series become dominant between Grass Patch and Truslove.

Discussion of analytical data

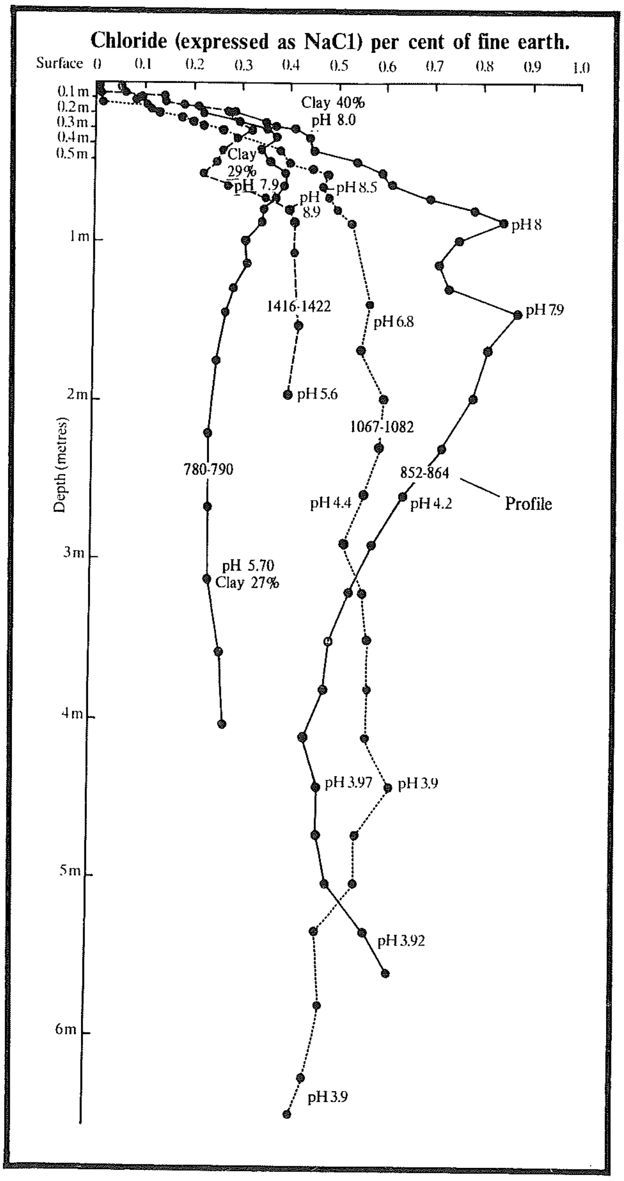


Figure 1. Circle Valley sand-salt profiles in virgin soil.

Mechanical analyses and chemical data

Analytical data for the soils, based on type samples, are given in appendix 4.
Salt status and qualitative assessments of physical characters (texture and consistency) were of major concern during the time of the survey. Type samples, collected from 64 sites, many to depths of 5 to 8 m were examined in the Government Chemical Laboratories in Perth during the survey and during 1936–1939.

Salt status of the soils

In the virgin state, all the major soil types of the area have substantial amounts (0.5–1.5%) of water soluble salts in the subsoils and deeper layers of their profiles (appendix 4). Chloride, conventionally expressed as NaCl, is the major constituent (60–90%). Surface soils, where mainly sand, contain very little soluble salts, but where they are calcareous and powdery, or of clay loam or clay texture, they often have 0.3 to 0.5% in the upper 30 cm. Typical virgin salt profiles for the three major soil groups are shown in figures 1, 2, and 3 where chloride (expressed as NaCl) in the fine earth is plotted against depth. These were selected from 11 profiles of Circle Valley sand, seven of Beete calcareous sandy loam, and eight of Kumarl clay loam and Dowak clay loam. The sites sampled were located in accessible places between major elements of the natural vegetation and were assumed to represent virgin conditions, but no studies of spatial variations of salts were made other than vertically at the sampling sites. In all, more than 60 type samples pits and borings were made during the survey. Most profiles show a maximum salt figure within one metre of the surface with NaCl levels of 0.35% – 0.9% in the Beete series and 0.6% – 1.1% in the heavy Kumarl and Dowak series. It is notable also that many profiles of all types reach a chloride peak 25–50 cm from the surface then have lower levels before rising to the deeper subsoil figures. Some of these peaks may represent the atmospheric salt accessions from a few thousand years of the present rainfall regime — light falls and rapid evapotranspiration under virgin conditions.

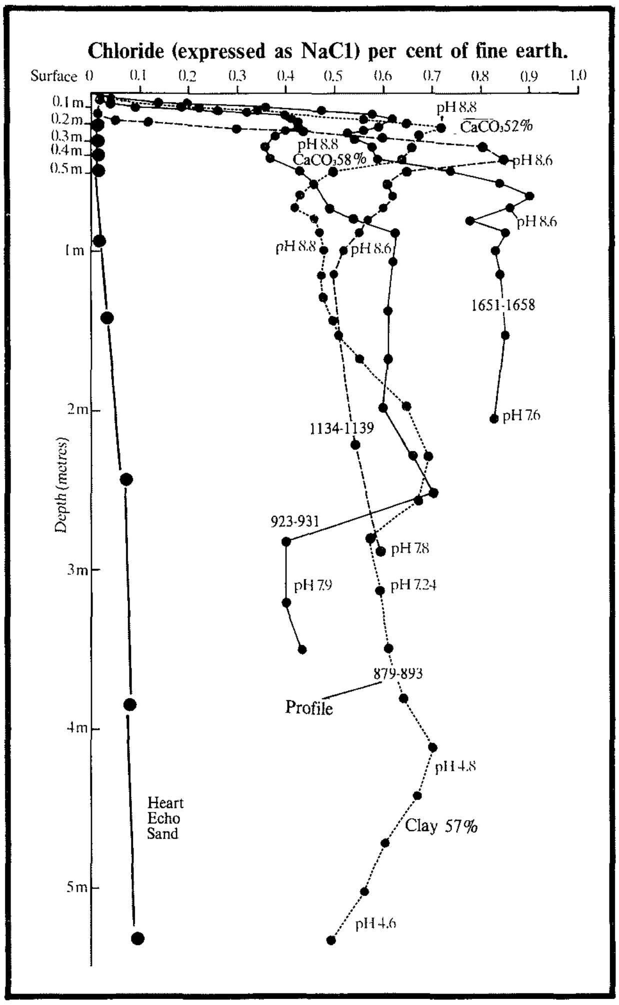


Figure 2. Beete calcareous sandy loam — salt profiles in virgin soils (includes Heart Echo sand profile).

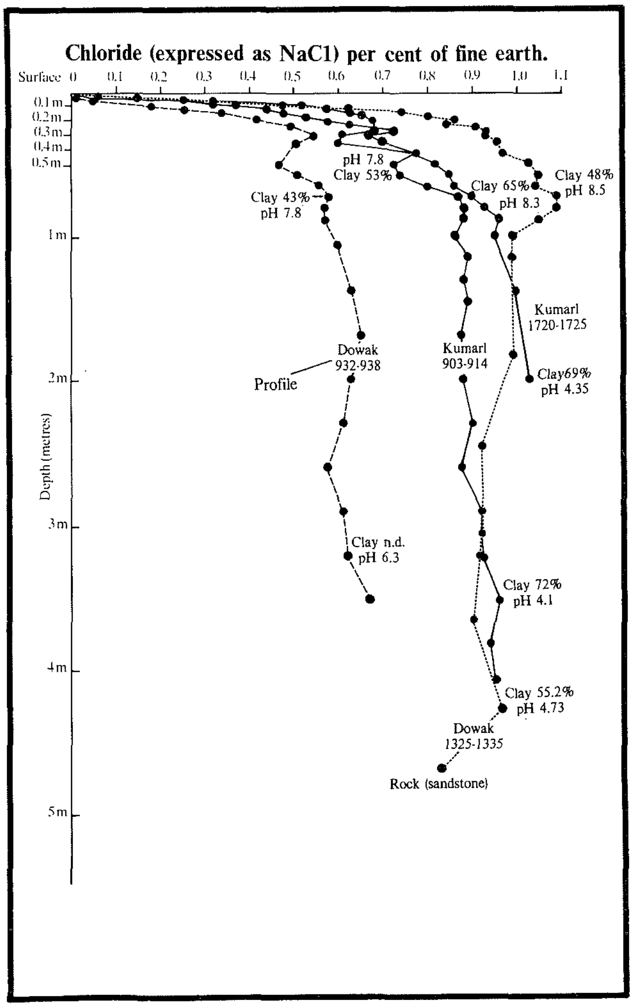


Figure 3. Kumarl clay loam and Dowak clay loam — salt profiles in virgin soils.

The soil survey embraced part of the 1932 winter and the 1933, 1934 and 1935 winters. The virgin soils rarely showed appreciable wetness in the top metre except soon after rain. Land used for agriculture, especially sandy surfaced soils, had moist subsoils. The change in salt status after removing the natural vegetation was discussed by Teakle and Burvill (1938). The movement of salt is a very important factor in determining suitability of these soils for agriculture.

The studies of salt changes from virgin to cleared areas indicate the powerful influence of the evapotranspiration from virgin areas in retaining salts in the upper metre of the major soil types. The sandy clay subsoils with 30–50% clay do not encourage deep penetration of rainfall under virgin conditions. The $CaCO_3$, present as hard nodules or rubble, or in a finely divided form, whatever its origin, is mainly concentrated from 20 cm to 1 m from the surface and is seldom found below 2 m even in the Beete calcareous sandy loam which is calcareous and powdery at the soil surface.

The Heart Echo sand, a minor type, which is a deep sandy soil provides a contrast to the major types. A salt and pH profile for this type is shown in figure 2. It shows a small amount of calcium carbonate at 2.5–5 m with a pH rising to 8.5. Below 6 m the pH drops again below 6. NaCl reaches a peak of 0.10% 5.5 m from the surface. Both the NaCl and $CaCO_3$ are probably from aeolian accessions. The yellow loamy sand more than 7 m deep is almost certainly an aeolian deposit. Under the prevailing rainfall conditions the sandy texture of this soil would allow penetration of rain water to much greater depths than in the clay subsoils of the major soil types. Occasional very heavy falls could penetrate and carry $CaCO_3$ and salts to considerable depth.

The agricultural significance of salt in soils

The southern half of Western Australia is mainly a winter rainfall area. Where the annual rainfall is 300–600 mm and the winter and spring temperatures are suitable, a range of cereals and annual pasture plants may be grown. Wheat, oats, barley, subterranean

clover, medics and lupins are the main plants and much breeding and selection has been done to produce suitable varieties (cultivars). But none of these will grow well if the soil is too salty. Plants absorb many of their essential nutrients from the soil solution which has to be replenished by rain and fertilizers, but if the concentration of cations and anions is too great many plants cannot absorb the water which is essential for their metabolism. If chloride, expressed as NaCl, exceeds 0.2% in the upper 15 cm of soil under rainfall conditions as at Salmon Gums, cereals and annual pastures make poor growth. This seldom occurs on sandy surfaced soil (Circle Valley sand and Scaddan sand), but is common on the powdery calcareous "kopi" (Beete calcareous sandy loam) and on the clay loams of the Kumarl and Dowak series. (see Teakle and Burvill (1938) table 3.)

The standards adopted in the soil surveys carried out from 1930 to 1936 in the 250–350 mm rainfall areas were:

Low salinity	0–30 cm < 0.10% NaCl
	30–60 cm < 0.25% NaCl
Medium salinity	0–30 cm 0.10–0.15% NaCl
	30–60 cm 0.25–0.30% NaCl
High salinity	0–30 cm > 0.15% NaCl
	30–60 cm > 0.30% NaCl

The division between medium and high salinity gives a mean of 0.22% NaCl to 60 cm depth. Salt in lesser amounts is unlikely to seriously affect the growth of wheat.

Teakle and Burvill (1938) published much information on the movement of soluble salts in soils under light rainfall conditions. Malcolm (1983) reproduced several diagrams, graphs and tables from the 1938 publication in his comprehensive review of many aspects of wheatbelt salinity in Western Australia.

Because the work at Salmon Gums in the 1930s revealed important changes in salt status after soils are cleared of natural vegetation and used for cereal growing, two of the tables (Nos 2 and 3) and associated text from Teakle and Burvill (1938) are quoted:

"Table 2 represents the incidence of salt at apparently normal sites in virgin and cleared land, taking four distinct groups of soils as representatives of the area. It is seen that, in the virgin state, all groups of soil show a considerable proportion of sites at which the salt (NaCl) content of the surface two feet (60 cm) exceeds 0.22%. This may be taken as the limit below which growth of wheat should not be seriously affected.

Table 2. Effect of clearing on the salinity of soils of various types in the Salmon Gums area

All analyses considered in this table are for "normal" sites; that is, sites not showing surface evidence of salt accumulation.

Group A — Sandy surfaced soils (with sandy clay subsoils) include the Circle Valley sand and Scaddan sand.

Group B — Medium textured soils include the Kumarl sandy loam and the Circle Valley sandy loam.

Group C — Highly calcareous soils — the Beete calcareous sandy loam.

Group D — Heavy textured soils include the Kumarl clay loam and the Dowak clay loam.

Analyses as per cent salt (NaCl) in the oven dry soil

Group	Condition	Total no. of sites	Percentage of sites within each range of salt (NaCl) concentration in the soil to a depth of two feet(60cm)				
			Below 0.13 %	0.13–0.17 %	0.18–0.22 %	0.23–0.29 %	Above 0.30 %
A	Virgin	4324	17.6	14.9	20.2	25.2	22.1
	Cleared	4255	78.2	13.0	5.7	1.9	1.2
B	Virgin	1901	8.6	8.7	15.3	23.4	44.0
	Cleared	1998	45.9	16.2	14.2	11.2	12.5
C	Virgin	1950	10.0	8.0	12.7	18.6	50.7
	Cleared	491	42.6	14.2	11.6	9.0	22.6
D	Virgin	1237	7.0	6.3	8.5	15.6	62.6
	Cleared	837	17.1	14.7	15.0	15.8	37.4

Of most importance is the distribution of sites according to salt status after the land has been cleared for some years.
The sandy-surfaced types show practically complete removal of deleterious quantities of salt in the surface two feet (60 cm) and, furthermore, as shown in table 3, a negligible amount of surface accumulation in the form of bare patches occurs. Bare patches associated with salt accumulation are very rarely seen on this group of soils.

A very considerable improvement has taken place in the medium-textured soils represented by the Circle Valley sandy loam and the Kumarl sandy loam (Group B), but still about one quarter of the "normal" sites sampled on cleared country show above 0.22% salt in the surface two feet (60 cm). In addition, surface accumulation of salt in bare patches occurs to a certain extent in the types in this group (table 3), so that recovery may be estimated at about 60% in the areas affected by high concentrations of salt in the virgin state.

The calcareous-surfaced soils of Group C, as represented by the Beete calcareous sandy loam, resemble somewhat the other sandy loam types of Group B as far as salt distribution in the virgin state is concerned. Improvement after clearing has taken place in the "normal" sites as shown by table 2 but still over 30% of the samples fall in the high group (above 0.22% salt in the surface two feet (60 cm)) as compared with 69% in the virgin soils. In addition, considerable development of bare patches showing surface accumulation of salt has taken place in this type and from table 3 it is seen that most of these bare patches are very high in salt. This is probably due to the superior capillary properties of the soils of this group. As field observations suggested that in this soil type the bare patches are even more important than is indicated by the proportion of bare patches sampled, and normal sites retain a considerable proportion of salt, areas of this type where saline in the virgin state must still be regarded as subject to serious reduction in value for wheat production if brought under cultivation. Recovery following clearing may be estimated at less than 50%. Furthermore, the Beete calcareous sandy loam, known locally as "Kopi" soil in the Salmon Gums district, is found to be unsatisfactory for wheat growing under low rainfall conditions, even where free of salt, and must be regarded as an unsatifactory type generally for development for wheat farming.

The heavy-textured soils of Group D, including the Kumarl clay loam and the Dowak clay loam, are by far the most saline soils in the virgin state and from the evidence available show small improvement only (probably not more than 25 to 30%) in normal sites after clearing. Furthermore, these types, and more particularly the Dowak clay loam, are very subject to the development of bare patches, showing, as indicated in table 3, considerable salt accumulation. Development of saline bare patches has even occurred to a small extent under virgin conditions in this group.

Surface accumulation of salt in these types of this group has occurred both on the rims of crabholes (gilgais) and on the areas showing no evidence of micro-relief. In many instances, the incidence of bare patches alone seriously reduces the yield of wheat crops. This reduction is difficult to estimate, as the proportion of bare patches sampled is only a slight index of their relative abundance in cleared country. The soils of this group have proved generally unsatisfactory for wheat growing for a number of reasons, of which soil salinity is one of the most important. Fortunately, investigations at the Salmon Gums Research Station indicate that Wimmera Rye Grass and certain salt bushes of high salt tolerance may do much towards the profitable utilisation of these soils and may even promote more substantial reclamation. (Teakle 1937)."

Table 3

Number sampled and analyses of bare patches suspected of being due to salt accumulation in the principal soil types of the Salmon Gums soil survey

Sites in cleared and virgin country are segregated for purposes of comparision
Analyses as per cent salt (NaCl) in the oven dry soil. Sampling depth is 12 inches (30 cm)

Soil type	Condition	Total number of bare patches sampled	Percentage of samples from bare patches within each range of salt (NaCl) concentration to a depth of one foot (30cm)					Total number of sites sampled including bare patches no.	Bare patches as percentage of total sites sampled %
			Below 0.11 %	0.11—0.24 %	0.25—0.49 %	0.50—1.00 %	Above 1.00 %		
Circle Valley sand (shallow phase) (Group A)	Virgin	3	33	...	...	67	...	2799	0.1
	Cleared	24	21	21	21	37	...	2958	0.8
Circle Valley sandy loam (Group B)	Virgin	5	40	40	...	20	...	993	0.5
	Cleared	146	13	22	32	30	3	1638	8.0
Beete calcareous sandy loam (Group C)	Virgin	19	5	26	21	27	21	1969	1.0
	Cleared	96	5	10	29	45	11	587	16.4
Kumarl-Dowak clay loam (Group D)	Virgin	24	17	12	8	25	38	1261	1.9
	Cleared	166	1	6	30	55	8	1003	16.5

The demarcation of salt status on the soil maps

The soil maps (1:15840) when prepared during the survey showed the soil types or complexes with an indication of salt status. Thus, soil type 3B (afterwards named Circle Valley sand) was mapped -

3B if most sites had low salt status
$3B^M$ if the salt was medium
$3B^S$ if high salinity prevailed.

At the beginning of the survey all the major soil types and subtypes were similarly identified as to salt status and the colours green, brown and yellow were used to show low, medium and high salinity.

When it became apparent that the salt status changed after the land was cleared for agriculture, especially in the sandy surfaced soils, the maps were coloured according to the estimated suitability for wheat growing. Thus, 3B, $3B^M$ and $3B^S$ were all given similar (and top) ranking, whereas 4B, $4B^M$ and $4B^S$ (the Beete calcareous sandy loam or "Kopi") were classed as unsuitable for wheat growing. Also unsuitable for wheat growing on account of salt were subtypes $6A^S$ (Kumarl clay loam of high salinity) and $6B^S$ (Dowak clay loam of high salinity).

Reconstruction of the district's farms after the Great Depression placed emphasis on sheep husbandry rather than wheat growing and the suitability of the soils for pastures became very important. Wimmera rye grass (*Lolium rigidum*) had shown its ability to grow well on many soils. In fact it did better on the heavier soils in spite of their salt content than on the sandy surfaced soils, especially if the surface sand was deeper than 15 cm. In late 1945, Teakle and the author drew up a ranking of all soil types and subtypes shown on the 1:15,840 map sheets according to their estimated suitability for wimmera rye grass. Four groups were defined:

1) Most suitable;
2) Less suitable;
3) Generally unsuitable; and
4) Grey powdery "kopi" soils. The "kopi" soils were found quite useful in the wetter areas south of Grass Patch, but not in the northern parts of the district.

Wimmera rye grass grew well on the Kumarl clay loam at the Salmon Gums Experiment Farm from 1930 onwards, but to maintain its vigour, annual or biennial ripping of the soil with a scarifier proved beneficial. In a trial in 1953, bare patches, due to surface concentration of salt, were greatly reduced on scarified plots, but persisted on adjacent controls with no cultivation. The controls had also lost most of their Wimmera rye grass and carried a sparse covering of a native *Danthonia* sp. Unfortunately, Wimmera rye grass is now (1980s) out of favour for sheep grazing because of the spread of rye grass toxicity in many districts. A bacterium and an eelworm multiplying in the rye grass inflorescences produce substances toxic to the sheep grazing on them.

Mechanical analysis

Circle Valley, Scaddan and Truslove series

The sandy surfaced duplex soils of the Circle Valley, Scaddan and Truslove series have hard limestone nodules of irregular shape embedded in their sandy clay subsoils usually from 30–150 cm. Soft lime also occurs in variable amounts. The fraction > 2 mm was not determined, but is estimated to be 30–40% in many cases. Mechanical analysis of the fine earth often showed 30–40% clay in the subsoils with silt seldom above 3% and sometimes $< 1\%$. Fine sand usually exceeded coarse sand giving coarse sand:fine sand ratios about 0.4 except in profiles in the north of the area where ratios between 0.7 and 1.0 were found at east Kumarl and east Dowak. The ratio in the subsoil is similar to that in the surface sand which contained 3–7% clay in the samples analysed. The coarse sand:fine sand ratios of the Pallarup sand in the Lakes District were mostly greater than unity, but otherwise Circle Valley sand and Pallarup sand have similar characters.

The very acid clay at depth in most profiles showed coarse sand:fine sand ratios similar to the upper parts of the profile, but often contained more clay (about 50%) and very little silt (1% or less). The silt in the upper parts of the profile, may be made up of fine calcium carbonate or calcium-magnesium carbonate not completely dissolved by cold acid treatment. Three travertine nodules from the Kumarl — Dowak area analysed in 1933 gave CaO:MgO ratios by weight of 7:1, 3:1 and 3:1; a fourth gave a ratio of 24:1. Magnesium is the major exchangeable cation in the fine earth of all the subsoils at Salmon Gums.

Beete, Geordie and Dundas series

The powdery calcareous soils of the Beete, Geordie and Dundas series contain hard round nodules of calcium carbonate and/or calcium-magnesium carbonate to depths of 1–2 m and also have much of these same compounds in the fine earth (see appendix 4 for $CaCO_3$ figures calculated from CO_2). The finely divided carbonates are apparently responsible for the powdery consistency of these soils which do not wet easily when dry. The grey snuffy morrel soils of the eastern wheatbelt of Western Australia are similar and achieved a poor reputation when used for wheat growing from 1910 onwards.

The standard mechanical analysis methods used in the 1930s are not well suited for very calcareous fine earths because the loss on acid treatment is so large that figures for sand, silt and clay have little meaning in relation to field texture.

The acid sandy clays found at depth in all deep borings usually contained 45–70% clay with silt <5%.

Kumarl and Dowak series

The clay loam and clay soils of the Kumarl and Dowak series have 40–50% clay in the first 10 cm and 45–72% clay was measured in the deep acid layers. Silt was 2–6%. Around Kumarl and Dowak the coarse sand:fine sand ratios ranged from 0.56–1.16 in the upper one metre of the soils, but at Red Lake and Grass Patch the ratio was 0.2–0.4. The deep acid layers gave values of 0.15–0.54.

If marine sediments have been the parent materials for the major soil groups the coarse sand : fine sand ratios north of Salmon Gums point to coarser sediments than in the areas around Circle Valley, Red Lake, Grass Patch and Scaddan where the percentage of fine sand is usually at least twice that of the coarse sand.

Chemical data

Calcium and magnesium carbonates

Calcium carbonate (calculated from CO_2 produced by acid treatment) is a regular constituent of the fine earth below about 15 cm in the major soils. It is probably a mixture of calcium and magnesium carbonates. In the Dundas calcareous loam formed over greenstone the magnesium carbonate dominates. Carbonates occur in the surface layers of the Beete, Dundas and Geordie series; in the fine earth of the subsoils from 30–100 cm, amounts up to 57% were recorded.

The Kumarl clay loam has less lime in the profile than the Circle Valley and Beete series, but the Dowak clay loam, especially in the Red Lake — Grass Patch area is often calcareous at the surface and thus shows characters of the Beete series.

The deep layers of all the profiles below 2–3 m have no carbonates. They are almost devoid of calcium, but contain acid soluble forms of sodium, potassium and magnesium ranging from 0.5–1.5% when expressed as the oxides Na_2O, K_2O and MgO.

Reaction (pH)

In the 1930s, pH was usually determined with the quinhydrone electrode with soil:water ratios of 1:1 or 1:2.5. The values obtained are recorded in appendix 3. The surface sands of the Circle Valley, Scaddan and Truslove series have pH 6–7 and so do the Doust, Red Lake and Heart Echo sands. Calcareous subsoils gave pH values 8–9 with the highest values in the Beete series. The deep layers of the three major soil groups are strongly acid with pH values 3.5–4.5. They are similar mottled tough sandy clays in spite of the contrasting features of the surface layers and the upper 1.5–2.0 m of the profiles. The origin of the acid clays at depth and of the carbonates in the upper layers is uncertain. They may be features from the marine submersion of the Eocene and more recent times.

Organic carbon and nitrogen

The type sample pits and borings were mostly in virgin areas. Two Circle Valley sand profiles were located in cleared and farmed land adjacent to virgin country where samples were also obtained for comparison. Surface sands contained < 1% organic carbon and C:N ratios of 20–30. In the calcareous powdery soils 2–3% organic carbon was found in the surface layers of the Beete series; somewhat less in the Geordie series and 4% in the Dundas calcareous loam. Carbon:nitrogen ratios ranged from 11–27 in the three series. The heavy Kumarl and Dowak surfaces gave 1–2% organic carbon in surface soils and C:N ratios of 15–20.

Sandy surfaced soils contained, in their surface layers, about 0.03% total nitrogen while the powdery calcareous group had much more, 0.07–0.20%. The heavy surfaced soils were intermediate; 0.05–0.10% N was the range for surface samples.

Phosphorus

As for most Western Australian soils, phosphorus values were very low. Expressed as P_2O_5 most surface and subsoil samples were below 0.005% in the sandy surfaced soils. The calcareous group gave values for surface soils of 0.007–0.03% and the heavy surfaced soils were around 0.01%. Subsoil values were all lower.

Potassium, magnesium and sodium

In all horizons with > 20% clay in the fine earth, potassium, magnesium and sodium, (expressed as K_2O, MgO and Na_2O and soluble in strong hydrochloric acid) were found to be abundant; by contrast with the low values for P_2O_5, K_2O ranged mainly from 0.5–1.5%. The same order of magnitude was shown for MgO, but with much higher levels in the Beete series subsoil (e.g. Serial No. 881 east Dowak). Figures for Na_2O were found to be somewhat less than MgO and K_2O and ranged from 0.5–1.0%.

Calcium

The major soil types have, in their subsoils, free calcium carbonate (or calcium-magnesium carbonate) in soft form or as hard nodules. Below about 2 m the sandy clay seldom has free lime. The acid mottled sandy clay found under all soil types is almost devoid of calcium. Fifteen samples (5 Circle Valley, 1 Geordie, 3 Beete, 3 Kumarl and 3 Dowak) ranged from nil to 0.036% CaO (soluble in strong HCl).

Appendix 3 shows the values for $CaCO_3$ (calculated from CO_2) as well as the CaO soluble in strong hydrochloric acid and the exchangeable Ca. Except in surface sands and the deep subsoils Ca is, like Mg, K and Na, abundant in the major soils of the area.

Exchangeable metal cations

Exchangeable metal cations (Ca, Mg, K and Na) were determined on many samples, mainly subsoils. The dominance of Mg and Na is common. In surface samples Ca displaces Na from dominance (appendix 4). The leaching of NaCl from the surface and the addition of Ca in the leaf fall of the native vegetation and/or from oceanic aerosols may be the determining factors.

Total water soluble salts (T.W.S.S.) and sodium chloride

Samples from the fine earth of all layers of the type samples were analysed in the Government Chemical Laboratories for total water soluble salts and for NaCl (calculated from chlorine). Separate subsamples were analysed for chloride in the field laboratory. In general, there was good agreement between the determinations. The appendix tables give the Government Chemical Laboratories figures as well as the NaCl/T.W.S.S. percentage.

The deeper parts of the principal soils contain 0.5–1.5% total water soluble salts and NaCl (Cl x 1.648) was commonly measured as about 70% of the T.W.S.S. Values above 80% were common and a few exceeded 90%. Sea salts have 55.3% chlorine and calculated to NaCl this would be 91.1% of the total salts. However, the Na in sea water is insufficient for such a figure. Sea salts have 77.76% NaCl and 10.88% $MgCl_2$. The salts in the deeper layers of the soils at Salmon Gums — below the depths to which calcium carbonate occurs — obviously are generally similar to sea salts and may in fact, be residual from the Eocene or later submersion of these areas.

The composition of the water soluble fraction in the upper parts of the profiles of the major soils — the upper 1.5–2 m — is influenced by the presence of calcium-magnesium carbonates and by the leaching which occurs, especially in sandy surfaced types (e.g. Circle Valley and Scaddan). Profiles of Circle Valley sand from virgin and adjacent cleared areas were studied in detail in the 1930s and the results reported by Teakle and Burvill (1938). Tables 8 and 9 from the publication are here reproduced.

These tables show that Na is the dominant cation and chloride and bicarbonate the dominant anions, but the proportions and amounts change after clearing the native vegetation. In the upper 1m of the soil, chloride in particular and Na to a less degree are reduced while bicarbonate increases. The changes in K, Mg, Ca, SO_4 and NO_3 are small. The amounts of Mg and Ca are remarkably low considering the dominant place of Mg in the exchangeable cations and the occurrence of abundant calcium-magnesium carbonates to depths of 2 m.

Table 8. (Teakle and Burvill, 1938)

The constituents of the water soluble salts of virgin and cleared soils of the Circle Valley sand type.

Results expressed as per cent of the oven-dry soil

Serial number	Depth	T.W.S.S.*	Sodium Na	Potassium K.	Magnesium Mg	Calcium Ca.	Sulphate SO_4	Nitrate NO_3	Carbonate CO_3	Bicarbonate HCO_3	Chloride Cl.
	cm	%	%	%	%	%	%	%	%	%	%
A. Samples from Fitzgerald Location 588.											
Virgin soil											
853	10-25	0.456	0.230	0.006	0.003	0.002	0.028	0.005	...	0.149	0.133
854	25-43	0.602	0.206	0.007	0.003	0.002	0.040	0.004	...	0.113	0.218
855	43-84	0.832	0.321	0.008	0.005	0.003	0.076	0.006	...	0.075	0.335
Cleared soil											
866	10-20	0.196	0.052	0.009	0.002	0.003	0.008	0.005	...	0.098	0.019
867	20-83	0.331	0.099	0.007	0.001	0.002	0.015	0.009	...	0.159	0.039
868	33-64	0.517	0.155	0.007	0.001	0.002	0.043	0.007	...	0.151	0.151
869	64-91	0.649	0.246	0.011	0.002	0.003	0.076	0.006	...	0.073	0.232
B. — Samples from Fitzgerald Location 422											
Virgin soil											
1117	31-61	0.625	0.220	0.007	0.003	0.008	0.043	0.003	0.006	0.066	0.269
1118	61-91	0.669	0.237	0.006	0.004	0.005	0.053	0.001	0.005	0.063	0.295
1121	183-274	0.699	0.250	0.006	0.003	0.003	0.059	0.002	0.004	0.050	0.322
1123	366-457	0.792	0.282	0.008	0.005	0.002	0.070	0.002	Nil	0.006	0.417
Cleared soil											
1127	33-64	0.342	0.108	0.002	0.001	0.002	0.022	0.003	0.024	0.106	0.074
1128	64-94	0.452	0.135	0.011	0.002	0.002	0.039	0.002	0.005	0.106	0.125
1131	133-274	0.768	0.247	0.011	0.005	0.008	0.073	0.002	Nil	0.062	0.360
1133	366-457	0.764	0.257	0.014	0.008	0.001	0.062	Tr.	Nil	0.002	0.420
Sea water	...	3.48	1.03	0.06	0.13	0.05	0.28				1.90

Analyst — F.F. Allsop

*Total water soluble salts (T.W.S.S.) is obtained in this instance by addition of the ions determined by analysis as Co_3 is lost in the determinination of T.W.S.S. by the usual gravimetric method.

Note: The above table has been converted to metric format.

Table 9. (Teakle and Burvill, 1938)
Relation between constituents of the water soluble salts of virgin and cleared sites in the Circle Valley sand from information reported in table 8.
Ratios expressed as per cent

Serial number	Depth cm	Na. / T.W.S.S. %	Cl. / T.W.S.S. %	HCO_3† / T.W.S.S. %	SO_4 / T.W.S.S. %	Cl.* / Na %	HCO_3† / Na %	HCO_3† / Cl %	T.W.S.S. % dry soil
				A. — Samples from Fitzgerald Location 588					
Virgin soil —									
853	10-25	28.5	29.2	32.8	6.1	102	115.0	112.0	0.456
854	24-43	34.2	36.2	18.8	8.1	106	54.9	51.8	0.602
855	43-84	38.9	40.3	9.0	9.1	103	23.1	22.4	0.832
Cleared soil —									
866	10-20	26.5	9.7	50.0	4.1	36	618.8	516.0	0.196
867	20-33	29.9	11.8	48.0	4.3	39.4	161	408.0	0.331
868	33-64	30.0	29.4	29.4	8.3	97.4	97.4	100.0	0.517
869	64-91	37.9	35.8	11.2	11.7	94.3	29.7	31.4	0.649
				B. — Samples from Fitzgerald Location 422					
Virgin soil —									
1117	31-61	35.2	43.1	12.5	6.9	122	35.5	29.0	0.625
1118	61-91	35.4	44.1	10.9	7.9	125	30.8	24.4	0.669
1121	183-274	35.8	46.1	8.3	8.4	129	23.2	18.0	0.699
1123	366-457	35.6	52.7	0.8	8.8	148	2.1	1.4	0.792
Cleared soil —									
1127	33-64	31.6	21.6	45.3	6.4	68.5	144.0	210.0	0.342
1128	64-94	29.9	27.7	31.2	8.6	93	104.0	113.0	0.452
1131	183-274	32.2	46.9	8.1	9.5	146	25.1	17.2	0.768
1133	366-457	33.6	55.0	0.3	8.1	164	0.8	0.5	0.764
Sea water ...	...	29.6	54.6	?	8.0	184	?	?	3.48

*Ratio Cl to Na in common salt (NaCl) = 154%
†CO_3 is converted to an equivalent weight of HCO_3 by multiplying by 2.03 and added to the HCO_3 determined.
Note: The table has been metricated and revised in technical format.

Chemical and physical properties of the deep subsoils

The deep subsoils of the major soil types have been mentioned and chemical and physical details are included in the tables of appendix 4. Many type sample borings penetrated these horizons and samples selected from 17 borings were subjected to detailed chemical and physical analyses. The results are set out in table 4. All are sandy clays, mottled grey, brown and red brown. Most have around or upwards of 50% clay. The Kumarl clay loam has 60–72%. All are acid; most have pH in the 3.5–4.5 range. They contain very little Ca while acid soluble Mg, K and Na are abundant with values 0.5–1.5% common (expressed as MgO, K_2O and Na_2O). Mg and Na dominate the exchangeable metal cations with exchangeable Ca virtually absent. Exchangeable H was determined and allowed base saturation to be calculated. It ranged from 52% (pH 3.53 and 3.49) to 60–70% (pH 4 to 5). Two samples with pH 5.28 and 5.70 were 76 and 78% base saturated. The general similarity of the deep subsoils of the three major soil groups is in marked contrast with the varying features of the upper 2 m. Physical and chemical features of the upper 2 m are, of course, the defining features of the various named soil types.

Table 4. Chemical and physical properties of the deep subsoils of the major soil types

Soil Type	CVs	CVs	CVs	CVs	CVsl	Ss	Bsl	Bsl	Bsl	Bsl	Gsl	Kcl	Kcl	Kcl	Docl	Docl	Docl
Serial No.	787	837	1351	1123	1392	1750	799	803	891	1343	965	777	912	1725	1334	1381	1732
Depth — cm	243—290	323—831	305—366	366—457	305—396	243—285	243—290	427—457	396—457	264—388	366—427	150—267	274—335	168—229	396—457	335—396	246—295
— inches	96—114	127—150	120—144	144—180	120—156	96—112	96—114	168—180	156—180	104—153	144—168	59—105	108—132	66—90	156—180	132—156	97—116
Mechanical analysis — percentage of air dry fine earth																	
Coarse sand 2.0—0.2mm	40.8	13.2	11.3	17.9	8.5	12.7	18.4	11.0	18.2	5.3	22.3	8.4	1.4	3.5	7.0	7.1	15.7
Fine sand 0.2—0.02mm	28.4	40.0	28.1	47.6	36.7	25.7	22.3	20.4	20.3	18.5	42.3	16.8	9.5	10.4	24.6	34.3	29.5
Silt 0.02—0.002mm	Nil	1.6	1.1	0.5	1.5	1.1	2.0	4.7	0.1	1.9	3.4	5.8	5.6	6.3	2.6	2.7	3.8
Clay <0.002mm	26.6	41.9	52.8	29.3	49.2	56.3	49.0	58.4	57.0	65.9	29.1	59.9	72.2	69.2	55.2	50.1	44.6
Coarse sand/fine sand ratio	1.44	0.33	0.40	0.38	0.23	0.49	0.82	0.54	0.90	0.29	0.53	0.50	0.15	0.34	0.28	0.21	0.53
Chemical properties — percentage of air dry fine earth																	
$CaCO_3$ (from CO_2)	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Exchangeable hydrogen in m eq./100g soil	2.40	7.90	10.40	5.20	9.25	n.d	11.90	13.30	6.90	9.10	5.80	18.40	17.40	15.75	9.20	10.40	6.60
Cation exchange capacity	10.70	20.94	28.63	16.51	27.59	n.d	27.94	27.46	18.01	31.76	17.14	38.60	45.92	42.48	38.02	30.74	28.00
Base saturation %	78	62	64	69	65	n.d	57	52	62	71	66	52	62	63	76	66	76
pH	5.70	4.51	4.38	4.36	4.97	4.45	4.00	3.53	4.85	5.88	4.35	3.48	4.13	4.35	4.73	4.28	5.28
Constituents soluble in concentrated hydrochloric acid — %																	
P_2O_5	0.004	0.003	n.d	0.003	0.002	0.004	0.006	0.004	n.d	n.d	0.008	0.007	0.003	0.005	n.d	n.d	0.003
CaO	nil	nil	0.011	0.036	0.003	n.d	0.012	0.025	n.d	0.011	0.029	0.012	0.042	0.008	0.008	0.003	nil
MgO	0.271	0.689	0.608	0.540	0.618	n.d	0.708	0.716	n.d	0.736	0.389	0.804	0.791	0.681	n.d	1.069	0.815
K_2O	0.211	0.928	1.328	0.753	1.057	0.787	0.993	1.026	n.d	1.764	0.821	0.904	1.071	1.122	1.172	1.090	0.967
Na_2O	0.277	0.516	0.719	0.515	0.596	n.d	0.507	0.594	n.d	0.873	0.439	0.617	0.895	0.875	0.867	0.597	0.628
Exchangeable metal cations																	
Total m. eq./100g soil	8.30	13.04	18.23	11.31	18.34	15.01	16.04	14.16	11.11	22.66	11.35	20.20	28.52	26.73	28.82	20.34	21.40
Total m. eq./100g clay	31.21	31.10	34.50	38.60	37.30	26.60	32.70	24.20	19.50	34.30	39.00	33.70	39.50	38.60	52.20	40.60	48.00
Ca — % of total cations	Nil	Nil	Nil	7	1	1	Nil	1	1	2	10	Nil	2	2	Nil	Trace	1
Mg — % of total cations	57	47	47	40	43	52	43	25	41	47	42	50	47	52	51	52	48
K — % of total cations	7	10	10	9	11	9	11	13	10	12	7	7	8	7	7	10	10
Na — % of total cations	42	43	43	44	45	38	46	61	48	39	41	43	43	39	42	38	41
Total water soluble salts — percentage of oven dry fine earth																	
T.W.S.S	0.424	0.784	1.216	0.821	0.922	0.640	0.688	0.798	0.860	1.536	0.665	0.864	1.160	1.369	1.270	1.036	0.851
NaCl (Cl x 1.648)	0.231	0.658	0.923	0.687	0.651	0.480	0.481	0.571	0.681	1.211	0.570	0.638	0.921	1.012	0.951	0.737	0.600
NaCl/T.W.S.S. Percentage	54.5	83.9	75.9	83.6	70.6	75.0	69.9	71.6	79.2	78.8	85.7	73.8	79.3	73.9	74.9	71.1	71.2

Circle Valley sand — CVs; Circle Valley sandy loam — CVsl; Scaddan sand — Ss; Beete calcareous sandy loam — Bsl; Geordie sandy loam — Gsl; Kumarl clay loam — Kcl; Dowak clay loam — Docl; n.d — not determined; T.W.S.S. — Total water soluble salts

Discussion

Origin of salt at Salmon Gums

Teakle (1937) reported that analyses of water from the rain gauge at Salmon Gums Experiment Farm 1932–1936 showed atmospheric accessions of NaCl of 30 kg/ha.a. No estimate was made of how much might have come from oceanic aerosols and how much from terrestrial sources (soil dust and material from dry salt lakes). Net accessions may be somewhat less than the amount quoted, but, with no losses to streams or local drainage sumps, might well account for some of the peaks in the upper 50–100 cm of the profiles shown in figures 1, 2 and 3.

Like the salts in sea water, the soil salts at Salmon Gums are dominated by NaCl, but whether they are from marine submersion or from atmospheric accessions or both remains a matter of conjecture. Some detailed studies of the water soluble extracts from the soils and subsoils at Salmon Gums were made. These were tabulated and discussed by Teakle and Burvill (1938) along with other studies of the movement of soluble salts in soils under light rainfall conditions.

Clark (1924), gives many analyses of ocean waters. The world's interconnected oceans including the Baltic Sea, the Mediterranean Sea and the Red Sea are very similar in their major constituents in spite of variations in total salt concentration from 0.72% in the Baltic to over 4% in the Red Sea. A common level in the world's oceans is 3.2–3.5%. Clark's Indian Ocean analyses were 3.55% and 3.66%. The major constituents of the soluble materials are:

Cl	55.3%
SO_4	7.7%
Na	30.6%
Mg	3.7%
Ca	1.2%
K	1.1%

Primary minerals containing Cl are not common in the earth's crust; it seems probable that the ocean is the prime source of Cl and perhaps of NaCl. The SO_4, Mg, K and Ca may have come from rock weathering and transport in streams but, as with Cl and Na, their constancy in the world's oceans is remarkable.

Sea spray can form aerosols and be carried inland on prevailing winds. Winds from the west and south from the Indian Ocean have carried substantial quantities inland in the southern half of Western Australia (Hingston and Gailitis, 1976). It reaches the ground

surface as dust or in rain. In inland southern parts as at Salmon Gums, annual rainfall (about 300 mm) is low and light and run-off and return to the ocean via streams does not occur.

The measured accession of NaCl at Salmon Gums (Teakle 1937, Hingston and Gailitis 1976) is about 22–30 kg/ha.a which would add about 25 tonnes/ha in 1000 years. This would be about 0.2% in a metre depth of soil. The high NaCl levels in the first metre of most virgin profiles (figures 1, 2 and 3) may represent 3000–5000 years accessions with climate and natural vegetation as at present.

Kelley (1934) writing about the so-called solonetz soils of southern California discussed the possibility that some were derived from marine sediments. He treated soils and bentonite clay with sea water and then, after leaching out the salts, estimated the exchangeable metal cations (replaceable bases). For a soil, the percentages were: Ca - 20%, Mg - 37%, K - 7% and Na - 36%. For the bentonitic clay the percentages were: Ca - 10%, Mg - 46%, K - 7% and Na - 37%. Similar ratios are common in the subsoils at Salmon Gums (table 4) and in California. The deep acid layers are, however, almost devoid of calcium. Burvill and Teakle (1938) published some of Kelley's data and comparable figures for Western Australian solonetzic soils.

Conclusion

The Salmon Gums Soil Survey 1932–1935 was recorded on 42 map sheets on a scale of 20 chains to an inch (1:15840). The various soil types and their salt status were shown. The maps were coloured to show the estimated suitability of the various soil units for wheat growing. Wheat had been the principal rural product in the district. However, the disastrous fall in wheat prices in 1930 and the persistence of low prices till the World War which started in 1939, caused widespread abandonment of farms. Throughout the low and medium rainfall (275–450 mm) farming areas of Australia similar conditions prevailed. The reconstruction of marginal areas during the 1930s and 1940s was a major task of rural administrators and those providing rural finance.

At Salmon Gums the soil survey maps provided a good base for selecting areas and locations with the best prospects for successful rural production. The State-run Agricultural Bank had been the main source of development funds. Those farmers remaining (about 150) were allotted much larger holdings — about 4000 acres (1600 hectares) instead of the original 1000–1100 acres. The sandy surfaced soils such as Circle Valley sand were favoured and problem soils Beete ("kopi") Kumarl and Dowak were avoided where possible. Debts were adjusted to what appeared to be a manageable level and a combination of sheep grazing and cereal production encouraged. Earth tanks (dams) for stock water supplies were improved.

The World War brought additional problems and until 1950, progress was slow in the 'Marginal Areas'. Wool prices doubled in 1950 and brought prosperity to most of these areas. A run of years of above average rainfall, 1958–1968, and favourable prices for cereals and wool, consolidated this wealth. Further land was opened up and developed for farming. Unfortunately, at the time of writing (1987), while wool prices are stable, returns from wheat are declining and many farmers have great problems in servicing debts which carry high interest rates. Economic conditions, as much as rainfall and soil problems, determine marginal conditions for successful farming. The area 90 km by 50 km from Beete to Scaddan, centred on Salmon Gums, now has about 100 farms with properties up to 8000 ha. In the mid 1920s there were 500 farmers on 450 ha farms.

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Nomenclature

Names of some of the places and periods mentioned in the text.

Kumarl — Aboriginal for possum

Dowak — Aboriginal for waddy (a stick)

Beete — Captain Bicton Beete, one time Administrator of the Colony of Western Australia, 1834.

Truslove — Originally Treslove (1917). Renamed Truslove (1933). A soldier who died in the Great War?

Scaddan — John Scaddan, former Premier of the State of Western Australia 1911–1916.

The Great War — Historically the name given to the war of 1914–1918. Sometimes called 'The Great European War' and, after the start of the World War in 1939, World War I.

The World War — The global war of 1939–1945. Sometimes called World War II.

The Great Depression — The world-wide economic depression of 1929–1940.

References

Bettenay, E. and Hingston, F.J. (1961). Soils of the Merredin area, Western Australia. CSIRO Australia, Division of Soils, soils and land use series No. 41.

Bowler, J.M. (1976). Aridity in Australia. Age, origins and expression in aeolian landforms and sediments. *Earth Science Review,* **12:** 279–310.

Burvill, G.H. (1936). Soil survey of the Salmon Gums district, Western Australia. *Journal Australian Institute of Agricultural Science* **2:** 117–119.

Burvill, G.H. and Teakle, L.J.H. (1938). The occurrence of solonetz (structural alkali) soils in Western Australia. *Journal of Agriculture, Western Australia* (2nd Series) **15:** 97–109.

Clark, F.W. (1924). Data of Geochemistry. United States Geological Survey Bulletin No. 776. Fifth edition (Reprinted 1959).

Cockbain, A.E. (1968). The stratigraphy of the Plantagenet Group. Geological Survey, Western Australia Annual Report 1967; 61–67.

Crocker, R.L. (1946). Post-Miocene climate and geological history and its significance in relation to the genesis of the major soil types of South Australia. C.S.I.R. (Australia) Bulletin No. 193.

Elms, R.G., Matthews, R.D. and Chapman, D.G. (1982). Notes on the geology of the lignite resources — Esperance, Western Australia. In, Australian coal geology 4, Part 1, pp. 101–110.

Hingston, F.J. and Gailitis, V. (1976). The geographic variation of salt precipitated over Western Australia. *Australian Journal of Soil Research,* **14:** 319–335.

Johnston, D.A.W. (1983) ed. Wheat in Western Australia, Western Australian Department of Agriculture, Bulletin No. 4076.

Kelley, W.P. (1934). The so-called solonetz soils of California and their relation to alkali soils. American Soil Survey Bulletin No. 15: 45–52.

Loxton, I.W. (1977). Kalgoorlie Inspectorate. Peat. Western Australian Department of Mines Annual Report. 1977: 34–36.

Malcolm, C.V. (1983). Wheatbelt Salinity — A review of the salt land problem in south-western Australia (Revised edition) Western Australian Department of Agriculture, Technical Bulletin No. 52.

Marshall, T.J. and Hooper, P.D. (1935. A soil survey of the Berri, Cobdogla, Kingston and Moorook irrigation areas and Lyrup village district, South Australia. C.S.I.R. (Australia) Bulletin No. 86, 1935.

Morgan, K.H. and Peers, R. (1973). Explanatory notes for the Esperance — Mondrain Island Sheet. S.I.: 51–6, 10 International Index. Geological Survey of Western Australia.

Northcote, K.H. (1971). A factual key for the recognition of Australian soils. (Relim Technical Publication: Glenside, South Australia).

Northcote, K.H., Bettenay, E., Churchward, H.M. and McArthur, W.M. (1967). Atlas of Australian soils, sheet 5, Perth-Albany-Esperance area, with explanatory data. CSIRO Australia and Melbourne University Press, Melbourne.

Prescott, J.A. (1931). The soils of Australia in relation to vegetation and climate. C.S.I.R. (Australia) Bulletin No. 52.

Royal Commission on the Mallee Belt and Esperance Lands, (1917), (Charles E. Dempster, Chairman), *Report.* Fred. Wm. Simpson, Controller of Printing. Perth, Western Australia.

Samuel, L.W. and Teakle, L.J.H. (1931). Procedure for the rapid estimation of soil alkali and salt under field conditions. *Journal of Agriculture, Western Australia* (2nd Series) **8:** 219–227.

Shier, F.L., Dunne, T.C. and Fitzpatrick, E.N. (1963). Agriculture on the Esperance Downs. *Journal of Agriculture, Western Australia.* (4th Series) **4:** 66–80 and 106–121.

Stace, H.C.T. *et al.* (1968). Handbook of Australian Soils, Published for C.S.I.R.O. and the International Society of Soil Science. (Rellim Technical Publication, Glenside, South Australia.)

Stephens, C.G. (1961). The soil landscapes of Australia. C.S.I.R.O. Soil Publication No. 18.

Teakle, L.J.H. (1937). The salt (sodium chloride) content of rainwater. *Journal of Agriculture, Western Australia* (2nd series) **14:** 115–123.

Teakle, L.J.H. (1938). A regional classification of the soils of Western Australia (Presidential address). *Journal Royal Society, Western Australia* **24:** 123–195.

Teakle, L.J.H. (1946). Aeolianite and soil formation in Western Australia. *Journal of the Australian Institute of Agricultural Science* **12:** 95–96.

Teakle, L.J.H. and Burvill, G.H. (1938). The movement of soluble salts in soils under light rainfall conditions. *Journal of Agriculture, Western Australia* (2nd series) **15:** 218–245.

Teakle, L.J.H., Southern, B.L. and Stokes, S.J. (1940). A soil survey of the Lakes District, Western Australia. *Journal of Agriculture, Western Australia* (2nd series) **17:** 251–294.

Appendix 1

A soil survey of the Salmon Gums district
Draft by L.J.H. Teakle, 1939

There is no agricultural district in Western Australia which has been subjected to more investigations by various authorities than the Salmon Gums area, or concerning which there has been so much attention and disappointment.

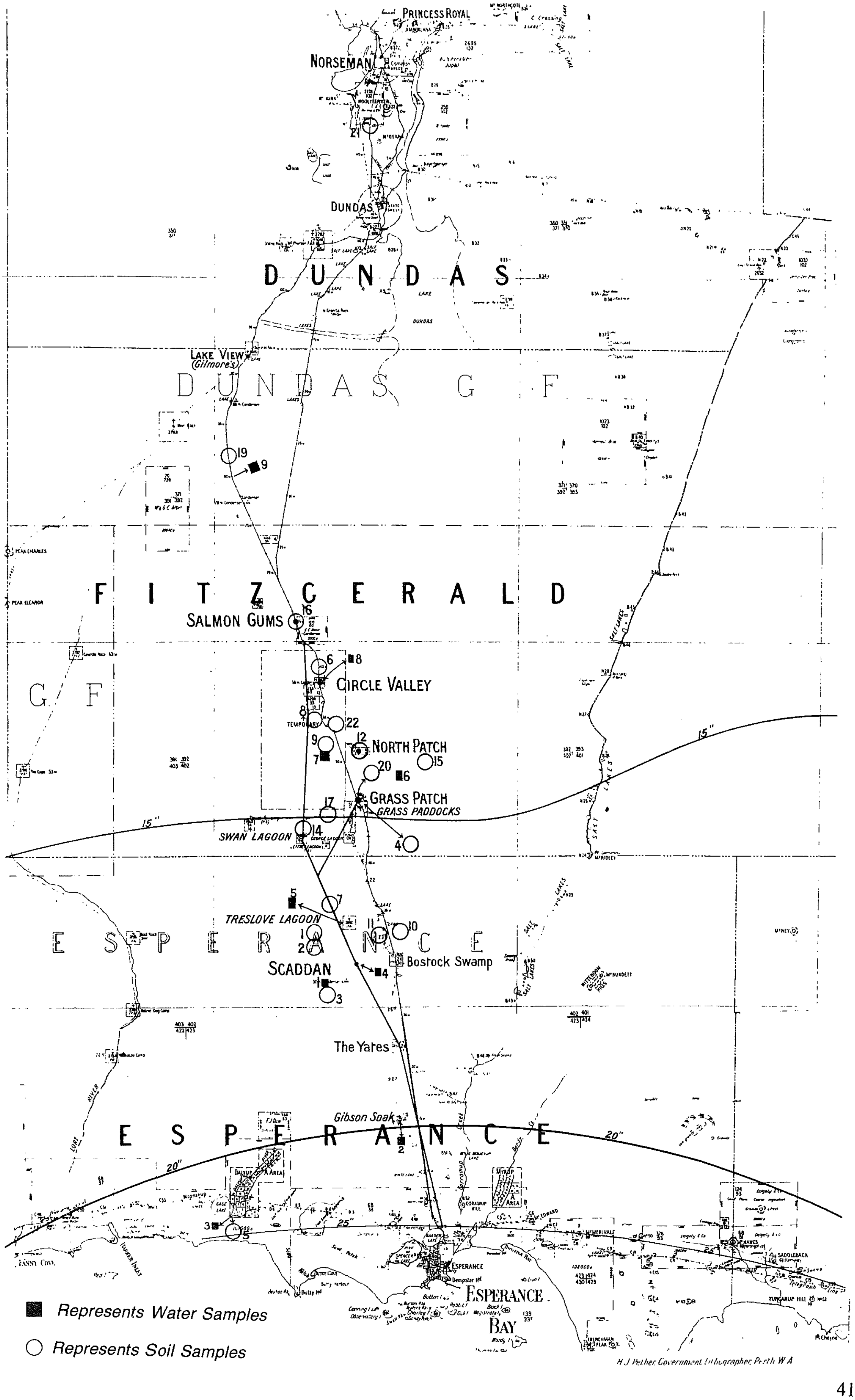
The district lies on the Norseman-Esperance railway line and is sometimes referred to as the Esperance mallee. Its south boundary coincides with Scaddan, some 30 miles (48 km) north of Esperance, and settlement extended another 55 miles (88 km) further north to Beete. Farms have been occupied as far as 15 miles (24 km) eastward and westward of the railway line. To the south lies the coastal sandplain. This is a broad, undulating expanse of heath, growing on a sandy soil with a gravelly and gravelly clay subsoil. The semi-arid *Eucalyptus* woodland of the Coolgardie region (Teakle, 1937) stretches northward from Beete.

The town and port of Esperance came into being about 1893, as a jumping-off point for the Coolgardie Goldfields. For the next four years there was heavy road traffic from Esperance northward to serve the gold mines. During the next five years there were agitations for the railway from Esperance to Coolgardie and a railway survey was made in 1902–1903. The Coolgardie-Norseman section was built first and the railway opened in November, 1909.

Hitherto, there had been little attention given to agricultural prospects. It is true that a few people had grown small areas of cereals to provide hay for the teams at lucrative prices, but no thought was given to development as an agricultural district until 1910. Crops had been grown prior to this date at Grass Patch (since 1897), Circle Valley (since 1904) and at Lake View (between Beete and Norseman).

The opening of the railway gave an impetus to the extension of agriculture and considerable areas of land were selected north of Esperance, and there were insistent demands for the completion of the railway to Esperance. Although agreed to by the Legislative Assembly, the Bill to authorise this railway was rejected in 1911 by the Legislative Council on the grounds that there was insufficient knowledge of the agricultural potentialities of the country which the railway purposed to serve.

Then followed several years of enquiry and there arose considerable divergences of opinion regarding the agricultural value of the area. There were reports by engineers, surveyors and chemists, culminating in a Royal Commission appointed in September 1916, and which submitted a comprehensive report to the Western Australian Government in July 1917. (See map from Royal Commission Report).



■ Represents Water Samples

○ Represents Soil Samples

There is no need to repeat the details embodied in these reports as they are included in the appendices of the comprehensive report by the Royal Commission. A summary of the salient points, showing the scope and direction of the enquiries and the various conclusions should suffice. With few exceptions, the reports were eulogistic of the country and optimistic of the agricultural prospects. The minority which warned caution included W. Paterson, the Chairman of the Agricultural Railways Advisory Board and Managing Trustee of the Agricultural Bank, Professor J.W. Paterson, Professor of Agriculture at the University of Western Australia, and E.A. Mann, Government Analyst.

The first comprehensive report on the country between Norseman and Esperance is that of C.E. Watkins, Government Surveyor. This was presented on December 30, 1910. Watkins[1] estimated that between Scaddan and Salmon Gums and 40–50 miles (64–80 km) in an east-west direction, there existed nearly a million acres (405,000 ha) of splendid agricultural country of uniform quality which should give a yield of 20 bushels per acre with approved methods of cultivation.

About the same time, A.O. Hewby, Chief Inspector of the Agriculture Bank, and G.M. May, Chief Inspector of Lands[2] examined the country and in their report of January 4, 1911, gave a favourable, if less optimistic, opinion. Hewby and May divided the country between Esperance and Norseman into three belts —

1. Esperance to Scaddan — 30 miles (48 km): poor sandplain country.

2. Scaddan to approximately 75 miles (120 km) north of Esperance (between Dowak and Kumarl): the mallee belt. It was estimated that 576,000 acres (233,000 ha) of country sufficiently good for wheat growing occurred in this belt within 15 miles (24 km) of the railway survey.

3. Beyond 75 miles (120 km) north of Esperance: good forest land with occasional patches of scrub and granite outcrops and a number of very large salt lakes. The low rainfall was deemed to preclude agricultural development.

On the basis of these two reports, the Agricultural Railways Advisory Board furnished a report on March 17, 1911. Two members optimistically recommended the construction of the Norseman-Esperance line. The Chairman, W. Paterson, advised caution until the land was proved agriculturally and the water supply position examined to determine means of a suitable supply.

Following the rejection by the Legislative Council of the Bill for the construction of a railway from Esperance to Norseman, the Engineer in the Goldfields Water Supply, P.V. O'Brien, was requested by the Hon. Minister for Mines[3] to report on the country, especially with respect to water supply.

O'Brien secured the services of Surveyor A. Middleton, who spent 6 1/2 months in the district and made a general examination of the water supply prospects and the soils, including the collection of some 200 soil samples.

The examination indicated that the water supply position was satisfactory, as the country generally was not porous, as had been concluded by certain earlier observers, but "clay of splendid quality exists ... in ample quantities" for the construction of water-tight tanks. Catchments may need special attention. The search for underground waters proved most disappointing. In his borings, Middleton found an abundance of salt water at depths ranging from 3–40 feet (1 to 12 m) in the lower parts of the country.

On the other hand, the analyses of the soils, while showing that the ordinary chemical constituents were normal in comparison with other Western Australian types known to be suitable for agriculture, pointed to an unusual concentration of salt in many samples. The Government Analyst, E.A. Mann, in reporting on the analyses, stated[4] "the results were far from reassuring and confirm the suspicion that the country, generally, is salt". Mann recommended that settlement should not be attempted without fully testing the land by means of "fairly extensive experimental crops".

[1] Royal Commission Report pp 112–113
[2] Royal Commission Report pp 111–112

[3] Royal Commission Report pp 116–126
[4] Royal Commission Report pp 124

Unfortunately, Mann was ill-advised in the figure which he adopted for "maximum allowable salinity" for a fertile soil. There is no evidence to support his belief that 0.05% salt, NaCl, was a reasonable upper limit for wheat-growing. If the data[5] obtained by Mann be re-examined, and the more reasonable figure of 0.20% be taken as indicative of excessive salinity for permanent wheat growing, only 16 out of 107 surface samples (15%) contain more than this amount. A similar proportion of the subsoils would be judged excessively saline.

O'Brien rejected Mann's conclusions regarding the significance of the salt of the mallee soils collected by Middleton. After a study of the American literature, he decided that 'the safe limit of salt percentage which permits of profitable agriculture very largely depends upon special conditions and the farmer will be on much safer ground in experimenting for himself than in seeking advice from the agricultural expert or chemist'[6]. In his conclusion, O'Brien stated[7] 'the quantity of salt in our samples compares favourably with the limit of endurance for wheat given by American authorities'. He accepted Middleton's estimate of 922,500 acres (373,250 ha) of agricultural land worth from 8/- to 15/- an acre ($2.00 to $3.70 per ha) within 15 miles (24 km) of the railway survey between the 30 and 80 mile (48 and 128 ha) posts from Esperance.

The position in the mallee was examined by the Agricultural Bank Trustees in 1916. Reports by experienced officers were most disappointing. Crops generally had been poor and there was nothing to indicate that matters were likely to improve, even with fallowing, in the future. Of 12,258 acres (4,959 ha) rolled, only 5,722 acres (2,324 ha) were being maintained. Only 34 settlers of the 57 who had had work done on their holdings actually remained on their properties, and these were struggling along in the face of crushing difficulties. For the four years, 1912–1915 inclusive, the wheat yield average was only 4.36 bushels per acre (0.3 t/ha). The Trustees asked that the Treasury indemnify the Bank against loss in respect to advances made in the Esperance district.

The Royal Commission made an exhaustive enquiry into the mallee lands. Much evidence was taken in Western Australia and the mallee areas in South Australia and Victoria were visited to obtain first hand information. Valuable data were collected.

The report by Professor Paterson[8] is of particular interest, in view of experience in succeeding years. Paterson examined the earlier chemical data and visited the area in the company of the Commissioners. Samples of soil were taken from 20 sites to represent the most important soil conditions recognized and these were analysed by analysts in Western Australia and Victoria. His evaluation of the country which he saw and the deductions from the chemical work have proved sound over the years. Subsequent work has amplified his conclusions without necessitating any modifications of major practical importance. Paterson concluded that about half of the area contained too much salt for profitable farming and that the lighter loams offered the best prospect for immediate success in wheat farming[9]. He suggested that the salinity had its origin in two sources — the rocks from which the soil was formed and the cyclic salt brought in by the rainfall.

The Royal Commission rejected the advice and conclusions of Professor Paterson, E.A. Mann and all the Agricultural Bank Trustees. It accepted O'Brien's recommendations and the condemnation of the agricultural expert, and evidenced antagonism towards those who expressed doubts about the fertility of the mallee[10]. It is difficult to see how many of its findings were arrived at when the data in the appendix are examined critically and without bias.

Great importance was attached to the statements of witnesses in Victoria, to the effect that mallee lands gave low wheat yields in the first four or five years while the suckers are being eliminated by a process of annual cropping and stubble burning, but marked improvement was general, subsequently, when a three course rotation and fallowing were adopted.

[5] Royal Commission Report pp 125-126
[6] Royal Commission Report page 117 (italics by the authors)
[7] Royal Commission Report page 118

[8] Royal Commission Report, page 158
[9] Royal Commission Report, page 176
[10] Royal Commission Report, page xiv

For example, A.S. Kenyon[11], Civil and Hydraulic Engineer of the State Rivers and Water Supply, Victoria, stated that in the first six years of establishment, a reasonably good farmer could expect yields of 6–8 bushels per acre (0.04–0.5 t/ha), but thereafter, on a three course rotation, 14–18 bushels (0.9–1.2 t/ha) can be obtained. Most district records from South Australia and Victoria, published in the appendix of the Royal Commission Report, do not support such statements, and many parts of the eastern States mallee country have experienced many years of low wheat yields. Serious soil deterioration has occurred over wide areas.

The Royal Commission concluded that a large area existed in the mallee belt and the Esperance district which was adapted to wheat growing and general farming. Transport and market facilities and adequate water supplies were essential to enable successful farming to be carried out.

The Royal Commission shunned experimental work. It considered that[12] "no benefit is likely to occur from the establishment of experimental farms in the mallee belt at present". Railway facilities prior to experimentation were recommended. The Royal Commission recommendations included the construction of a railway line from Esperance to Salmon Gums, and later, the connection being completed between Norseman and Salmon Gums. It also recommended that the country be tested for artesian water and that proper provision be made to serve the settlement with roads and water supplies, put in as a capital charge against the price of land.

The settlement of the mallee lands was proceeded with. The railway from Esperance to Salmon Gums was opened on September 1, 1925, and the link between Norseman and Salmon Gums on August 8, 1927. The classification of the country for wheat growing was undertaken by the Lands Department and a sub-division designed. The land was thrown open to selection in the early 1920s, and by 1929 some 550 holdings had been selected and many were in the course of improvement.

Distribution table of analyses for salt (NaCl) in samples collected by surveyor A. Middleton.

	Per cent salt								
No. of samples	<0.05 %	0.05-0.10 %	0.10-0.15 %	0.15-0.20 %	0.20-0.25 %	0.25-0.35 %	0.35-0.50 %	>0.50 %	Total
Surface soils	43	38	9	11	9	3	3	2	117
Subsoils	1	5	4	7	9	6	2	2	36

11 Royal Commission Report page 158
12 Royal Commission Report page xv

Appendix 2

Report by G.H. Burvill to:

L.J.H. Teakle, Plant Nutrition Officer

I have made a study of the wheat yields of the Salmon Gums Experiment Farm for the seasons 1927–34, segregating them as accurately as possible into the three main groups, according to the soils on which the crops were grown.

The attached statement and table sets out this information and gives figures to support the valuations adopted in the Soil and Alkali survey of the district. The soils of Group (A), (principally Circle Valley sand and Circle Valley sandy loam) have given an average yield of 15 bushels per acre, or 1.9 bushels per acre per inch of May-October rain. At the Yilgarn Experiment Farm the yield per inch of May-October rain for the period 1928–34 has been 2.1 bushels per acre, and at Merredin Experiment Farm 2.3 bushels per acre. The unsatisfactory nature of the "kopi", and the heavy crabholey soils for wheat growing is revealed in averages 8 and 9 bushels per acre respectively from fallowed land, equivalent to only 0.8 and 1.0 bushel per acre respectively per inch of May-October rain.

The data of the statement and table would no doubt be of interest to other officers, and should be of interest to the Agricultural Bank, and additional copies are attached for distribution.

Rainfall records for the May-October period at the Salmon Gums Experiment Farm are now available for the 10 years, 1926–35, and are as follows:-

	Points
1926	731
1927	744
1928	579
1929	710
1930	837
1931	1305
1932	1005
1933	676
1934	682
1935	628
Average	790

Although the average is nearly 8 inches, it is interesting to note that only in 3 years has the average been exceeded. In the other 7 years the May-October rainfall has been less than 7 1/2 inches.

(Sgd) G.H. Burvill
Agricultural Adviser
November 26, 1935

Wheat yields — Salmon Gums Experiment Farm

The soils of the Experiment Farm are representative of the soils of the district and may be divided into three general groups:—

(A) Soils with a sand or sandy loam surface over a rubbly clay subsoil (chiefly Circle Valley sand and Circle Valley sandy loam). In general these soils are low in salt.

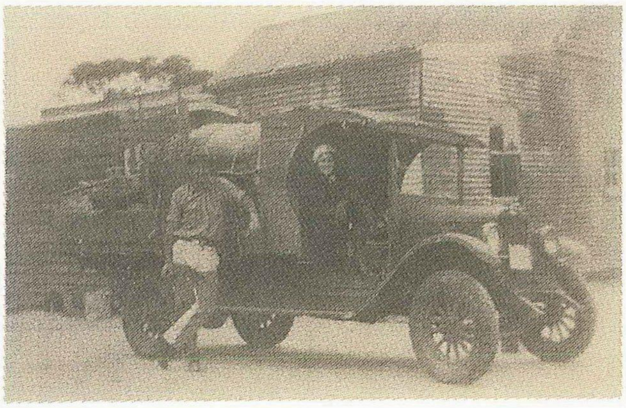
(B) "Kopi" soils — loose powdery very calcareous soils (Beete calcareous sandy loam) more or less affected with salt.

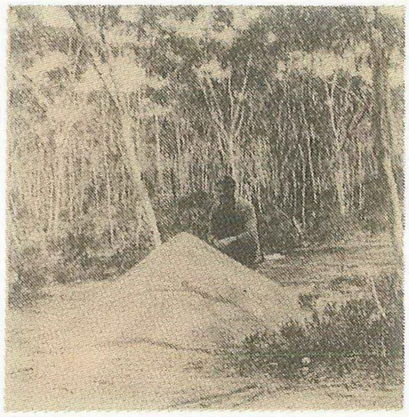
(C) Heavy textured crabholey soils more or less generally affected with salt.

A study of the crop yields gives the information in the following table, rainfall data being also included.
1927 was the first cropping year at the Farm.

Year	Rainfall		Soil									Remarks
			(A)			(B)			(C)			
	Year inches	May-October inches	Area acres	Yield bush/ac.	Bush per inch May-Oct	Area acres	Yield bush/ac.	Bush per inch May-Oct	Area acres	Yield bush/ac.	Bush per inch May-Oct	
1927	11.65	7.44	Mixture of (A) & (B)			106	7	0.9	—	—	—	New land — not fallowed
1928	7.92	5.79	205	15	2.6	—	—	—	—	—	—	New land — fallowed.
1929	11.73	7.10	Mixture of (A) & (B)			56	8½	1.2	90	4½	0.6	90 ac. soil (C) new land not fallowed
1930	16.23	8.37	117	17½	2.1	—	—	—	58	16	1.9	Soil (C) new land fallowed.
1931	16.69	13.05	44	14½	1.1	55	8½	0.6	93	8	0.6	Soil (C) new land fallowed & frost injury severe on 43 acres of this soil.
1932	13.07	10.05	55	19	1.9	2½	14	1.4	78	10	1.0	
1933	12.13	6.76	69	15	2.3	3	6	0.9	75	6	0.9	
1934	14.95	6.82	57	9½	1.4	5	2½	0.4	62	4½	0.7	November storms caused losses from all crops.
Average	13.05	8.17		15	1.9		8	0.8		9	1.0	Averages for fallowed land

One acre = 0.405 hectare. The bushel was usually 60 lbs for wheat or about 27.2 kg. One bushel of wheat approximates 75 kg/hl.
Rainfall, 1.0 inch = 100 points = 25mm.





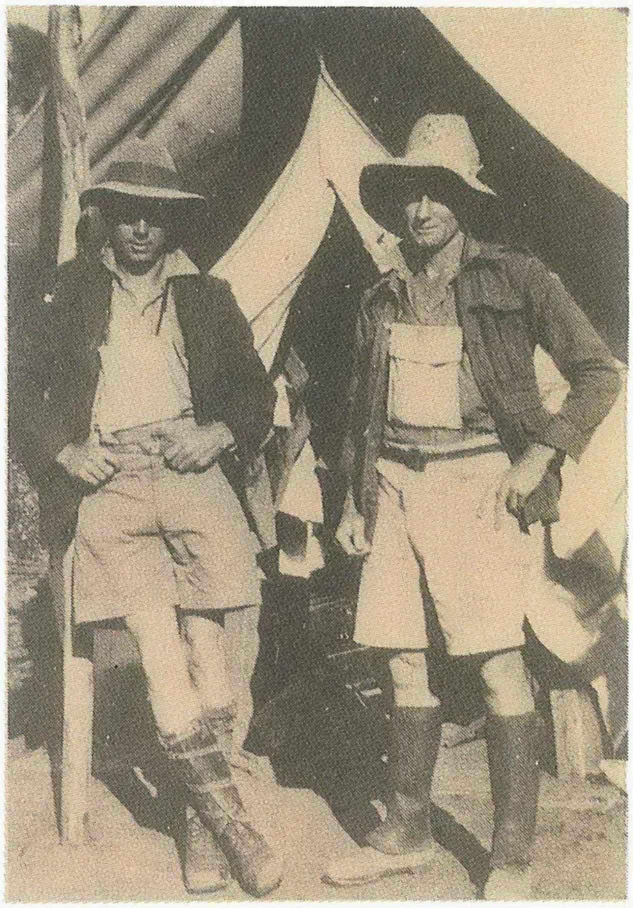
The author's and Mrs Burvill's first home, an abandoned farm house at west Dowak, October 1933. L-R. Surveyor S.J. Stokes and Mrs G.H. Burvill.

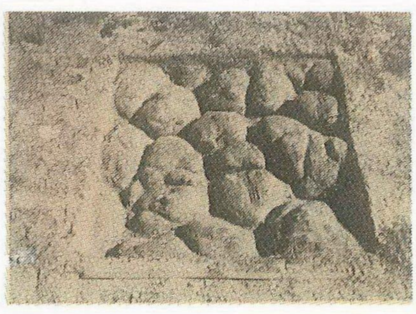
Laboratory assistant Mr Ben Scrivener beside the remains of 10,000 soil samples, collected and analysed at east Kumarl, August to December, 1932. The typical mallee and sapling growth of the vegetation is also shown.

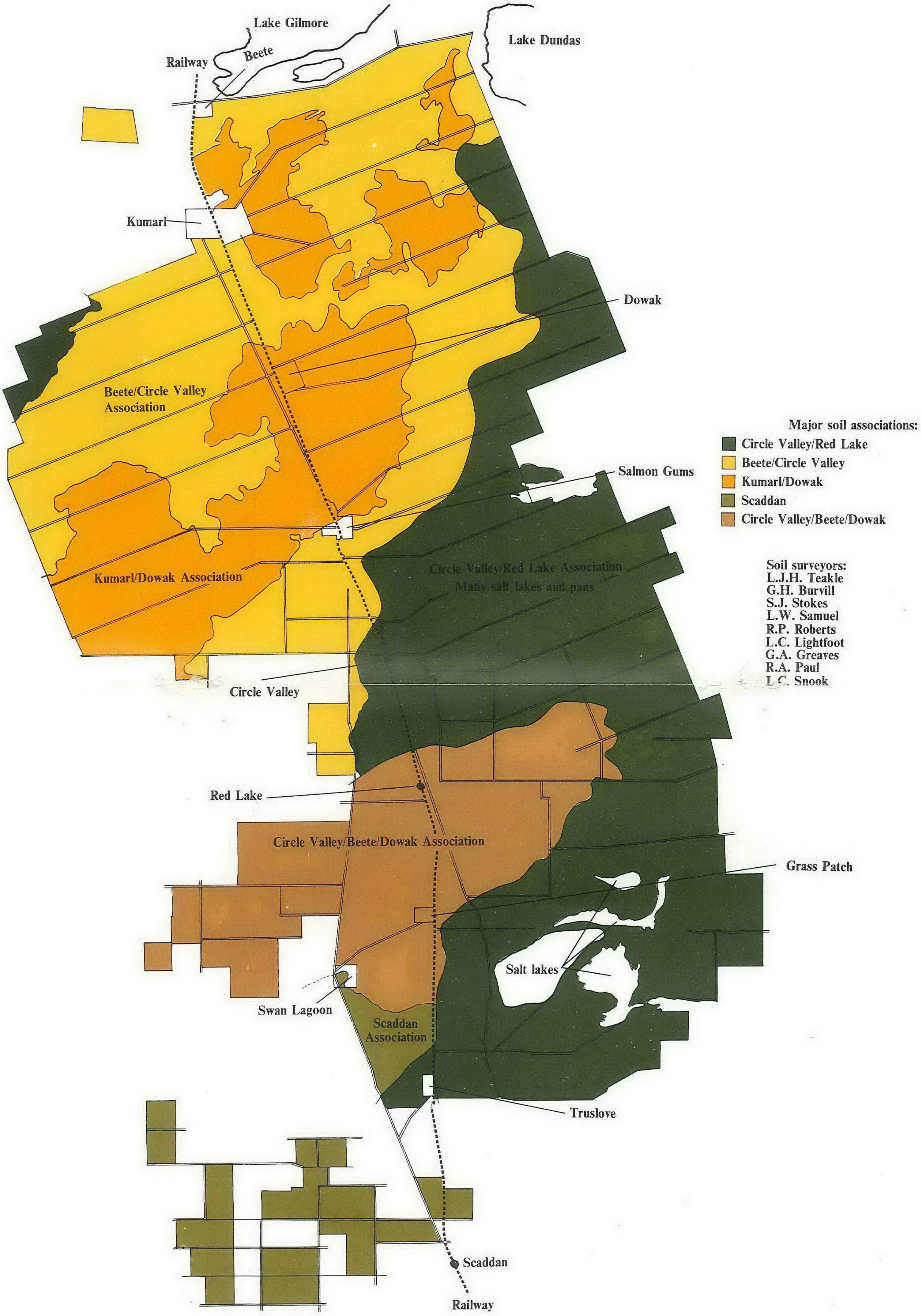
L-R. Soil surveyors Messrs R.P. Roberts and G.H. Burvill at Kumarl, October, 1932.

Lunch break at Peak Charles, August 1932. L-R. Messrs B. Scrivener, R.P. Roberts, L.J.H. Teakle, H. O'Shaughnessy (in truck), G.H. Burvill, P. Coulson and C. Hancock.

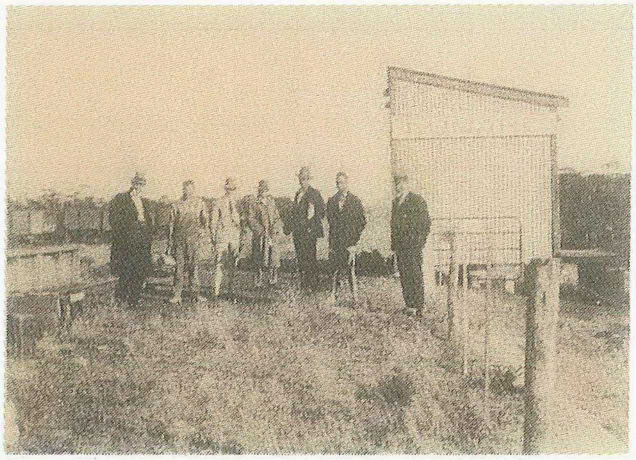
A domed subsoil in the Scaddan series. The area shown is 1 m².

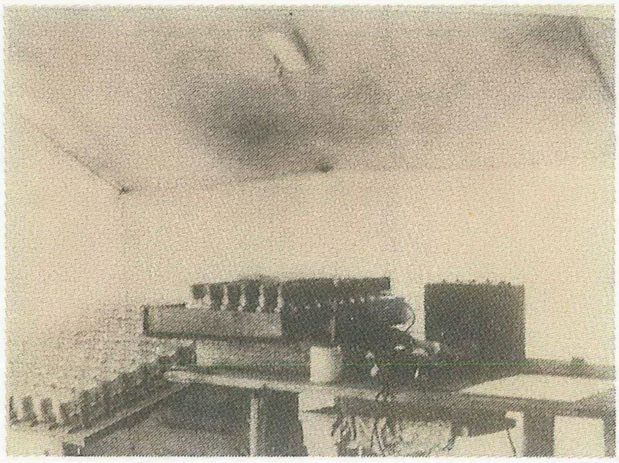


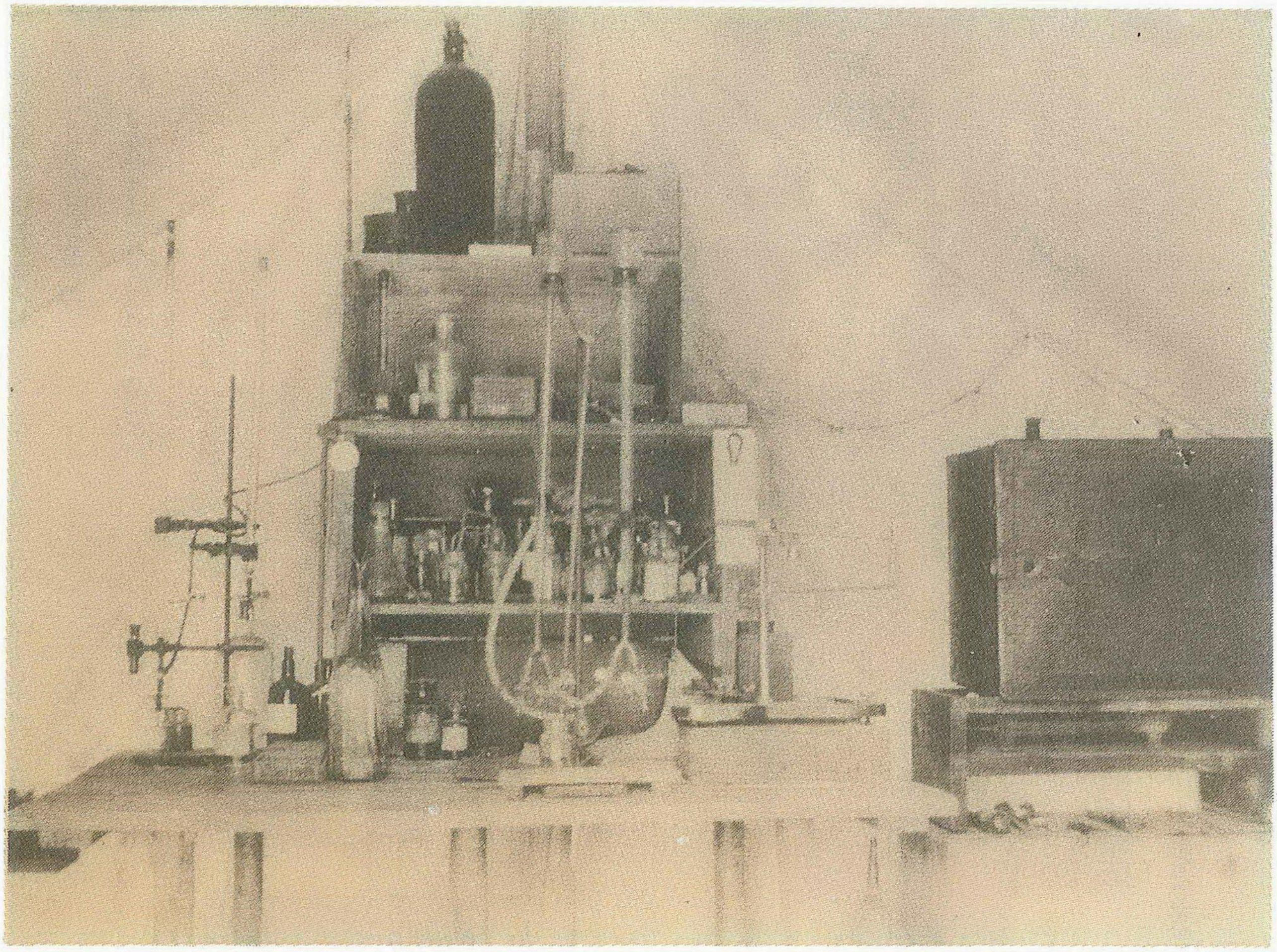


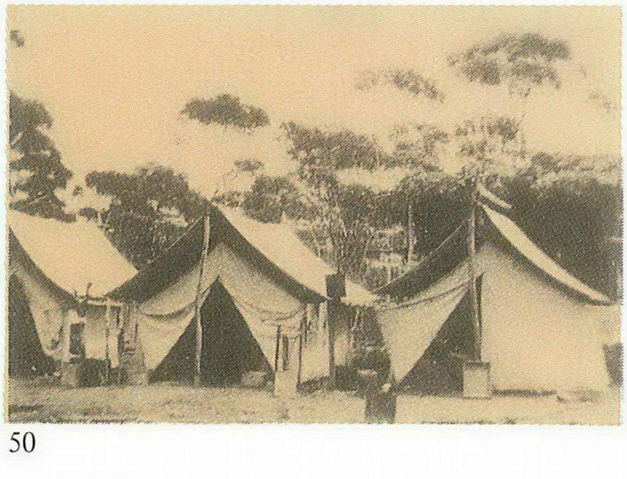


Map 3. Soil associations. The major soil associations in the area encompassed by the Salmon Gums soil survey, 1932-1935.









The railway siding at Kumarl, north of Salmon Gums at 6.00 a.m. The survey team about to leave for Perth after 11 months fieldwork, December, 1932. L-R. Messrs S.J. Stokes, C. Hancock, G.H. Burvill, J. Ralph, B. Scrivener, H. O'Shaughnessy and P. Coulson.

The tent laboratory in which the chemical analyses were made. Established by Mr L.W. Samuel in 1932.

Camp scene at Kumarl, 1932. Living quarters and field laboratory (right).

Appendix 3

In March 1936, Teakle sent the following memo to G.L. Sutton, the Director of Agriculture.

"Now that the field work in connection with the Soil Alkali Survey Project has been completed, I wish to place on record my highest appreciation of the co-operation and assistance rendered by the Department of Lands and Surveys.

Surveyor S.J. Stokes was appointed to this work in 1930 and continued throughout the five year period as an invaluable officer in charge of the general organization in the field. In addition, he maintained a keen interest in the technical phases of the work and was able to assist in the classification of the soils and the mapping. He undertook the draughting work in connection with the survey and the maps produced prove the careful and accurate nature of his work.

I have noted with interest Surveyor Stokes' appointment to the Boundary Survey in the Kimberleys. I am sure that his experience in soil work will enable him to gather valuable information concerning the soils of this remote section of the continent, which will form the basis for the more accurate description and classification of the soil formations of the north."

(Sgd) L.J.H. Teakle
Plant Nutrition Officer
March, 1936

Appendix 4 Mechanical analyses and chemical data

Locality	East Kumarl, Fitzgerald Location 994										
Soil type	**Circle Valley sand — CVs**										**(pH Q 1:1)**
Serial No.	780	781	782	783	784	785	786	787	788	789	790
Depth — cm	0—8	8—36	36—76	76—122	122—152	152—198	198—244	244—290	290—335	335—381	381—427
— inches	0—3	3—14	14—30	30—48	48—60	60—78	78—96	96—114	114—132	132—150	150—168
Mechanical analysis — percentage of air dry fine earth											
Coarse sand 2.0—0.2mm	45.0	32.4	34.8	—	—	—	—	—	40.8	—	—
Fine sand 0.2—0.02mm	44.0	32.7	28.4	—	—	—	—	28.4	—	—	—
Silt 0.02—0.002mm	2.6	2.3	0.1	—	—	—	—	nil	—	—	—
Clay <0.002mm	7.4	28.1	29.5	—	—	—	—	26.6	—	—	—
Coarse sand/fine sand ratio	1.02	0.99	1.22	—	—	—	—	1.44	—	—	—
Chemical properties — percentage of air dry fine earth											
$CaCO_3$ (from CO_2)	0.1	0.5	1.1	—	—	—	—	Nil	—	—	—
Organic carbon	0.818	0.442	0.120	—	—	—	—	—	—	—	—
Total nitrogen	0.027	0.021	0.006	—	—	—	—	0.007	—	—	—
C/N ratio	30.4	21.0	20.0	—	—	—	—	—	—	—	—
pH Q1:1	6.23	7.94	7.94	7.94	7.76	7.31	6.26	5.70	5.70	5.66	5.56
Constituents soluble in concentrated hydrochloric acid — %											
P_2O_5	0.005	0.006	0.006	—	—	—	—	0.004	—	—	—
CaO	0.071	0.292	0.544	—	—	—	—	nil	—	—	—
MgO	0.110	0.740	0.814	—	—	—	—	0.271	—	—	—
K_2O	0.078	0.388	0.426	—	—	—	—	0.211	—	—	—
Na_2O	—	—	0.451	—	—	—	—	0.277	—	—	—
Exchangeable metal cations											
Total m. eq./100g soil		17.78	17.56	—	—	—	—	8.30	—	—	—
Total m. eq./100g clay		63.2	59.5	—	—	—	—	31.2	—	—	—
Ca — % of total cations		23	16	—	—	—	—	nil	—	—	—
Mg — % of total cations		40	40	—	—	—	—	51	—	—	—
K — % of total cations		6	6	—	—	—	—	7	—	—	—
Na — % of total cations		31	38	—	—	—	—	42	—	—	—
Total water soluble salts — percentage of oven dry fine earth											
T.W.S.S	0.092	0.496	0.568	0.568	0.980?	0.832?	0.400	0.424	0.696?	0.396	0.448
NaCl (Cl x 1.648)	0.013	0.290	0.389	0.363	0.366	0.287	0.284	0.231	0.257	0.254	0.284
NaCl/T.W.S.S. Percentage	14.1	58.4	68.5	63.9	37.4?	34.5	71.0	54.5?	36.9?	64.1	63.4

Big lime nodules, 36—122 (14—48")

Appendix 4 Mechanical analyses and chemical data

Locality	South Kumarl, Fitzgerald Location 568															
Soil type	**Circle Valley sand — CVs**															
Serial No.	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841
Depth — cm	0—8	8—13	13—20	20—38	38—81	81—97	97—147	147—191	191—213	213—262	262—323	323—381	381—467	467—518	518—559	559—610
— inches	0—3	3—5	5—8	8—15	15—32	32—38	38—58	58—75	75—84	84—103	103—127	127—150	150—184	184—204	204—220	220—240
Mechanical analysis — percentage of air dry fine earth																
Coarse sand 2.0—0.2mm	24.7	—	20.1	16.3	18.6	—	—	—	—	—	—	13.2	—	—	—	—
Fine sand 0.2—0.02mm	65.1	—	54.9	35.0	41.1	—	—	—	—	—	—	40.0	—	—	—	—
Silt 0.02—0.002mm	2.0	—	2.4	2.8	0.8	—	—	—	—	—	—	1.6	—	—	—	—
Clay <0.002mm	6.7	—	20.4	38.4	32.4	—	—	—	—	—	—	41.9	—	—	—	—
Coarse sand/fine sand ratio	0.38	—	0.37	0.46	0.45	—	—	—	—	—	—	0.33	—	—	—	—
Chemical properties — percentage of air dry fine earth																
$CaCO_3$ (from CO_2)	0.1	—	0.05	2.3	3.0	—	—	—	—	—	—	Nil	—	—	—	—
Organic carbon	0.77	—	0.46	0.23	0.11	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.028	—	0.027	0.024	0.011	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	27.5	—	17.0	9.6	10.6	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:1	6.96	7.36	8.24	8.64	8.63	8.57	8.48	8.45	8.36	7.23	4.86	4.51	4.23	4.08	4.02	4.04
Constituents soluble in concentrated hydrochloric acid — %																
P_2O_5	0.004	—	0.005	0.007	0.005	—	—	—	—	—	—	0.003	—	—	—	—
CaO	—	—	—	—	1.346	—	—	—	—	—	—	nil	—	—	—	—
MgO	—	—	—	—	1.099	—	—	—	—	—	—	0.689	—	—	—	—
K_2O	—	—	—	—	1.052	—	—	—	—	—	—	0.928	—	—	—	—
Na_2O	—	—	—	—	0.421	—	—	—	—	—	—	0.516	—	—	—	—
Exchangeable metal cations																
Total m. eq./100g soil	—	—	—	—	15.75	—	—	—	—	—	—	13.04	—	—	—	—
Total m. eq./100g clay	—	—	—	—	48.6	—	—	—	—	—	—	31.1	—	—	—	—
Ca — % of total cations	—	—	—	—	13	—	—	—	—	—	—	Nil	—	—	—	—
Mg — % of total cations	—	—	—	—	34	—	—	—	—	—	—	47	—	—	—	—
K — % of total cations	—	—	—	—	14	—	—	—	—	—	—	10	—	—	—	—
Na — % of total cations	—	—	—	—	39	—	—	—	—	—	—	43	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth																
T.W.S.S	0.029	0.037	0.383	0.512	0.517	0.528	0.594	0.676	0.730	0.842	0.799	0.784	0.768	0.842	0.875	1.038
NaCl (Cl x 1.648)	0.003	0.003	0.067	0.287	0.353	0.384	0.500	0.518	0.568	0.588	0.660	0.658	0.668	0.726	0.767	0.900
NaCl/T.W.S.S. Percentage	10.3	8.1	17.5	56.0	68.2	72.7	84.1	76.6	77.8	69.8	82.6	83.9	87.0	86.2	87.6	86.7

Soft lime and lime nodules, 20—262 cm (8—103"), especially at 38—97 cm (15—38"). Brown red and grey mottled sandy clay, 262—610 cm (103—240") Feruginous sandstone pieces 323 + cm (127" +)

Appendix 4 Mechanical analyses and chemical data

Locality	East Salmon Gums, Fitzerald Location 516															
Soil type	**Circle Valley sand — CVs**															
Serial No.	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082
Depth — cm	0—13	13—30	30—53	53—76	76—117	117—183	183—213	213—274	274—335	335—396	396—457	457—518	518—549	549—610	610—640	640—655
— inches	0—5	5—12	12—21	21—30	30—46	46—72	72—84	84—108	108—132	132—156	156—180	180—204	204—216	216—240	240—252	252—258
Mechanical analysis — percentage of air dry fine earth																
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth																
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Organic carbon	0.428	0.404	0.191	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.022	0.025	0.025	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	19.4	16.1	7.6	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.12	8.65	8.67	8.55	8.40	6.78	?	4.41	4.22	4.08	3.88	3.88	3.91	3.85	?	3.88
Constituents soluble in concentrated hydrochloric acid — %																
P_2O_5	0.004	0.005	0.006	—	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	0.156	0.681	1.094	—	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations																
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth																
T.W.S.S	0.074	0.334	0.462	0.569	0.642	0.821	0.711	0.685	0.698	0.743	0.735	0.705	0.622	0.647	0.623	0.562
NaCl (Cl x 1.648)	0.010	0.156	0.317	0.403	0.481	0.547	0.569	0.550	0.552	0.590	0.587	0.570	0.500	0.532	0.506	0.471
NaCl/T.W.S.S. Percentage	13.5	46.7	68.6	70.8	74.9	66.6	80.0	80.3	79.1	79.4	79.8	80.8	80.4	82.2	81.2	83.8

Lime nodules, 28—117 cm (11—46″). Mottled sandy clay — white and feruginous sandstone below 610 cm (240″)

Appendix 4 Mechanical analyses and chemical data

Locality	East Grass Patch, Fitzgerald Location 542					
Soil type	**Circle Valley sand — CVs**					
Serial No.	1298	1299	1300	1301	1302	1303
Depth — cm	0—13	13—20	30—43	43—97	97—122	122—163
— inches	0—5	5—8	8—17	17—38	38—48	48—64
Mechanical analysis — percentage of air dry fine earth						
Coarse sand 2.0—0.2mm	25.3	19.6	16.6	15.8	14.0	10.8
Fine sand 0.2—0.02mm	66.3	58.4	38.4	36.0	35.6	25.9
Silt 0.02—0.002mm	0.8	0.9	2.1	1.9	0.3	1.2
Clay <0.002mm	7.0	18.6	34.2	33.7	37.0	38.3
Coarse sand/fine sand ratio	0.38	0.34	0.43	0.44	0.39	0.41
Chemical properties — percentage of air dry fine earth						
$CaCO_3$ (from CO_2)	0.05	0.07	4.3	9.6	10.0	22.3
Organic carbon	0.72	—	—	—	—	—
Total nitrogen	0.028	—	—	—	—	—
C/N ratio	25.7	—	—	—	—	—
pH Q 1:2.5	6.64	8.14	8.31	8.31	8.26	8.43
Constituents soluble in concentrated hydrochloric acid — %						
P_2O_5	—	—	—	—	—	—
CaO	—	—	—	—	—	—
MgO	—	—	—	—	—	—
K_2O	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—
Exchangeable metal cations						
Total m. eq./100g soil	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth						
T.W.S.S	0.171	0.390	0.695	0.868	0.820	0.731
NaCl (Cl x 1.648)	0.011	0.159	0.477	0.626	0.621	0.534
NaCl/T.W.S.S. Percentage	6.4	40.7	68.6	72.1	75.7	73.0

Appendix 4 Mechanical analyses and chemical data

Locality:	East Red Lake, Fitzgerald Location 33									
Soil type	Circle Valley sand — CVs									
Serial No.	1344	1345	1346	1347	1348	1349	1350	1351	1352	1353
Depth — cm	0—10	10—15	15—76	76—130	130—183	183—244	244—305	305—366	366—404	404—434
— inches	0—4	4—6	6—30	30—51	51—72	72—96	96—120	120—144	144—159	159—171
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	Sand	18.2	10.7	—	—	—	—	11.3	—	—
Fine sand 0.2—0.02mm	—	47.4	26.1	—	—	—	—	28.1	—	—
Silt 0.02—0.002mm	—	3.6	3.0	—	—	—	—	1.1	—	—
Clay <0.002mm	—	26.2	51.5	—	—	—	—	52.8	—	—
Coarse sand/fine sand ratio	—	0.38	0.41	—	—	—	—	0.40	—	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	—	0.2	3.6	—	—	—	—	nil	—	—
Organic carbon	—	1.31	—	—	—	—	—	—	—	—
Total nitrogen	—	0.045	—	—	—	—	—	—	—	—
C/N ratio	—	29.1	—	—	—	—	—	—	—	—
pH Q1:1	6.83	7.44	8.58	8.38	7.58	5.42	4.68	4.38	4.29	4.48
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	—	0.005	—	—	—	—	—	—	—	—
CaO	—	—	1.603	—	—	—	—	0.011	—	—
MgO	—	—	1.481	—	—	—	—	0.608	—	—
K_2O	—	0.718	1.625	—	—	—	—	1.328	—	—
Na_2O	—	—	0.646	—	—	—	—	0.719	—	—
Exchangeable metal cations										
Total m. eq./100g soil	—	18.19	27.17	—	—	—	—	18.23	—	—
Total m. eq./100g clay	—	69.4	52.7	—	—	—	—	34.5	—	—
Ca — % of total cations	—	16	12	—	—	—	—	nil	—	—
Mg — % of total cations	—	50	40	—	—	—	—	47	—	—
K — % of total cations	—	8	13	—	—	—	—	10	—	—
Na — % of total cations	—	26	35	—	—	—	—	43	—	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S.S	0.069	0.683?	0.679	0.934	0.878	1.104	1.158	1.216	1.286	0.716
NaCl (Cl x 1.648)	0.009	0.247	0.546	0.718	0.703	0.845	0.884	0.923	0.986	0.568
NaCl/T.W.S.S. Percentage	13.0	36.2?	80.4	76.8	80.1	76.5	76.3	75.9	76.6	79.3

Lime rubble, especially at 15—76 cm (6—30″). Mottled sandy clay on sandstone 434 cm (171″). Decomposed sandstone and clay pockets 404—434 cm.

Appendix 4 Mechanical analyses and chemical data

Locality:	**East Truslove, Esperance Location 1310**						
Soil type	Circle Valley sand — CVs						
Serial No.	1416	1417	1418	1419	1420	1421	1422
Depth — cm	0—8	8—10	10—53	53—84	84—124	124—183	183—208
— inches	0—3	3—4	4—21	21—33	33—49	49—72	72—82
Mechanical analysis — percentage of air dry fine earth							
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth							
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—
Total notrogen	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—
pH Q 1:2.5	7.90	8.41	8.86	8.95	8.63	6.80	5.58
Constituents soluble in concentrated hydrochloric acid — %							
P_2O_5	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—
Exchangeable metal cations							
Total m. eq./100g soil	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	-	—
Total water soluble salts — percentage of oven dry fine earth							
T.W.S.S	0.042	0.392	0.482	0.548	0.618	0.570	0.514
NaCl (Cl x 1.648)	0.012	0.160	0.294	0.352	0.452	0.440	0.422
NaCl/T.W.S.S. Percentage	28.5	40.8	61.0	64.2	73.1	77.1	82.1

Soft lime and some hard nodules, 10—124 cm (4—49"). Subsoil clay tends to domes as in Scaddan sand. Subsoil hard tending to Truslove sand.

Appendix 4 Mechanical analyses and chemical data

Locality:	East Dowak, Fitzgerald Location 588												
Soil type	**Circle Vallěy sand — CVs — Virgin soil (adjacent area cleared 2-3 years). April 4-5, 1933.**												
Serial No.	852	853	854	855	856	857	858	859	860	861	862	863	864
Depth — cm	0—10	10—25	25—43	43—84	84—122	122—152	152—213	213—274	274—335	335—396	396—457	457—518	518—568
— inches	0—4	4—10	10—17	17—33	33—48	48—60	60—84	84—108	108—132	132—156	156—180	180—204	204—224
Mechanical analysis — percentage of air dry fine earth													
Coarse sand 2.0—0.2mm	34.6	25.5	18.6	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	50.9	33.3	26.8	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	2.6	2.8	2.5	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	8.1	34.6	40.3	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.68	0.77	0.69	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth													
$CaCO_3$ (from CO_2)	0.2	0.8	7.2	—	—	—	—	—	—	—	—	—	—
Organic carbon	0.90	0.45	0.34	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.031	0.027	0.014	—	—	—	—	—	—	—	—	—	—
C/N ratio	29.1	16.7	24.3	—	—	—	—	—	—	—	—	—	—
pH Q 1:1	6.79	8.03	8.03	7.96	7.85	7.66	5.13	4.24	4.42	3.97	4.00	4.35	3.92
Constituents soluble in concentrated hydrochloric acid — %													
P_2O_5	0.005	0.006	0.006	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	0.147	0.719	0.921	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations													
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % (of total cations)	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % (of total cations)	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % (of total cations)	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % (of total cations)	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth													
T.W.S.S	0.086	0.391	0.568	0.762	0.890	0.921	0.884	0.817	0.686	0.598	0.574	0.621	0.707
NaCl (Cl x 1.648)	0.014	0.221	0.374	0.584	0.735	0.787	0.77	0.698	0.554	0.480	0.445	0.468	0.545
NaCl/T.W.S.S. Percentage	16.2	56.5	65.8	76.6	82.5	85.4	87.2	85.4	80.7	80.2	77.5	75.3	77.1

Lime nodules and soft lime, 25—152cm (10—60"). Brown, red-brown, grey mottled sandy clay 152—569 cm (60—224") on sandstone.

Appendix 4 Mechanical analyses and chemical data

Locality:	East Circle Valley, Fitzgerald Location 422									
Soil type	**Circle Valley sand — CVs — Virgin soil (adjacent area cleared and farmed for several years).**									
Serial No.	1115	1116	1117	1118	1119	1120	1121	1122	1123	1124
Depth — cm	0—15	15—30	30—61	61—91	91—122	122—183	183—274	274—366	366—457	457—495
— inches	0—6	6—12	12—24	24—36	36—48	48—72	72—108	108—144	144—180	180—195
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	29.4	19.6	19.2	—	—	—	—	—	17.9	—
Fine sand 0.2—0.02mm	65.0	51.6	43.9	—	—	—	—	—	47.6	—
Silt 0.02—0.002mm	0.8	1.0	0.4	—	—	—	—	—	0.5	—
Clay <0.002mm	3.5	23.9	31.1	—	—	—	—	—	29.3	—
Coarse sand/fine sand ratio	0.45	0.38	0.44	—	—	—	—	—	0.38	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	nil	0.7	1.2	—	—	—	—	—	nil	—
Organic carbon	0.64	0.28	0.15	—	—	—	—	—	—	—
Total nitrogen	0.025	0.018	0.010	—	—	—	—	—	—	—
C/N ratio	25.6	15.5	15.0	—	—	—	—	—	—	—
pH Q 1:2.5	6.87	8.66	8.54	8.66	8.59	8.45	8.42	7.29	4.36	3.93
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	0.001	0.003	0.004	—	—	—	—	—	0.003	—
CaO	—	—	0.602	—	—	—	—	—	0.036	—
MgO	—	—	0.769	—	—	—	—	—	0.540	—
K_2O	—	—	0.899	—	—	—	—	—	0.753	—
Na_2O	—	—	0.459	—	—	—	—	—	0.515	—
Exchangeable metal cations										
Total m. eq./100g soil	—	—	16.03	—	—	—	—	—	11.31	—
Total m. eq./100g clay	—	—	51.5	—	—	—	—	—	38.6	—
Ca — % of total cations	—	—	15	—	—	—	—	—	7	—
Mg — % of total cations	—	—	35	—	—	—	—	—	40	—
K — % of total cations	—	—	11	—	—	—	—	—	9	—
Na — % of total cations	—	—	39	—	—	—	—	—	44	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S.S	0.067	0.497	0.637	0.641	0.545	0.621	0.699	0.773	0.821	0.803
NaCl (Cl x 1.648)	0.007	0.328	0.443	0.487	0.450	0.538	0.531	0.632	0.687	0.752
NaCl/T.W.S.S. Percentage	10.4	66.0	69.5	76.0	82.5	86.6	76.0	81.8	83.6	93.6

Lime nodules and soft lime. 30—274 cm (12—108"). Mottled sandy clay. 274—495 cm (108—195"). Ferriginous sandstone 495 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Dowak, Fitzgerald Location 588													
Soil type	**Circle Valley sand — CVs — Cleared area (adjacent to serial numbers 852 to 864) Cleared 2-3 years and cropped**													
Serial No.	865	866	867	868	869	870	871	872	873	874	875	876	877	878
Depth — cm	0—10	10—20	20—33	33—64	64—91	91—147	147—213	213—274	274—335	335—396	396—457	457—518	518—578	579—610
— inches	0—4	4—8	8—13	13—25	25—36	36—58	58—84	84—108	108—132	132—156	156—180	180—204	204—228	228—240
Mechanical analysis — percentage of air dry fine earth														
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth														
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Constituents soluble in concentrated hydrochloric acid — %														
P_2O_5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations														
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth														
T.W.S.S	0.095	0.204	0.261	0.522	0.610	0.904	0.943	0.859	0.796	0.648	0.624	0.620	0.711	1.021
NaCl (Cl x 1.648)	0.013	0.031	0.063	0.249	0.382	0.681	0.792	0.722	0.640	0.550	0.515	0.503	0.585	0.838
NaCl/T.W.S.S. Percentage	13.6	15.1	24.1	47.7	62.6	75.3	83.9	84.0	80.4	84.8	82.5	81.1	82.2	82.0

Lime nodules and soft lime. 20—137cm (8-54"). Mottled sandy clay 147—670cm on sandstone.

Appendix 4 Mechanical analyses and chemical data

Locality	East Circle Valley, Fitzgerald Location 422								
Soil type	**Circle Valley sand — CVs — Cleared area (adjacent to serial numbers 1115 to 1124).**								
Serial No.	1125	1126	1127	1128	1129	1130	1131	1132	1133
Depth — cm	0—18	18—33	33—64	64—94	94—124	124—183	183—274	274—366	366—460
— inches	0—7	7—13	13—25	25—37	37—49	49—72	72—108	108—144	144—181
Mechanical analysis — percentage of air dry fine earth									
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth									
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.34	8.85	8.88	8.72	8.62	8.38	7.99	4.47	4.04
Constituents soluble in concentrated hydrochloric acid — %									
P_2O_5	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—
Exchangeable metal cations									
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth									
T.W.S.S	0.061	0.155	0.314	0.430	0.495	0.535	0.754	0.725	0.786
NaCl (Cl x 1.648)	0.006	0.033	0.122	0.206	0.284	0.430	0.593	0.644	0.692
NaCl/T.W.S.S. Percentage	9.8	21.3	38.9	47.9	57.3	80.3	78.6	88.8	88.0

Lime nodules and soft lime. 30—274 cm (12—108"). Mottled sandy clay. 274—460 cm (108—181"). Ferruginous sandstone 460 cm (195").

Appendix 4 Mechanical analyses and chemical data

Locality	East Grass Patch, Fitzgerald Location 49												
Soil type	**Circle Valley sandy loam — CVsl**												
Serial No.	1385	1386	1387	1388	1389	1390	1391	1392	1393	1394	1395	1396	1397
Depth — cm	0—8	8—25	25—46	46—91	91—127	127—183	183—251	251—305	305—396	396—488	488—549	549—602	602—650
— inches	0—3	3—10	10—18	18—36	36—50	50—72	72—99	99—120	120—156	156—192	192—216	216—237	237—256
Mechanical analysis — percentage of air dry fine earth													
Coarse sand 2.0—0.2mm		7.5	7.7	4.7	—	—	—	8.5	—	—	—	—	—
Fine sand 0.2—0.02mm		37.3	34.2	23.6	—	—	—	36.7	—	—	—	—	—
Silt 0.02—0.002mm		0.4	0.9	0.0	—	—	—	1.5	—	—	—	—	—
Clay <0.002mm		38.7	33.8	28.4	—	—	—	49.2	—	—	—	—	—
Coarse sand/fine sand ratio		0.20	0.22	0.20	—	—	—	0.23	—	—	—	—	—
Chemical properties — percentage of air dry fine earth													
$CaCO_3$ (from CO_2)		10.0	18.6	31.4	—	—	—	nil	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	6.29	8.78	9.01	8.78	8.60	8.31	6.67	5.21	4.97	4.90	4.63	4.56	4.76
Constituents soluble in concentrated hydrochloric acid — %													
P_2O_5		0.004	0.002	0.002	—	—	—	0.002	—	—	—	—	—
CaO			8.960	—	—	—	—	0.003	—	—	—	—	—
MgO			7.358	—	—	—	—	0.618	—	—	—	—	—
K_2O		1.232	1.149	1.227	—	—	—	1.057	—	—	—	—	—
Na_2O			0.065	—	—	—	—	0.596	—	—	—	—	—
Exchangeable metal cations													
Total m. eq./100g soil			16.43	—	—	—	—	18.34	—	—	—	—	—
Total m. eq./100g clay			57.8	—	—	—	—	37.3	—	—	—	—	—
Ca — % of total cations			5	—	—	—	—	1	—	—	—	—	—
Mg — % of total cations			34	—	—	—	—	43	—	—	—	—	—
K — % of total cations			19	—	—	—	—	11	—	—	—	—	—
Na — % of total cations			42	—	—	—	—	45	—	—	—		—
Total water soluble salts — percentage of oven dry fine earth													
T.W.S.S	0.044	0.626	0.724	0.846	1.054	0.998	0.860	0.892	0.922	0.922	1.020	0.736	0.648
NaCl (Cl x 1.648)	0.009	0.358	0.435	0.560	0.739	0.719	0.608	0.614	0.645	0.651	0.730	0.560	0.486
NaCl/T.W.S.S. Percentage	20.4	57.2	60.1	66.2	70.1	72.0	70.7	68.8	70.0	70.6	71.6	76.1	75.0

Soft lime and some nodules. 25—183cm (10—72"). Rounded pebbles at 610cm (240") Sandstone at 650cm (256")

Appendix 4 Mechanical analyses and chemical data

Locality	East Red Lake, Fitzgerald Location 11									
Soil type	**Natural grass patch 200 metres (diameter) (North Patch) — CVsl**									
Serial No.	1354	1355	1356	1357	1358	1359	1360	1361	1362	1363
Depth — cm	0—18	18—38	38—76	76—119	119—183	183—229	229—274	274—315	315—348	348—396
— inches	0—7	7—15	15—30	30—47	47—72	72—90	90—108	108—124	124—137	137—156
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	Dark-	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	grey	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	sandy	—	—	—	—	—	—	—	—	—
Clay <0.002mm	loam	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.68	8.86	8.90	8.90	8.58	7.96	6.77	5.18	4.76	4.48
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations										
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S.S	0.073	0.115	0.144	0.560	0.600	0.600	0.646	0.742	0.738	0.686
NaCl (Cl x 1.648)	0.006	0.029	0.277	0.340	0.400	0.449	0.483	0.540	0.543	0.520
NaCl/T.W.S.S. Percentage	8.2	25.2	62.8	60.7	66.7	74.8	74.8	72.8	73.6	75.8

Soft lime and lime nodules 18—183cm in grey-brown sandy clay. Red-brown grey, white and yellow mottled sandy clay on ferruginous sandstone at 396cm.

Appendix 4 Mechanical analyses and chemical data

Locality	**West Scaddan, Esperance Location 509**					
Soil type	**Scaddan sand — Ss.**					
Serial No.	1660	1661	1662	1663	1664	1665
Depth — cm	0—8	8—20	20—30	30—61	61—97	—
— inches	0—3	3—8	8—12	12—24	34—38	—
Mechanical analysis — percentage of air dry fine earth						
Coarse sand 2.0—0.2mm	—	17.3	14.8	10.9	—	—
Fine sand 0.2—0.02mm	—	45.8	45.2	27.5	—	—
Silt 0.02—0.002mm	—	2.6	2.6	2.0	—	—
Clay <0.002mm	—	30.2	33.2	37.5	—	—
Coarse sand/fine sand ratio	—	0.38	0.33	0.40	—	—
Chemical properties — percentage of air dry fine earth						
$CaCO_3$ (from CO_2)	—	0.1	1.1	17.0	—	—
Organic carbon	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—
pH Q 1:2.5	7.39	7.68	8.39	8.56	8.40	—
Constituents soluble in concentrated hydrochloric acid — %						
P_2O_5	—	—	—	—	—	—
CaO	—	—	—	—	—	—
MgO	—	—	—	—	—	—
K_2O	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—
Exchangeable metal cations						
Total m. eq./100g soil	—	—	—	20.65	—	—
Total m. eq./100g clay	—	—	—	55.6	—	—
Ca — % of total cations	—	—	—	16	—	—
Mg — % of total cations	—	—	—	41	—	—
K — % of total cations	—	—	—	6	—	—
Na — % of total cations	—	—	—	37	—	—
Total water soluble salts — percentage of oven dry fine earth						
T.W.S.S	0.058	0.249	0.307	0.504	0.570	—
NaCl (Cl x 1.648)	0.015	0.103	0.169	0.302	0.401	—
NaCl/T.W.S.S. Percentage	25.8	41.3	55.0	59.9	70.3	—

Soft lime and small nodules, 30—97 cm. Decomposing gneiss or granite below 61 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	West Scaddan, Esperance Location 543						West Scaddan, Esperance Location 530						
Soil type	**Scaddan sand — Ss.**						**Scaddan sand — Ss**						
Serial No.	1672	1673	1674	1675	1676	1677	1684	1685	1686	1687	1688	1689	1690
Depth — cm	0—5	5—15	15—33	33—71	71—107	107—163	0—8	8—20	20—43	43—56	56—97	91—125	125—147
— inches	0—2	2—6	6—13	13—28	28—42	42—64	0—3	3—8	8—17	17—22	22—38	38—49	49—58
Mechanical analysis — percentage of air dry fine earth													
Coarse sand 2.0—0.2mm	—	18.0	17.3	16.3	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	43.5	42.6	38.8	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	1.8	Trace	Trace	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	32.9	35.0	36.1	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	0.41	0.41	0.42	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth													
$CaCO_3$ (from CO_2)	—	0.1	0.4	3.1	—	—	—	—	—	—	—	—	—
Organic carbon	—	0.74	0.34	0.12	—	—	—	—	—	—	—	—	—
Total nitrogen	—	0.028	0.017	0.008	—	—	—	—	—	—	—	—	—
C/N ratio	—	26.4	20.0	15.0	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.17?	6.80	7.88	8.47	8.14	6.77	6.46	7.09	7.80	8.64	8.06	7.23	5.71
Constituents soluble in concentrated hydrochloric acid — %													
P_2O_5	—	0.002	0.003	0.003	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	0.608	0.702	0.891	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations													
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth													
T.W.S.S	0.068	0.205	0.249	0.500	0.721	0.626	0.054	0.180	0.186	0.290	0.315	0.417	0.575
NaCl (Cl x 1.648)	0.010	0.053	0.112	0.333	0.562	0.477	0.09	0.020	0.067	0.129	0.217	0.307	0.417
NaCl/T.W.S.S. Percentage	14.2	25.8	44.9	66.6	77.9	76.1	16.6	11.1	36.0	44.4	68.8	73.6	72.5

Location 543: Lime nodules, 33—71 cm. Surface sand goes 13, 20 and 28cm between domes of subsoil.

Location 530: Lime, mainly at 43—56 cm. Decomposing rock pieces in clay below 97 cm. Acid gneiss boulders on surface.

Appendix 4 Mechanical analyses and chemical data

Locality	West Truslove, Esperance Location 954							
Soil type	Scaddan sand — Ss							
Serial No.	1743	1744	1745	1746	1747	1748	1749	1750
Depth — cm	0—5	5—20	20—69	69—91	91—27	127—183	183—244	244—284
— inches	0—2	2—8	8—27	27—36	36—50	50—72	72—96	96—112
Mechanical analysis — percentage of air dry fine earth								
Coarse sand 2.0—0.2mm	27.8	20.8	16.6	17.3	—	—	—	12.7
Fine sand 0.2—0.02mm	65.5	41.7	38.7	41.6	—	—	—	25.7
Silt 0.02—0.002mm	1.7	1.2	0.2	0.3	—	—	—	1.169
Clay <0.002mm	4.3	32.3	35.5	36.6	—	—	—	56.3
Coarse sand/fine sand ratio	0.42	0.50	0.43	0.43	—	—	—	0.49
Chemical properties — percentage of air dry fine earth								
$CaCO_3$ (from CO_2)	nil	0.1	4.3	1.0	—	—	—	nil
Organic carbon	0.595	0.663	0.153	0.085	—	—	—	0.169
Total nitrogen	0.027	0.028	0.013	0.011	—	—	—	0.011
C/N ratio	22.0	23.8	11.8	7.87	—	—	—	15.4
pH Q 1:2.5	6.92	7.40	8.55	8.35	—	—	—	4.45
Constituents soluble in concentrated hydrochloric acid — %								
P_2O_5	0.003	0.005	0.003	0.003	—	—	—	0.004
CaO	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—
K_2O	0.064	0.598	0.750	—	—	—	0.787	
Na_2O	—	—	—	—	—	—	—	—
Exchangeable metal cations								
Total m. eq./100g soil	2.39	18.40	19.34	18.87	—	—	—	15.01
Total m. eq./100g clay	51.9	54.0	54.5	51.6	—	—	—	26.6
Ca — % of total cations	61	21	18	13	—	—	—	1
Mg — % of total cations	23	49	41	45	—	—	—	52
K — % of total cations	11	6	8	9	—	—	—	9
Na — % of total cations	5	24	33	33	—	—	—	38
Total water soluble salts — percentage of oven dry fine earth								
T.W.S.S	0.034	0.25	0.47	0.51	0.52	0.53	0.58	0.64
NaCl (Cl x 1.648)	0.008	0.11	0.28	0.37	0.41	0.42	0.41	0.48
NaCl/T.W.S.S. Percentage	23.5	44.0	59.5	72.5	78.8	79.2	70.6	75.0

Soft lime and nodules 20—91cm

Appendix 4 Mechanical analyses and chemical data

Locality	East Truslove, near Esperance Location 887									Scaddan, Esperance Location 442					
Soil type	Truslove sand — Ts.									Truslove sand — Ts					
Serial No.	1432	1433	1434	1435	1436	1437	1438	1439	1440	1666	1667	1668	1669	1670	1671
Depth — cm	0—20	20—41	41—91	91—152	152—185	185—244	244—305	305—366	366—427	0—28	28—48	48—71	71—122	122—183	183—244
— inches	0—8	8—16	16—36	36—60	60—73	73—96	96—120	120—144	144—168	0—11	11—19	19—28	28—48	48—72	72—96
Mechanical analysis — percentage of air dry fine earth															
Coarse sand 2.0—0.2mm	30.2	21.6	19.9	—	—	—	—	—	—	25.7	16.7	16.9	—	—	—
Fine sand 0.2—0.02mm	66.7	38.7	32.4	—	—	—	—	—	—	71.1	47.3	46.8	—	—	—
Silt 0.02—0.002mm	0.1	0.0	0.0	—	—	—	—	—	—	0.8	0.9	nil	—	—	—
Clay <0.002mm	4.0	36.4	37.5	—	—	—	—	—	—	2.1	31.9	32.2	—	—	—
Coarse sand/fine sand ratio	0.45	0.56	0.61	—	—	—	—	—	—	0.36	0.35	0.36	—	—	—
Chemical properties — percentage of air dry fine earth															
$CaCO_3$ (from CO_2)	0.1	0.5	7.2	—	—	—	—	—	—	—	Trace	5.6	—	—	—
Organic carbon	0.15	0.22	0.23	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.004	0.021	0.013	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	37.5	10.4	17.6	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	6.39	8.56	8.78	8.78	8.81	8.71	8.51	7.34	6.66	6.89	7.92	8.61	8.57	8.64	8.64
Constituents soluble in concentrated hydrochloric acid — %															
P_2O_5	Trace	0.004	0.004	—	—	—	—	—	—	0.002	0.004	0.005	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	0.041	1.272	1.382	—	—	—	—	—	—	0.036	1.036	1.052	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations															
Total m. eq./100g soil	—	13.82	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	38.0	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	16	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	34	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	15	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	35	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth															
T.W.S.S	0.042	0.744	0.716	0.734	0.669	0.779	0.790	1.118	1.086	0.052	0.336	0.362	0.415	0.415	0.422
NaCl (Cl x 1.648)	0.009	0.422	0.548	0.615	0.524	0.653	0.673	0.847	0.903	0.008	0.171	0.215	0.253	0.262	0.277
NaCl/T.W.S.S. Percentage	21.4	56.7	76.5	83.8	79.1	84.1	85.1	75.7	83.1	15.4	50.9	59.3	61.0	63.1	65.6

East Truslove: Soft lime and lime nodules 41—244 cm Ferruginous sandstone at 427 cm

Scaddan: Soft lime and soft lime nodules 48—244 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Kumarl, Fitzgerald Location 994																			
Soil type	Beete calcareous sandy loam — Bsl																			
Serial No.	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810
Depth — cm	0-5	5-22	22-36	36-81	81-119	119-155	155-198	198-244	244-290	290-335	335-396	396-427	427-457	457-503	503-549	549-579	579-610	610-640	640-671	671-688
— metres	0-2	2-9	9-14	14-32	32-47	47-61	61-78	78-96	96-114	114-132	132-156	156-168	168-180	180-198	198-216	216-228	228-240	240-252	252-264	264-271
Mechanical analysis — percentage of air dry fine earth																				
Coarse sand 2.0—0.2mm	23.6	—	20.5	17.17	—	—	—	—	18.4	—	—	—	11.0	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	31.5	—	28.8	20.5	—	—	—	—	22.3	—	—	—	20.4	—	—	—	—	—	—	—
Silt 0.02—0.002m	8.9	—	8.2	3.8	—	—	—	—	2.9	—	—	—	4.7	—	—	—	—	—	—	—
Clay < 0.002mm	23.4	—	26.9	29.7	—	—	—	—	49.0	—	—	—	58.4	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.75	—	0.71	0.86	—	—	—	—	0.82	—	—	—	0.54	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth																				
$CaCO_3$ (from CO_2)	4.4	—	11.4	25.9	—	—	—	—	nil	—	—	—	nil	—	—	—	—	—	—	—
Organic carbon	2.08	—	0.63	0.45	—	—	—	—	0.16	—	—	—	0.09	—	—	—	—	—	—	—
Total nitrogen	0.077	—	0.036	0.018	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	27.0	—	17.5	25.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.78	8.09	8.17	8.18	7.82	7.78	5.28	4.22	4.00	3.83	3.65	3.61	3.53	3.46	3.53	3.50	3.48	3.46	3.50	3.50
Constituents soluble in concentrated hydrochloric acid — %																				
P_2O_5	0.010	—	0.009	0.006	—	—	—	—	0.006	—	—	—	0.004	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	0.012	—	—	—	0.025	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	0.708	—	—	—	0.716	—	—	—	—	—	—	—
K_2O	0.910	—	1.006	0.971	—	—	—	—	0.993	—	—	—	1.026	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	0.507	—	—	—	0.594	—	—	—	—	—	—	—
Exchangeable metal cations																				
Total m. eq./100g soil	24.38	—	21.34	17.67	—	—	—	—	16.04	—	—	—	14.16	—	—	—	—	—	—	—
Total m. eq./100g clay	96.0	—	79.3	59.5	—	—	—	—	32.7	—	—	—	24.2	—	—	—	—	—	—	—
Ca — % of total cations	44	—	15	10	—	—	—	—	nil	—	—	—	1	—	—	—	—	—	—	—
Mg — % of total cations	34	—	40	37	—	—	—	—	43	—	—	—	25	—	—	—	—	—	—	—
K — % of total cations	8	—	12	15	—	—	—	—	11	—	—	—	13	—	—	—	—	—	—	—
Na — % of total cations	14	—	33	38	—	—	—	—	46	—	—	—	61	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth																				
T.W.S.S	0.142	0.410	0.437	0.526	0.606	0.645	0.636	0.654	0.688	0.694	0.738	0.783	0.798	0.820	0.844	0.875	0.866	0.904	0.913	0.919
NaCl (Cl x 1.648)	0.009	0.129	0.270	0.308	0.383	0.407	0.425	0.454	0.481	0.484	0.520	0.553	0.571	0.592	0.623	0.640	0.640	0.652	0.661	0.672
NaCl/T.W.S.S. Percentage	7.5	31.5	61.8	58.5	63.2	63.1	66.8	69.4	69.9	69.7	71.4	70.6	71.6	72.2	73.8	73.1	73.9	72.1	72.4	73.1

Soft lime at surface to 155cm (61") Lime nodules at 22—36cm (9—14"). Mottled stiff clay below 155cm (61") living roots and rootlets 610—671cm (240—264")

Appendix 4 Mechanical analyses and chemical data

Locality	East Kumarl, Fitzgerald Location 575									
Soil type	**Beete calcareous sandy loam — Bsl**									
Serial No.	842	843	844	845	846	847	848	849	859	851
Depth — cm	0—8	8—18	18—28	28—41	41—91	91—124	124—218	218—330	330—417	417—475
— inches	0—3	3—7	7—11	11—16	16—36	36—49	49—86	86—130	130—164	164—187
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.47	8.69	8.54	8.63	8.69	8.49	8.17	6.01	4.66	4.37
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations										
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S.S	0.110	0.170	0.470	0.648	0.760	0.802	0.891	0.908	0.832	0.828
NaCl (Cl x 1.648)	0.008	0.025	0.314	0.390	0.466	0.521	0.594	0.623	0.556	0.556
NaCl/T.W.S.S. Percentage	7.2	14.7	66.8	60.2	61.3	64.9	66.6	68.6	66.8	67.1

Powdery and calcareous, 0—18 cm (0—7"). Brown clay, much soft lime 18—24 cm (7—49"). Brown, red and grey mottled stiff clay below 124cm (48") and no lime apparent.

Appendix 4 Mechanical analyses and chemical data

Locality	East Dowak, Fitzgerald Location 496														
Soil type	**Beete calcareous sandy loam — Bsl**														
Serial No.	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893
Depth — cm	0—15	15—38	38—74	74—114	114—152	152—183	183—213	213—244	244—269	269—290	290—335	335—396	396—457	457—488	488—549
— inches	0—6	6—15	15—29	29—45	45—60	60—72	72—84	84—96	96—106	106—114	114—132	132—156	156—180	180—192	192—216
Mechanical analysis — percentage of air dry fine earth															
Coarse sand 2.0—0.2mm	19.5	9.2	10.2	—	—	—	—	—	—	—	—	—	18.2	—	—
Fine sand 0.2—0.02mm	26.5	10.5	9.8	—	—	—	—	—	—	—	—	—	20.3	—	—
Silt 0.02—0.002mm	15.1	9.0	5.8	—	—	—	—	—	—	—	—	—	0.1	—	—
Clay <0.002mm	16.3	16.0	21.3	—	—	—	—	—	—	—	—	—	57.0	—	—
Coarse sand/fine sand ratio	0.74	0.88	1.04	—	—	—	—	—	—	—	—	—	0.90	—	—
Chemical properties — percentage of air dry fine earth															
$CaCO_3$ (from CO_2)	7.6	45.2	52.3	55.0	44.6	—	—	—	—	—	—	—	nil	—	—
Organic carbon	2.14	0.68	0.42	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.164	0.046	0.014	—	—	—	—	—	—	—	—	—	0.008	—	—
C/N ratio	13.0	14.8	30.0	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.44	8.79	9.00	8.79	8.74	8.60	8.41	8.44	8.06	7.86	7.24	5.02	4.85	4.50	4.60
Constituents soluble in concentrated hydrochloric acid — %															
P_2O_5	0.017	0.007	0.003	0.006	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	8.876	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	19.58	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	0.563	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	0.695	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations															
Total m. eq./100g soil	—	—	17.41	—	—	—	—	—	—	—	—	—	11.11	—	—
Total m. eq./100g clay	—	—	81.7	—	—	—	—	—	—	—	—	—	19.5	—	—
Ca — % of total cations	—	—	10	—	—	—	—	—	—	—	—	—	1	—	—
Mg — % of total cations	—	—	23	—	—	—	—	—	—	—	—	—	41	—	—
K — % of total cations	—	—	11	—	—	—	—	—	—	—	—	—	10	—	—
Na — % of total cations	—	—	56	—	—	—	—	—	—	—	—	—	48	—	—
Total water soluble salts — percentage of oven dry fine earth															
T.W.S.S	0.446	0.920	0.760	0.660	0.720	0.820	0.900	0.920	0.866	0.700	0.820	0.820	0.860	0.700	0.660
NaCl (Cl x 1.648)	0.246	0.681	0.517	0.468	0.517	0.535	0.657	0.657	0.665	0.566	0.599	0.616	0.681	0.632	0.550
NaCl/T.W.S.S. Percentage	55.9	74.0	68.6	70.9	71.8	64.6	73.6	71.4	77.3	80.8	73.6	75.1	79.2	90.2	83.3

Soft lime 0—152 cm, lime rubble to 213 cm. Quartz, ironstone and siliceous grit pebbles 183—244 cm. Small rootlets 335—457 cm. Mottled stiff clay. White pockets.

Appendix 4 Mechanical analyses and chemical data

Locality	West Dowak, Fitzgerald Location 309								
Soil type	**Beete calcareous sandy loam — Bsl**								
Serial No.	923	924	925	926	927	928	929	930	931
Depth — cm	0—12	12—30	30—66	66—89	89—122	122—213	213—259	295—335	335—366
— inches	0—5	5—12	12—26	26—35	35—48	48—84	84—102	102—132	132—144
Mechanical analysis — percentage of air dry fine earth									
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth									
$CaCO_3$ (from CO_2)	18.15	34.89	57.68	32.75	—	—	—	—	—
Organic carbon	3.01	1.31	0.32	0.11	—	—	—	—	—
Total nitrogen	0.204	0.090	0.029	0.015	—	—	—	—	—
C/N ratio	14.8	14.5	11.0	7.3	—	—	—	—	—
pH Q 1:2.5	8.37	9.05	8.86	8.51	8.42	8.17	7.99	7.92	7.92
Constituents soluble in concentrated hydrochloric acid — %									
P_2O_5	0.028	0.013	0.003	0.002	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—
K_2O	0.555	0.536	0.587	1.105	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—
Exchangeable metal cations									
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth									
T.W.S.S	0.260	0.660	0.614	0.675	0.804	0.758	0.790	0.490	0.520
NaCl (Cl x 1.648)	0.085	0.388	0.392	0.545	0.604	0.586	0.660	0.398	0.426
NaCl/T.W.S.S. Percentage	32.6	58.7	63.8	80.7	75.1	77.3	83.5	81.2	81.9

Lime nodules, 12—66cm (5—26"). Soft lime, 0—122 cm (0—48") Soil contains $MgCO_3$.

Appendix 4 Mechanical analyses and chemical data

Locality	East Circle Valley, Fitzgerald Location 617								East Red Lake, Fitzgerald Location 136					
Soil type	Beete calcareous sandy loam — Bsl								Beete calcareous sandy loam — Bsl					
Serial No.	1317	1318	1319	1320	1321	1322	1323	1324	1134	1135	1136	1137	1138	1139
Depth — cm	0—28	28—43	43—74	74—122	122—163	163—185	185—246	246—295	0—28	28—46	46—122	122—183	183—259	259—325
— inches	0—11	11—17	17—29	29—48	48—64	64—73	73—97	97—116	0—11	11—18	18—48	48—72	72—102	102—128
Mechanical analysis — percentage of air dry fine earth														
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	11.0	8.6	7.4	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	37.2	23.9	25.5	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	13.7	8.7	6.8	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	12.4	8.7	15.2	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	0.30	0.36	0.29	—	—	—
Chemical properties — percentage of air dry fine earth														
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	12.8	38.6	35.6	—	—	nil
Organic carbon	—	—	—	—	—	—	—	—	1.77	0.49	0.34	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	0.154	0.041	0.018	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	11.5	12.0	18.8	—	—	—
pH Q 1:2.5	8.53	9.00	8.83	8.78	8.66	8.26	7.64	6.57	8.48	8.62	8.62	8.45	7.99	7.84
Constituents soluble in concentrated hydrochloric acid — %														
P_2O_5	—	—	—	—	—	—	—	—	0.007	0.003	0.003	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	0.691	0.519	0.705	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations														
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth														
T.W.S.S	0.633	1.045	0.647	0.705	0.857	0.961	0.985	0.853	0.621	1.043	0.787	0.717	0.731	0.771
NaCl (Cl x 1.648)	0.289	0.720	0.448	0.506	0.634	0.794	0.831	0.703	0.301	0.796	0.573	0.514	0.527	0.597
NaCl/T.W.S.S. Percentage	45.6	68.9	69.2	71.8	74.0	82.6	84.4	82.4	48.4	76.3	72.8	71.6	72.1	75.1
	Soft lime, 0—25cm. Less below 183cm. Some small lime nodules. Stiff sandy clay below 244cm								Soft lime and small nodules, 0—163cm. Powdery surface and very calcareous to 122cm. Brown, red-brown and grey mottled stiff clay, 163—295cm					

Appendix 4 Mechanical analyses and chemical data

Locality	East Red Lake, Fitzgerald Location 33								West Scaddan, Esperance Location 529							
Soil type	**Beete calcareous sandy loam — Bsl**								**Beete calcareous sandy loam — Bsl**							
Serial No.	1336	1337	1338	1339	1340	1341	1342	1343	1651	1652	1653	1654	1655	1656	1657	1658
Depth — cm	0—13	13—23	23—61	61—107	107—152	152—213	213—264	264—389	0—13	13—25	25—53	53—89	89—124	124—183	183—229	229—234
— inches	0—5	5—9	9—24	24—42	42—60	60—84	84—104	104—133	0—5	5—10	10—21	21—35	35—49	49—72	72—90	90—92
Mechanical analysis — percentage of air dry fine earth																
Coarse sand 2.0—0.2mm	15.2	—	7.8	—	—	—	—	5.3	12.5	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	39.3	—	18.6	—	—	—	—	18.3	30.2	—	—	—	—	—	—	—
Silt 0.02—0.002mm	5.5	—	3.6	—	—	—	—	1.9	15.6	—	—	—	—	—	—	—
Clay <0.002mm	20.8	—	38.1	—	—	—	—	65.9	15.5	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.39	—	0.42	—	—	—	—	0.29	0.42	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth																
$CaCO_3$ (from CO_2)	9.7	—	23.2	—	—	—	—	nil	13.7	20.4	21.2	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.48	8.90	8.71	8.48	8.21	7.73	7.27	5.88	8.49	8.86	8.66	8.63	8.46	7.94	7.60	—
Constituents soluble in concentrated hydrochloric acid — %																
P_2O_5	0.009	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	7.140	—	—	—	—	0.011	—	—	—	—	—	—	—	—
MgO	—	—	7.610	—	—	—	—	0.736	—	—	—	—	—	—	—	—
K_2O	0.824	—	1.419	—	—	—	—	1.764	—	—	—	—	—	—	—	—
Na_2O	—	—	0.683	—	—	—	—	0.873	—	—	—	—	—	—	—	—
Exchangeable metal cations																
Total m. eq./100g soil	—	—	24.55	—	—	—	—	22.66	—	24.45	—	—	—	—	—	—
Total m. eq./100g clay	—	—	64.4	—	—	—	—	34.3	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	7	—	—	—	—	2	—	5	—	—	—	—	—	—
Mg — % of total cations	—	—	48	—	—	—	—	47	—	37	—	—	—	—	—	—
K — % of total cations	—	—	16	—	—	—	—	12	—	10	—	—	—	—	—	—
Na — % of total cations	—	—	29	—	—	—	—	39	—	48	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth																
T.W.S.S	0.338	0.605	0.977	1.252	1.319	1.372	1.509	1.538	0.353	0.783	1.006	1.220	1.198	1.170	1.098	—
NaCl (Cl x 1.648)	0.117	0.326	0.720	0.977	1.074	1.114	1.183	1.211	0.163	0.878	0.715	0.895	0.892	0.872	0.828	—
NaCl/T.W.S.S. Percentage	34.6	53.9	73.7	7.0	81.4	81.2	78.4	78.8	46.2	74.1	71.1	73.4	74.5	74.5	75.4	—

Soft lime surface to 122 cm

Soft lime 0—53 cm, deeper. Lime nodules 25—53 cm. Decomposing gneiss or granite at 229 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	West Kumarl, Fitzgerald Location 525													East Grass Patch, Fitzgerald Location 52		
Soil type	**Geordie sandy loam — Gsl**													**Geordie sandy loam — Gsl**		
Serial No.	956	957	958	959	960	961	962	963	964	965	966	967	968	1314	1315	1316
Depth — cm	0—8	8—20	20—53	53—99	99—130	130—158	183—213	213—262	262—366	366—427	427—457	457—518	518—545	0—18	25—61	61—93
— inches	0—3	3—8	8—21	21—39	39—51	51—63	72—84	84—103	103—144	144—168	168—180	180—204	204—218	0—7	10—24	26—37
Mechanical analysis — percentage of air dry fine earth																
Coarse sand 2.0—0.2mm	40.0	34.0	25.7	—	—	—	—	—	—	22.3	—	—	—	18.4	12.0	9.7
Fine sand 0.2—0.02mm	31.5	33.6	28.9	—	—	—	—	—	—	42.3	—	—	—	40.8	31.4	20.9
Silt 0.02—0.002mm	7.7	9.9	6.8	—	—	—	—	—	—	3.4	—	—	—	8.2	3.0	1.7
Clay <0.002mm	15.6	18.0	23.3	—	—	—	—	—	—	29.1	—	—	—	25.8	30.9	28.2
Coarse sand/fine sand ratio	1.26	1.01	0.89	—	—	—	—	—	—	0.52	—	—	—	0.45	0.38	0.46
Chemical properties — percentage of air dry fine earth																
$CaCO_3$ (from CO_2)	0.1	0.3	10.6	—	—	—	—	—	—	—	—	—	—	1.9	19.7	35.6
Organic carbon	1.189	0.687	0.562	—	—	—	—	—	—	—	—	—	—	1.57	0.49	—
Total nitrogen	0.066	0.042	0.041	—	—	—	—	—	—	—	—	—	—	0.073	0.039	—
C/N ratio	18.0	16.4	13.7	—	—	—	—	—	—	—	—	—	—	21.5	12.6	—
pH Q 1:2.5	7.20	7.72	8.17	8.49	8.43	8.10	7.21	5.70	4.80	4.35	4.08	4.01	4.42	8.16	8.16	8.36
Constituents soluble in concentrated hydrochloric acid — %																
P_2O_5	0.011	0.007	0.011	—	—	—	—	—	—	0.008	—	—	—	0.009	0.008	—
CaO	—	—	5.919	—	—	—	—	—	—	0.029	—	—	—	—	—	—
MgO	—	—	0.498	—	—	—	—	—	—	0.389	—	—	—	—	—	—
K_2O	—	—	0.736	—	—	—	—	—	—	0.821	—	—	—	1.083	1.139	—
Na_2O	—	—	0.146	—	—	—	—	—	—	0.439	—	—	—	—	—	—
Exchangeable metal cations																
Total m. eq./100g soil	—	—	17.85	—	—	—	—	—	—	11.35	—	—	—	—	—	—
Total m. eq./100g clay	—	—	76.6	—	—	—	—	—	—	39.0	—	—	—	—	—	—
Ca — % of total cations	—	—	37	—	—	—	—	—	—	10	—	—	—	—	—	—
Mg — % of total cations	—	—	42	—	—	—	—	—	—	42	—	—	—	—	—	—
K — % of total cations	—	—	8	—	—	—	—	—	—	7	—	—	—	—	—	—
Na — % of total cations	—	—	13	—	—	—	—	—	—	41	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth																
T.W.S.S	0.068	0.111	0.192	0.268	0.365	0.464	1.050	0.787	0.702	0.665	0.768	0.678	0.658	0.201	0.427	0.345
NaCl (Cl x 1.648)	0.004	0.011	0.075	0.124	0.224	0.387	0.758	0.626	0.577	0.570	0.645	0.561	0.544	0.046	0.280	0.266
NaCl/T.W.S.S. Percentage	5.9	9.9	39.0	46.2	61.3	83.4	72.2	79.5	82.2	85.7	84.0	82.7	82.7	22.9	65.5	77.1

53—99 cm only 12.5% fine earth. No samples. 63—72 cm. Very calcareous. 20—183 cm. Soft lime and nodules. Sandstone pebbles from 427 cm. Solid stone at 545 cm.

Much limestone rubble below 25 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	North-east Kumarl, Location 987					East Dowak, Fitzgerald Location 531								
Soil type	**Dundas calcareous loam — Dl**					**Dundas calcareous loam — Dl**								
Serial No.	813	814	815	816	818	894	895	896	897	898	899	900	901	902
Depth — cm	0—8	8—20	20—38	38—61	89—125	0—5	5—11	11—27	27—37	37—72	72—114	114—153	155—244	244—305
— inches	0—3	3—8	8—15	15—24	35—49	0—2	2—4.5	4.5—10.5	10.5—14.5	14.5—28.5	28.5—45	45—61	61—96	96—120
Mechanical analysis — percentage of air dry fine earth														
Coarse sand 2.0—0.2mm	9.1	4.2	4.0	3.2	5.1		—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	37.3	22.9	19.8	19.0	38.9	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	9.0	6.4	7.3	7.5	13.6	—	—	—	—	—	—	—	—	—
Clay <0.002mm	20.4	19.4	22.0	25.2	31.1	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.24	0.18	0.20	0.17	0.13	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth														
$CaCO_3$ (from CO_2)	10.6	37.9	41.6	40.6	3.8	6.45	20.70	27.50	18.08	—	—	0.73	—	—
Organic carbon	4.02	1.18	0.69	0.38	0.16	1.98*	5.91*	17.30*	16.55*	—	—	6.79*	—	—
Total nitrogen	0.216	0.067	0.025	0.014	0.003	—	—	—	—	—	—	—	—	—
C/N ratio	18.6	17.6	27.6	27.2	53.3	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.55	8.79	8.55	8.55	8.68	8.68	8.78	9.03	8.80	8.22	7.97	8.64	8.41	8.19
Constituents soluble in concentrated hydrochloric acid — %														
P_2O_5	0.030	0.017	0.007	0.004	0.007	—	—	—	—	—	—	—	—	—
CaO		—	—	—	—	—	—	—	—	—	—	—	—	—
MgO		—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	0.743	0.663	0.795	0.876	0.817	—	—	—	—	—	—	—	—	—
Na_2O		—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations														
Total m. eq./100g soil	39.11	23.18	19.79	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	191.70	119.50	99.00	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	50	10	6	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	33	35	35	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	5	8	10	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	12	47	49	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth														
T.W.S.S	0.531	1.250	1.126	1.028	0.948	0.164	0.263	0.970	1.006	1.117	1.387	1.568	0.725	0.460
NaCl (Cl x 1.648)	0.223	0.803	0.770	0.732	0.680	0.021	0.126	0.401	0.576	0.728	0.896	1.024	0.413	0.265
NaCl/T.W.S.S. Percentage	43.4	64.2	68.3	71.2	71.7	12.8	47.9	41.3	57.2	65.2	64.5	65.3	56.9	57.6

Marl and greenstone pieces. 0—125cm (0—49")

*$MgCo_3$. from residual Co_2 Greenstone pieces and soft Ca—Mg carbonate. 0—305cm (0—120")
Magnesite fragments on surface.

Appendix 4 Mechanical analyses and chemical data

Locality	South-west Circle Valley, Fitzgerald Location 79						West Salmon Gums, Fitzgerald Location 356					
Soil Type	Salmon Gums sandy loam — SGsl						Salmon Gums sandy loam — SGsl					
Serial No.	1705	1706	1707	1708	1709	1710	1766	1767	1768	1769	1770	1771
Depth — cm	0—8	8—15	15—28	28—53	53—114	114—145	0—25	25—33	33—58	58—91	91—127	127—188
— inches	0—3	3—6	6—11	11—21	21—45	45—57	0—10	10—13	13—23	23—36	36—50	50—74
Mechanical analysis — percentage of air dry fine earth												
Coarse sand 2.0—0.2mm	37.6	—	23.4	18.7	21.6	17.8	42.5	30.6	25.0	—	—	—
Fine sand 0.2—0.02mm	46.8	—	32.4	22.1	21.8	17.1	43.4	26.6	19.0	—	—	—
Silt 0.02—0.002mm	6.5	—	3.3	1.3	1.3	0.6	6.3	3.4	1.7	—	—	—
Clay <0.002mm	6.5	—	35.6	46.6	40.5	34.7	7.4	36.4	48.0	—	—	—
Coarse sand/fine sand ratio	0.80	—	0.72	0.85	0.99	1.04	0.98	1.15	1.31	—	—	—
Chemical properties — percentage of air dry fine earth												
$CaCO_3$ (from CO_2)	0.1	—	0.3	5.9	11.0	28.9	0.1	0.1	1.2	—	—	—
Organic carbon	0.51	—	0.22	0.16	0.11	—	0.40	0.44	0.14	—	—	—
Total nitrogen	0.027	—	0.021	0.018	0.015	—	0.020	0.031	0.017	—	—	—
C/N ratio	18.8	—	10.4	8.9	7.3	—	20.0	14.2	8.23	—	—	—
pH Q 1:2.5	6.95	7.60	8.62	8.59	8.62	8.62	6.67	7.40	8.42	8.42	8.42	8.33
Constituents soluble in concentrated hydrochloric acid — %												
P_2O_5	—	—	—	—	—	—	0.007	0.009	0.008	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	0.236	0.904	1.336	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations												
Total m. eq./100g soil	6.40	—	19.57	22.14	19.45	—	—	16.92	—	—	—	—
Total m. eq./100g clay	98.4	—	54.97	47.5	47.9	—	—	46.4	—	—	—	—
Ca — % of total cations	43	—	24	19	18	—	—	18	—	—	—	—
Mg — % of total cations	41	—	42	42	40	—	—	51	—	—	—	—
K — % of total cations	12	—	13	14	15	—	—	12	—	—	—	—
Na — % of total cations	4	—	21	25	27	—	—	19	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth												
T.W.S.S	0.040	0.036	0.262	0.396	0.448	0.380	0.039	0.243	0.403	0.429	0.405	0.443
NaCl (Cl x 1.648)	0.003	0.008	0.135	0.253	0.271	0.230	0.009	0.118	0.275	0.277	0.235	0.294
NaCl/T.W.S.S. Percentage	7.5	22.2	51.5	63.9	60.5	60.5	23.1	48.5	68.2	64.5	58.0	66.4
	Soft lime and many nodules below 28 cm (11")						Soft lime and lime nodules, 36—188 cm (14—74")					

Appendix 4 Mechanical analyses and chemical data

Locality	East Kumarl, Fitzgerald Location 1155							
Soil type	Kumarl clay loam — Kcl							
Serial No.	771—772	773	774	775	776	777	778	779
Depth — cm	0—14	14—33	33—61	61—84	84—150	150—267	267—297	297—333
— inches	0—5.5	5.5—13	13—24	24—33	33—59	59—105	105—117	117—131
Mechanical analysis — percentage of air dry fine earth								
Coarse sand 2.0—0.2mm	19.1	15.2	17.7	—	—	8.4	—	—
Fine sand 0.2—0.02mm	24.2	17.2	15.3	—	—	16.8	—	—
Silt 0.02—0.002mm	4.3	3.9	6.0	—	—	5.8	—	—
Clay <0.002mm	43.7	43.5	45.9	—	—	59.9	—	—
Coarse sand/fine sand ratio	0.79	0.88	1.16	—	—	0.50	—	—
Chemical properties — percentage of air dry fine earth								
$CaCO_3$ (from CO_2)	1.0	13.8	7.1	—	—	—	—	—
Organic carbon	1.23	0.807	0.278	—	—	—	—	—
Total nitrogen	0.067	0.057	0.024	—	—	0.020	—	—
C/N ratio	18.4	14.1	11.6	—	—	—	—	—
pH Q 1:1.1	7.90	7.95	7.77	6.53	3.86	3.49	3.45	3.49
Constituents soluble in concentrated hydrochloric acid — %								
P_2O_5	0.011	0.012	0.008	—	—	0.007	—	—
CaO	0.997	7.48	3.78	—	—	0.012	—	—
MgO	0.871	0.991	1.035	—	—	0.804	—	—
K_2O	0.733	0.793	0.848	—	—	0.904	—	—
Na_2O	—	—	0.554	—	—	0.617	—	—
Exchangeable metal cations								
Total m. eq./100g soil	30.23	28.09	26.58	—	—	20.20	—	—
Total m. eq./100g clay	69.10	64.50	57.90	—	—	33.70	—	—
Ca — % of total cations	50	32	24	—	—	nil	—	—
Mg — % of total cations	33	38	40	—	—	50	—	—
K — % of total cations	5	6	7	—	—	7	—	—
Na — % of total cations	12	24	29	—	—	43	—	—
Total water soluble salts — percentage of oven dry fine earth								
T.W.S.S	0.242	0.629	0.715	0.757	0.728	0.864	0.916	0.824
NaCl (Cl x 1.648)	0.116	0.440	0.486	0.508	0.529	0.638	0.685	0.617
NaCl/T.W.S.S. Percentage	47.9	69.9	68.0	67.1	72.6	73.8	74.8	74.8

Appendix 4 Mechanical analyses and chemical data

Locality	Dowak townsite										
Soil type	**Kumarl clay loam — Kcl**										
Serial No.	903—904	905	906	907	908	909	910	911	912	913	914
Depth — cm	0—13	13—30	30—51	51—69	69—114	114—152	152—213	213—274	274—335	335—396	396—417
— inches	0—5	5—12	12—20	20—27	27—45	45—60	60—84	84—108	108—132	132—156	156—164
Mechanical analysis — percentage of air dry fine earth											
Coarse sand 2.0—0.2mm	12.3	13.2	12.1	—	—	—	—	—	1.4	—	—
Fine sand 0.2—0.02mm	22.1	21.3	18.3	—	—	—	—	—	9.5	—	—
Silt 0.02—0.002mm	1.7	2.8	6.8	—	—	—	—	—	5.6	—	—
Clay <0.002mm	50.3	51.9	53.1	—	—	—	—	—	72.2	—	—
Coarse sand/fine sand ratio	0.56	0.62	0.66	—	—	—	—	—	0.15	—	—
Chemical properties — percentage of air dry fine earth											
$CaCO_3$ (from CO_2)	1.2	1.6	2.1	—	—	—	—	—	nil	—	—
Organic carbon	0.68	0.37	0.20	—	—	—	—	—	—	—	—
Total nitrogen	0.048	0.028	0.017	—	—	—	—	—	0.013	—	—
C/N ratio	14.2	13.2	11.8	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.80	7.85	7.78	7.68	7.43	6.65	4.49	4.22	4.13	4.00	4.05
Constituents soluble in concentrated hydrochloric acid — %											
P_2O_5	0.008	0.005	0.004	—	—	—	—	—	0.003	—	—
CaO	—	—	1.168	—	—	—	—	—	0.042	—	—
MgO	—	—	1.101	—	—	—	—	—	0.791	—	—
K_2O	0.908	0.872	0.970	—	—	—	—	—	1.071	—	—
Na_2O	—	—	0.818	—	—	—	—	—	0.895	—	—
Exchangeable metal cations											
Total m. eq./100g soil	35.18	—	38.12	—	—	—	—	—	28.52	—	—
Total m. eq./100g clay	69.90	—	71.8	—	—	—	—	—	39.5	—	—
Ca — % of total cations	27	—	24	—	—	—	—	—	2	—	—
Mg — % of total cations	41	—	44	—	—	—	—	—	47	—	—
K — % of total cations	6	—	5	—	—	—	—	—	8	—	—
Na — % of total cations	26	—	27	—	—	—	—	—	43	—	—
Total water soluble salts — percentage of oven dry fine earth											
T.W.S.S	0.644	1.050	1.310	1.525	1.180	1.100	1.160	1.200	1.160	1.160	1.230
NaCl (Cl x 1.648)	0.450	0.738	0.800	0.762	0.904	0.904	0.904	0.896	0.921	0.942	0.971
NaCl/T.W.S.S. Percentage	70.0	70.2	61.1	50.0	76.6	82.2	77.9	74.6	79.3	81.2	78.9

Small gypsum pockets, 30—114 cm (12—45"). Red-brown ferruginous grit, 417 cm (164").

Appendix 4 Mechanical analyses and chemical data

Locality	West Grass Patch, Fitzgerald Location 92					
Soil type	**Kumarl clay loam — Kcl**					
Serial No.	1720	1721	1722	1723	1724	1725
Depth — cm	0—8	8—43	43—74	74—107	107—168	168—229
— inches	0—3	3—17	17—29	29—42	42—66	66—90
Mechanical analysis — percentage of air dry fine earth						
Coarse sand 2.0—0.2mm	5.4	4.0	3.8	—	—	3.5
Fine sand 0.2—0.02mm	18.9	13.5	12.6	—	—	10.4
Silt 0.02—0.002mm	10.1	5.8	6.6	—	—	6.3
Clay <0.002mm	52.9	62.9	65.0	—	—	69.2
Coarse sand/fine sand ratio	0.29	0.30	0.30	—	—	0.34
Chemical properties — percentage of air dry fine earth						
$CaCO_3$ (from CO_2)	2.4	4.1	1.0	—	—	—
Organic carbon	1.58	0.75	0.29	—	—	—
Total nitrogen	0.080	0.038	0.013	—	—	—
C/N ratio	19.8	18.7	22.3	—	—	—
pH Q 1:2.5	8.03	8.45	8.31	7.91	5.83	4.35
Constituents soluble in concentrated hydrochloric acid — %						
P_2O_5	0.013	0.008	0.006	—	—	0.005
CaO	—	—	0.336	—	—	0.008
MgO	—	—	1.222	—	—	0.681
K_2O	1.086	1.209	1.290	—	—	1.122
Na_2O	—	—	0.899	—	—	0.875
Exchangeable metal cations						
Total m. eq./100g soil	40.01	—	40.25	—	—	26.73
Total m. eq./100g clay	75.60	—	64.00	—	—	38.60
Ca — % of total cations	49	—	11	—	—	2
Mg — % of total cations	38	—	48	—	—	52
K — % of total cations	6	—	9	—	—	7
Na — % of total cations	7	—	32	—	—	39
Total water soluble salts — percentage of oven dry fine earth						
T.W.S.S	0.282	0.940	1.156	1.212	1.362	1.369
NaCl (Cl x 1.648)	0.147	0.636	0.847	0.924	0.983	1.012
NaCl/T.W.S.S. Percentage	52.2	67.6	73.2	76.2	72.2	73.9

Soft lime and small nodules to 84cm (33")

Appendix 4 Mechanical analyses and chemical data

Locality	West Dowak, Fitzgerald Location 393						West Dowak, Fitzgerald Location 393						
Soil type	Dowak clay loam — Docl						Dowak clay loam — Docl						
Serial No.	932/933	934	935	936	937	938	939	940	941	942	943	944	945
Depth — cm	0—10	10—38	38—69	69—183	183—274	274—366	0—6	6—28	28—69	69—122	122—183	183—274	274—366
— inches	0—4	4—15	15—27	27—72	72—108	108—144	0—2.5	2.5—11	11—27	27—48	48—72	72—108	108—144
Mechanical analysis — percentage of air dry fine earth													
Coarse sand 2.0—0.2mm	20.7	18.0	22.1	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	25.8	18.3	19.5	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	1.6	1.8	2.8	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	43.0	44.4	43.0	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.80	0.98	1.13	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth													
$CaCO_3$ (from CO_2)	0.3	9.3	3.7	—	—	—	—	—	—	—	—	—	—
Organic carbon	1.10	0.48	0.25	—	—	—	1.73	1.04	0.35	—	—	—	—
Total nitrogen	0.074	0.046	0.021	—	—	—	0.113	0.070	0.027	—	—	—	—
C/N ratio	14.8	10.4	11.9	—	—	—	15.3	14.8	12.9	—	—	—	—
pH Q 1:2.5	7.66	7.82	7.79	7.74	7.51	6.32	7.90	8.48	8.48	8.23	7.29	4.73	4.17
Constituents soluble in concentrated hydrochloric acid — %													
P_2O_5	0.010	0.007	0.004	—	—	—	0.011	0.009	0.005	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	1.005	1.101	1.075	—	—	—	0.937	1.054	1.131	—	—	—	—
Na_2O		—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations													
Total m. eq./100g soil	38.35	39.72	32.68	—	—	—	—	—	29.02	—	—	—	—
Total m. eq./100g clay	89.1	89.4	76.0	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	47	30	19	—	—	—	—	—	15	—	—	—	—
Mg — % of total cations	38	45	49	—	—	—	—	—	42	—	—	—	—
K — % of total cations	5	6	7	—	—	—	—	—	7	—	—	—	—
Na — % of total cations	10	19	25	—	—	—	—	—	36	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth													
T.W.S.S	0.257	0.807	0.847	0.930	0.850	0.830	0.158	0.628	0.950	1.200	1.160	1.200	1.196
NaCl (Cl x 1.648)	0.047	0.448	0.534	0.601	0.599	0.563	0.025	0.331	0.610	0.808	0.800	0.842	0.866
NaCl/T.W.S.S. Percentage	18.2	55.5	63.0	64.6	70.4	67.8	15.8	52.7	64.2	67.3	69.0	70.2	72.4

Soft lime, 10—69 cm (4—27″).

Soft lime, 6—122 cm (2.5—48″).

Appendix 4 Mechanical analyses and chemical data

Locality	East Red Lake, Fitzgerald Location 44										
Soil type	**Dowak clay loam — Docl**										
Serial No.	1325	1326	1327	1328	1329	1330	1331	1332	1333	1334	1335
Depth — cm	0—5	5—18	18—43	43—84	84—152	152—213	213—274	274—335	335—396	396—457	457—478
— inches	0—2	2—7	7—17	17—33	33—60	60—84	84—108	108—132	132—156	156—180	180—188
Mechanical analysis — percentage of air dry fine earth											
Coarse sand 2.0—0.2mm	11.9	9.0	10.1	9.3	—	—	—	—	—	7.0	—
Fine sand 0.2—0.02mm	40.2	28.5	30.2	28.4	—	—	—	—	—	24.6	—
Silt 0.02—0.002mm	3.3	2.2	2.0	2.9	—	—	—	—	—	2.6	—
Clay <0.002mm	26.2	39.2	43.8	48.4	—	—	—	—	—	55.2	—
Coarse sand/fine sand ratio	0.30	0.32	0.33	0.33	—	—	—	—	—	0.28	—
Chemical properties — percentage of air dry fine earth											
$CaCO_3$ (from CO_2)	7.4	11.4	3.8	1.4	—	—	—	—	—	nil	—
Organic carbon	1.97	0.87	—	—	—	—	—	—	—	—	—
Total nitrogen	0.104	0.049	—	—	—	—	—	—	—	—	—
C/N ratio	18.9	17.8	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.57	8.66	8.51	8.41	8.24	7.86	7.27	5.97	5.04	4.73	4.73
Constituents soluble in concentrated hydrochloric acid — %											
P_2O_5	0.011	0.008	—	—	—	—	—	—	—	—	—
CaO	—	—	—	0.445	—	—	—	—	—	0.008	—
MgO	—	—	—	0.401	—	—	—	—	—	?	—
K_2O	0.681	1.010	—	1.314	—	—	—	—	—	1.172	—
Na_2O	—	—	—	0.919	—	—	—	—	—	0.867	—
Exchangeable metal cations											
Total m. eq./100g soil	—	29.40	—	34.91	—	—	—	—	—	28.82	—
Total m. eq./100g clay	—	75.00	—	—	—	—	—	—	—	52.20	—
Ca — % of total cations	—	11	—	7	—	—	—	—	—	nil	—
Mg — % of total cations	—	48	—	52	—	—	—	—	—	51	—
K — % of total cations	—	9	—	9	—	—	—	—	—	7	—
Na — % of total cations	—	31	—	32	—	—	—	—	—	42	—
Total water soluble salts — percentage of oven dry fine earth											
T.W.S.S	0.179	0.843	1.309	1.490	1.398	1.384	1.284	1.308	1.272	1.270	1.052
NaCl (Cl x 1.648)	0.037	0.626	0.900	1.023	0.957	0.965	0.911	0.906	0.894	0.951	0.761
NaCl/T.W.S.S. Percentage	20.6	74.2	68.7	68.6	68.4	69.7	70.9	69.2	70.2	74.9	73.8

Soft lime, 0—84 cm (0—33″) sandstone at 478 cm (188″)

Appendix 4 Mechanical analyses and chemical data

Locality	East Grass Patch, Fitzgerald Location 49											
Soil type	**Dowak clay loam — Docl**											
Serial No.	1373	1374	1375	1376	1377	1378	1379	1380	1381	1382	1383	1384
Depth — cm	0—11	11—38	38—58	58—91	91—152	152—213	213—274	274—335	335—396	396—488	488—518	518—549
— inches	0—4.5	4.5—15	15—23	23—36	36—60	60—84	84—108	108—132	132—156	156—192	192—204	204—216
Mechanical analysis — percentage of air dry fine earth												
Coarse sand 2.0—0.2mm	6.8	6.3	7.3	—	—	—	—	—	7.1	—	—	—
Fine sand 0.2—0.02mm	30.4	23.0	29.4	—	—	—	—	—	34.3	—	—	—
Silt 0.02—0.002mm	4.6	2.4	4.5	—	—	—	—	—	2.7	—	—	—
Clay <0.002mm	42.8	34.5	43.2	—	—	—	—	—	50.1	—	—	—
Coarse sand/fine sand ratio	0.22	0.27	0.25	—	—	—	—	—	0.21	—	—	—
Chemical properties — percentage of air dry fine earth												
$CaCO_3$ (from CO_2)	5.5	25.1	8.9	—	—	—	—	—	nil	—	—	—
Organic carbon	1.876	0.665	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.091	0.041	0.010	—	—	—	—	—	—	—	—	—
C/N ratio	20.6	16.2	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.19	8.82	8.72	8.60	7.67	5.11	4.65	4.44	4.28	4.21	4.25	4.21
Constituents soluble in concentrated hydrochloric acid — %												
P_2O_5	0.009	0.006	—	—	—	—	—	—	—	—	—	—
CaO	—	—	3.304	—	—	—	—	—	0.003	—	—	—
MgO	—	—	2.948	—	—	—	—	—	1.069	—	—	—
K_2O	1.167	1.090	1.395	—	—	—	—	—	1.090	—	—	—
Na_2O	—	—	0.705	—	—	—	—	—	0.597	—	—	—
Exchangeable metal cations												
Total m. eq./100g soil	—	—	26.33	—	—	—	—	—	20.34	—	—	—
Total m. eq./100g clay	—	—	60.90	—	—	—	—	—	40.60	—	—	—
Ca — % of total cations	—	—	7	—	—	—	—	—	trace	—	—	—
Mg — % of total cations	—	—	47	—	—	—	—	—	52	—	—	—
K — % of total cations	—	—	13	—	—	—	—	—	10	—	—	—
Na — % of total cations	—	—	33	—	—	—	—	—	38	—	—	—
Total water soluble salts — percentage of oven dry fine earth												
T.W.S.S	0.375	0.805	1.138	1.243	1.152	1.047	0.962	1.043	1.036	0.960	0.904	0.857
NaCl (Cl x 1.648)	0.166	0.585	0.783	0.870	0.824	0.746	0.683	0.732	0.737	0.704	0.654	0.622
NaCl/T.W.S.S. Percentage	44.2	72.6	68.8	70.0	71.5	71.2	71.0	70.2	71.1	73.3	72.3	72.5

Soft lime, 11—91 cm (4.5—36"). Sandstone fragments below 498 cm (>192").

Appendix 4 Mechanical analyses and chemical data

Locality	West Grass Patch, Fitzgerald Location 92						
Soil type	**Dowak clay loam — Docl**						
Serial No.	1726	1727	1728	1729	1730	1731	1732
Depth — cm	0—5	5—38	38—79	79—122	122—183	183—246	246—295
— inches	0—2	2—15	15—31	31—48	48—72	72—97	97—116
Mechanical analysis — percentage of air dry fine earth							
Coarse sand 2.0—0.2mm	9.6	8.9	10.6	—	—	—	15.7
Fine sand 0.2—0.02mm	27.0	22.1	27.0	—	—	—	29.5
Silt 0.02—0.002mm	5.0	2.8	3.8	—	—	—	3.8
Clay <0.002mm	49.8	52.3	47.6	—	—	—	44.6
Coarse sand/fine sand ratio	0.36	0.40	0.39	—	—	—	0.53
Chemical properties — percentage of air dry fine earth							
$CaCO_3$ (from CO_2)	0.1	3.0	3.1	—	—	—	nil
Organic carbon	0.93	0.54	—	—	—	—	—
Total nitrogen	0.052	0.031	—	—	—	—	—
C/N ratio	17.9	17.4	—	—	—	—	—
pH Q 1:2.5	7.96	8.40	8.48	8.48	8.40	7.12	5.28
Constituents soluble in concentrated hydrochloric acid — %							
P_2O_5	0.008	0.004	0.004	—	—	—	0.003
CaO	—	—	1.596	—	—	—	nil
MgO	—	—	1.673	—	—	—	0.815
K_2O	—	—	1.348	—	—	—	0.967
Na_2O	—	—	0.791	—	—	—	0.628
Exchangeable metal cations							
Total m. eq./100g soil	34.99	—	30.96	—	—	—	21.40
Total m. eq./100g clay	70.2	—	65.0	—	—	—	48.0
Ca — % of total cations	34	—	10	—	—	—	1
Mg — % of total cations	40	—	45	—	—	—	48
K — % of total cations	9	—	11	—	—	—	10
Na — % of total cations	17	—	34	—	—	—	41
Total water soluble salts — percentage of oven dry fine earth							
T.W.S.S	0.230	1.155	1.167	1.211	1.115	0.961	0.851
NaCl (Cl x 1.648)	0.094	0.795	0.800	0.812	0.765	0.700	0.606
NaCl/T.W.S.S. Percentage	40.1	68.8	68.5	67.1	68.6	72.8	71.2

Soft lime 5—183 cm (2—72 "). Ferruginous sandstone pebbles, 152—295 cm. Rock 295 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Salmon Gums, Location 1431						
Soil type	Doust sand — Dts						
Serial No.	1083	1084	1085	1086	1087	1088	1089
Depth — cm	0—15	15—46	46—91	91—122	122—152	152—183	182—213
— inches	0—6	6—18	18—36	36—48	48—60	60—72	72—84
Mechanical analysis — percentage of air dry fine earth							
Coarse sand 2.0—0.2mm	—	—	—	24.7	—	—	—
Fine sand 0.2—0.02mm	—	—	—	52.2	—	—	—
Silt 0.02—0.002mm	—	—	—	1.3	—	—	—
Clay <0.002mm	—	—	—	21.3	—	—	—
Coarse sand/fine sand ratio	—	—	—	0.47	—	—	—
Chemical properties — percentage of air dry fine earth							
$CaCO_3$ (from CO_2)	—	—	—	0.1	—	—	—
Organic carbon	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—
pH Q 1:2.5	6.01	6.92	7.27	7.36	7.82	7.25	6.53
Constituents soluble in concentrated hydrochloric acid — %							
P_2O_5	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—
Exchangeable metal cations							
Total m. eq./100g soil	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—
Ca — % of total cations		—	—	—	—	—	—
Mg — % of total cations		—	—	—	—	—	—
K — % of total cations		—	—	—	—	—	—
Na — % of total cations		—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth							
T.W.S.S	0.027	0.031	0.023	0.176?	0.103	0.145	0.220?
NaCl (Cl x 1.648)	0.005	0.005	0.005	0.069	0.069	0.082	0.171?
NaCl/T.W.S.S. Percentage	18.5	16.1	21.7	—	67.0	56.5	—

Light grey sand and organic matter, 0—15cm. Light grey to white sand, 15—46cm. White sand, 46—91cm.

Appendix 4 Mechanical analyses and chemical data

Locality	West Dowak, Fitzgerald Location 525									
Soil type	**Red Lake sand — RLs**									
Serial No.	946	947	948	949	950	951	952	953	954	955
Depth — cm	0—13	13—30	30—61	61—152	152—229	229—287	287—335	335—381	381—419	419—478
— inches	0—5	5—12	12—24	24—60	60—90	90—113	113—132	132—150	150—165	165—188
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—
Silt 0.2—0.002mm	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—
Organic carbon	0.26	0.17	0.14	—	—	—	—	—	—	—
Total nitrogen	0.032	0.021	0.011	—	—	—	—	—	—	—
C/N ratio	8.1	8.1	12.7	—	—	—	—	—	—	—
pH Q 1:2.5	6.90	7.24	7.89	8.53	8.57	8.60	8.41	8.40	7.89	6.97
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	0.009	0.009	0.011	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—
K_2O	0.191	0.229	0.329	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations										
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S.S	0.074	0.066	0.163	0.065	0.295	0.344	0.284	0.427	0.438	0.304
NaCl (Cl x 1.648)	0.003	0.002	0.003	0.018	0.099	0.177	0.146	0.297	0.303	0.185
NaCl/T.W.S.S. Percentage	4.0	3.0	3.0	27.7	33.5	51.4	51.4	69.5	69.1	60.8

In dune formation east of salt lakes. Calcareous and with small nodules 127—138 cm. Loamy sand to 152 cm, then sandy loam to 419 cm where coarse grit layers occur.

Appendix 4 Mechanical analyses and chemical data

Locality	East Grass Patch, Fitzgerald Location 41								
Soil type	**Red Lake sand — RLs**								
Serial No.	1364	1365	1366	1367	1368	1369	1370	1371	1372
Depth — cm	0—48	48—84	84—168	168—244	244—279	279—320	320—366	366—437	437—528
— inches	0—19	19—33	33—66	66—96	96—110	110—126	126—144	144—172	172—208
Mechanical analysis — percentage of air dry fine earth									
Coarse sand 2.0—0.2mm	41.1	39.3	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	41.2	39.4	—	—	—	—	—	—	—
Silt 0.02—0.002mm	5.6	5.2	—	—	—	—	—	—	—
Clay <0.002mm	10.2	14.7	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	1.0	1.0	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth									
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—
Organic carbon	0.491	0.226	—	—	—	—	—	—	—
Total nitrogen	0.024	0.015	—	—	—	—	—	—	—
C/N ratio	20.4	15.0	—	—	—	—	—	—	—
pH Q 1:2.5	5.23	6.29	3.96	3.89	3.75	3.60	3.74	4.26	4.03
Constituents soluble in concentrated hydrochloric acid — %									
P_2O_5	0.021	0.021	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—
K_2O	0.450	0.426	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—
Exchangeable metal cations									
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	
Mg — % of total cations	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth									
T.W.S.S	0.127	0.282	0.310	0.322	0.356	0.396	0.610	0.478	0.942
NaCl (Cl x 1.648)	0.063	0.163	0.203	0.226	0.249	0.300	0.488	0.357	0.743
NaCl/T.W.S.S. Percentage	49.6	57.8	65.4	70.1	69.9	75.7	80.0	74.6	78.8

In dune formation east of salt lake. Orange-brown to 320 cm, then grey and white clay and quartz grit. Salt water 3.8%. NaCl below 366 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Circle Valley, Fitzgerald Location 408							West Scaddan, Esperance Location 540							
Soil type	**Heart Echo sand — HEs**							**Heart Echo sand — HEs**							
Serial No.	1140	1141	1142	1143	1144	1145	1146	1691	1692	1693	1694	1695	1696	1697	1698
Depth — cm	0—76	76—107	107—183	183—305	305—457	457—610	610—701	0—20	20—64	64—152	152—183	183—244	244—335	355—442	442—564
— inches	0—30	30—42	42—72	72—120	120—180	180—240	240—276	0—8	8—25	25—60	60—72	72—96	96—132	132—174	174—222
Mechanical analysis — percentage of air dry fine earth															
Coarse sand 2.0—0.2mm	46.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	49.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	1.2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	1.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	0.95	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth															
$CaCO_3$ (from CO_2)	nil	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Organic carbon	0.35	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	0.017	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	20.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	6.28	6.10	8.01	8.52	8.45	8.11	5.94	5.98	6.08	6.27	6.41	5.83	5.94	5.23	4.82
Constituents soluble in concentrated hydrochloric acid — %															
P_2O_5	0.001	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	0.012	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations															
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth															
T.W.S.S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
NaCl (Cl x 1.648)	0.005	0.005	0.028	0.068	0.085	0.105	0.095	0.005	0.004	0.004	0.004	0.055	0.089	0.097	0.116
NaCl/T.W.S.S. Percentage	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Small calcareous particles, 244—457 cm.

Sand is loamy below 183 cm — no lime apparent.

Appendix 4 Mechanical analyses and chemical data

Locality	East Dowak, Fitzgerald Location 1021					
Soil type	**Heart Echo sand — HEs**					
Serial No.	1760	1761	1762	1763	1764	1765
Depth — cm	0—23	23—61	61—84	84—137	137—198	198—316
— inches	0—9	9—24	24—33	33—54	54—78	78—85
Mechanical analysis — percentage of air dry fine earth						
Coarse sand 2.0—0.2mm	54.4	49.7	—	—	—	—
Fine sand 0.2—0.02mm	38.2	44.6	—	—	—	—
Silt 0.02—0.002mm	1.0	1.2	—	—	—	—
Clay <0.002mm	5.1	4.7	—	—	—	—
Coarse sand/fine sand ratio	1.42	1.11	—	—	—	—
Chemical properties — percentage of air dry fine earth						
$CaCO_3$ (from CO_2)	0.1	0.1	—	—	—	—
Organic carbon	0.81	0.17	—	—	—	—
Total nitrogen	0.025	0.008	—	—	—	—
C/N ratio	32.4	21.2	—	—	—	—
pH Q 1:2.5	6.90	7.45	7.96	8.08	7.74	7.63
Constituents soluble in concentrated hydrochloric acid — %						
P_2O_5	0.003	0.002	—	—	—	—
CaO	—	—	—	—	—	—
MgO	—	—	—	—	—	—
K_2O	0.019	0.022	—	—	—	—
Na_2O	—	—	—	—	—	—
Exchangeable metal cations						
Total m. eq./100g soil	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth						
T.W.S.S	0.049	0.067	0.066	0.197	0.205	0.179
NaCl (Cl x 1.648)	0.004	0.006	0.019	0.081	0.104	0.089
NaCl/T.W.S.S. Percentage	8.2	8.9	28.8	41.1	50.7	49.7

Sand, loamy and cemented below 84cm. Soft ferruginous pebbles.

Appendix 4 Mechanical analyses and chemical data

Locality	East (20 km) Salmon Gums, Fitzgerald Location 613								
Soil type	**Low lying — bordering salt lakes — 5C**								
Serial No.	1147	1148	1149	1150	1151	1152	1153	1154	1155
Depth — cm	0—8	8—33	33—69	69—117	117—137	137—259	259—351	351—396	396—450
— inches	0—3	3—13	13—27	27—46	46—54	54—102	102—138	138—156	156—177
Mechanical analysis — percentage of air dry fine earth									
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth									
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	8.18	—
Organic carbon	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.14	8.37	8.25	8.28	8.14	8.38	n.d.	3.90	5.23
Constituents soluble in concentrated hydrochloric acid — %									
P_2O_5	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—
Exchangeable metal cations									
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth									
T.W.S.S	0.107	0.881	1.207	1.381	1.633	2.041	n.d.	5.907	n.d.
NaCl (Cl x 1.648)	0.031	0.717	1.065	1.223	1.416	1.802	—	3.545	—
NaCl/T.W.S.S. Percentage	29.0	81.4	88.2	88.5	86.7	88.2	—	60.0	—

Much lime rubble, 91—183 cm. Salt water, 5.92% NaCl at 183 cm. Sandy slime and sandstone, 259—351 cm. Peat at 351—396 cm. Black and grey sand in water, 396—450 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Grass Patch, Fitzgerald Location 547									
Soil type	**Low lying — bordering salt lakes — 5C**									
Serial No.	1304	1305	1306	1307	1308	1309	1310	1311	1312	1313
Depth — cm	0—20	20—43	43—91	91—122	122—183	183—244	244—267	267—320	320—351	351—376
— inches	0—8	8—17	17—36	36—48	48—72	72—96	96—105	105—126	126—138	128—148
Mechanical analysis — percentage of air dry fine earth										
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth										
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	8.03	8.43	8.36	8.31	8.31	8.19	8.03	6.77	5.98	6.86
Constituents soluble in concentrated hydrochloric acid — %										
P_2O_5	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations										
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth										
T.W.S S	0.074	0.593	0.906	0.974	1.058	1.346	1.378	1.478	1.528	1.561
NaCl (Cl x 1.648)	0.006	0.434	0.728	0.788	0.868	1.134	1.171	1.243	1.305	1.277
NaCl/T.W.S.S. Percentage	8.1	73.2	80.3	80.9	82.0	84.2	84.9	84.1	85.4	81.8

Sand 0—20 cm, sandy clay loam 20—43 cm. Some soft lime 43—183 cm. Sandy clay, 183—244 cm. Sandy clay and black peaty material 244—267 cm. Sandy clay 267—320 cm. Salt water from 330 cm. Gravel on ferruginous sandstone at 276 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	East Truslove, Esperance Location 885								
Soil type	**Low lying — bordering salt lakes — 5C**								
Serial No.	1441	1442	1443	1444	1445	1446	1447	1448	1449
Depth — cm	0—13	13—36	36—69	69—114	114—183	183—244	244—302	302—366	366—457
— inches	0—5	5—14	14—27	27—45	45—72	72—96	96—119	119—144	144—180
Mechanical analysis — percentage of air dry fine earth									
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth									
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.73	8.14	8.76	8.60	8.53	8.09	7.95	7.95	7.60
Constituents soluble in concentrated hydrochloric acid — %									
P_2O_5	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—
Exchangeable metal cations									
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth									
T.W.S.S	0.042	0.560	0.841	1.044	1.350	1.603	1.854	1.750	1.900
NaCl (Cl x 1.648)	0.012	0.419	0.686	0.918	1.204	1.472	1.638	1.573	1.636
NaCl/T.W.S.S. Percentage	28.5	74.8	81.6	87.9	89.2	91.8	88.3	89.9	86.1

Sand 0—13 cm. Sandy clay loam 13—36 cm. Soft lime and small nodules 36—114 cm. Sandy clay 69—302 cm. Sand 302—447 cm. Water at 381 cm. Sandy clay at 447 cm.

Appendix 4 Mechanical analyses and chemical data

Locality	Reserve area 200m east of Kumarl					Grass Patch, Fitzgerald Location 118						
Soil type	**Associated with shallow granite — 2C**					**Grass Patch sand —GPs**						
Serial No.	821	822	823	824	825	1772	1773	1774	1775	1776	1777	1778
Depth — cm	0—8	8.25	25.51	51—56	74—97	0—10	10—33	33	0—10	10—36	36—66	66—112
— inches	0—3	3—10	10—20	22—22	28—38	0—4	4—13	13	0—4	4—14	14—26	26—44
Mechanical analysis — percentage of air dry fine earth												
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth												
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	5.11	5.00	5.18	5.71	6.61	5.71	5.98	n.d.	5.71	5.60	6.08	n.d.
Constituents soluble in concentrated hydrochloric acid — %												
P_2O_5	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations												
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth												
T.W.S.S	0.054	0.035	0.035	0.114	0.171	—	—	—	—	—	—	—
NaCl (Cl x 1.648)	0.029	0.010	0.026	0.081	0.123	—	—	—	—	—	—	—
NaCl/T.W.S.S. Percentage	53.7	28.5	49.0	71.0	71.9	—	—	—	—	—	—	—
	Brown loam 0.8 and 8.25cm. Red-brown sandy clay loam 25-51 cm. Granite rocks, 51-97cm. Red brown gritty clay and granite grit, 51-56cm. Yellow and black coarse granite grit, 74-97cm.					Much ironstone gravel on surface. Quartzite and laterite at 33cm.			Much ironstone gravel on surface and below 10cm laterized claystones at 66-112cm.			

Appendix 4 Mechanical analyses and chemical data

Locality	West Scaddan, Esperance Location 452						West Red Lake & Fitzgerald Location 211						
Soil type	**Yate *(Eucalyptus occidentalis)* hollows — subject to flooding — D**						**Yate *(E. occidentalis)* hollows — subject to flooding — D**						
Serial No.	1678	1679	1680	1681	1682	1683	1711	1712	1713	1714	1715	1716	1717
Depth — cm	0—3	3—28	28—58	58—91	91—124	124—152	0—13	13—20	30—61	61—99	99—137	137—213	213—231
— inches	0—1	1—11	11—23	23—36	36—49	49—60	0—5	5—12	12—24	24—39	39—54	54—84	84—91
Mechanical analysis — percentage of air dry fine earth													
Coarse sand 2.0—0.2mm	—	—	—	—	—	—	—	—	—	—	—	—	—
Fine sand 0.2—0.02mm	—	—	—	—	—	—	—	—	—	—	—	—	—
Silt 0.02—0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—
Clay <0.002mm	—	—	—	—	—	—	—	—	—	—	—	—	—
Coarse sand/fine sand ratio	—	—	—	—	—	—	—	—	—	—	—	—	—
Chemical properties — percentage of air dry fine earth													
$CaCO_3$ (from CO_2)	—	—	—	—	—	—	—	—	—	—	—	—	—
Organic carbon	—	—	—	—	—	—	—	—	—	—	—	—	—
Total nitrogen	—	—	—	—	—	—	—	—	—	—	—	—	—
C/N ratio	—	—	—	—	—	—	—	—	—	—	—	—	—
pH Q 1:2.5	7.33	8.45	8.42	8.50	8.54	8.45	8.14	8.28	8.09	8.11	8.18	8.35	8.52
Constituents soluble in concentrated hydrochloric acid — %													
P_2O_5	—	—	—	—	—	—	—	—	—	—	—	—	—
CaO	—	—	—	—	—	—	—	—	—	—	—	—	—
MgO	—	—	—	—	—	—	—	—	—	—	—	—	—
K_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Na_2O	—	—	—	—	—	—	—	—	—	—	—	—	—
Exchangeable metal cations													
Total m. eq./100g soil	—	—	—	—	—	—	—	—	—	—	—	—	—
Total m. eq./100g clay	—	—	—	—	—	—	—	—	—	—	—	—	—
Ca — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Mg — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
K — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Na — % of total cations	—	—	—	—	—	—	—	—	—	—	—	—	—
Total water soluble salts — percentage of oven dry fine earth													
T.W.S.S	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.
NaCl (Cl x 1.648)	0.010	0.008	0.009	0.016	0.028	0.092	0.017	0.010	0.007	0.007	0.006	0.012	0.020
NaCl/T.W.S.S. Percentage	—	—	—	—	—	—	—	—	—	—	—	—	—

Greenish-grey hard sandy clay with small lime nodules.
Dense lime nodules and ferruginous gravel below 152 cm.
n.d. = not determined.

Greenish-grey friable clay to 137 cm, then more yellow.
Rock grit and decomposed rock from 213 cm.
(Arkosic grit from granite or gneiss). n.d. = not determined.

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