A RECONNAISSANCE SURVEY OF THE SOILS OF THE SHIRE OF KOWREE, VICTORIA

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FOREWORD

The investigation within the Shire of Kowree covered in the present publication were carried out in 1953-54 as a joint enterprise of the Commonwealth Scientific and Industrial Research Organisation and the Soil Conservation Authority of Victoria.

The initial step was a study of the soils, which developed into an examination of the present and potential land use of the Shire. An attempt has been made to deal with fertility and other problems facing new development and with the question of erosion hazards. The cooperative work of the authors has extended from field work to the preparation of the manuscript, and the responsibility for the views expressed is shared equally by both.

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1. INTRODUCTION

This survey was made jointly by officers of the CSIRO Division of Soils and the Soil Conservation Authority of Victoria, as a result of a request made to the former by the Council of the Shire of Kowree in June 953. This Shire consists of 2114 square miles in the west of Victoria, adjacent to the South Australian border. Most of the land is used for sheep-grazing but thee is some cereal-growing and horticulture. Uncleared timber and forest lands, mostly Crown Land, total approximately 800 square miles. Part of this occurs as government forest reserves, especially in the uncleared hilly country of the Black Range. The major part of the Shire consists of an undulating plain stretching eastward from the Victorian-South Australian border to the Black Range, the western extremity of the Grampians, and south from the Little Desert to the Glenelg River.

Large areas of natural grassland and the numerous freshwater lakes and swamps facilitated wool production a century ago. No great technical improvements in this industry occurred until about 20 years ago, when sown pastures and the use of superphosphate became popular. Progress has been made in increased wool production and cereal growing but the population of 3 700 is still small and one-third of it lives in the townships of Edenhope, Goroke, Apsley, and Harrow.

The current period of pasture improvement has been long enough to allow a summing-up of the new experiences and a reappraisal of the soil resources in the Shire. Two important attitudes to pastures and soils are met with in this Shire, and are important elsewhere too. Firstly there is the view that subterranean clover does not remain as productive as in the first few years of its establishment on any land. Secondly, the undeniable advances due to the use of this clover and the complex fertilizer usage adopted first in South Australia have stimulated interest in pasture establishment on the large area of infertile virgin land in the Shire. These attitudes undoubtedly influenced the request by the Shire Council for an investigation of local soils.

The survey consisted of systematic inspections of soils and related features along 2000 miles of roads and tracks in October and November 1953. Standard laboratory determinations were made on samples from 30 soil profiles. The report gives a description of the area, with emphasis on the soils and an assessment of them in relation to erosion hazards, soil fertility, and the scope for increased production based on soil conservation and improvement. The Shire of Kowree has been divided into 15 land units, each with particular soil variations. The occurrence of these units is shown on the soil map at the end of this survey.

II. ENVIRONMENT

(a) Climate

The rainfall decreases gradually from south to north. Balmoral, on the south-eastern Shire boundary, has a mean annual rainfall of 24.7 inches, which is probably exceeded only on the lack Range or in the south-west towards Poolaigelo. The lowest recorded rainfall is 19.5 inches at Goroke, but the country in the extreme north-east probably has lower rainfall. The general distribution of annual rainfall is shown in Figure 1; details cannot be shown owing to the lack of rainfall stations in the south-west and north of the Shire.

Rain falls mainly in the cooler months, Edenhope, for example, receives on the average two-thirds of its rainfall in the six months April-September. The growing season for annual grain and pasture plants at Kybybolite has been estimated as eight months (Trumble 1948) but growth is restricted in June, July,

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and August, when mean temperatures are between 45 and 50° F. These months also have the greatest incidence of heavy frosts, i.e. when minimum temperatures of 32°F or less are recorded in the standard screen. At Kybybolite the mean such frosts in the period April-November is 17, but 11 of these occur in months June-August. The late frosts are likely to damage horticultural crops as well as pastures and cereals, as in the case of the widespread heavy frost of October 13, 1954, when the minimum temperature at Kybybolite was as low as 26.5°F.

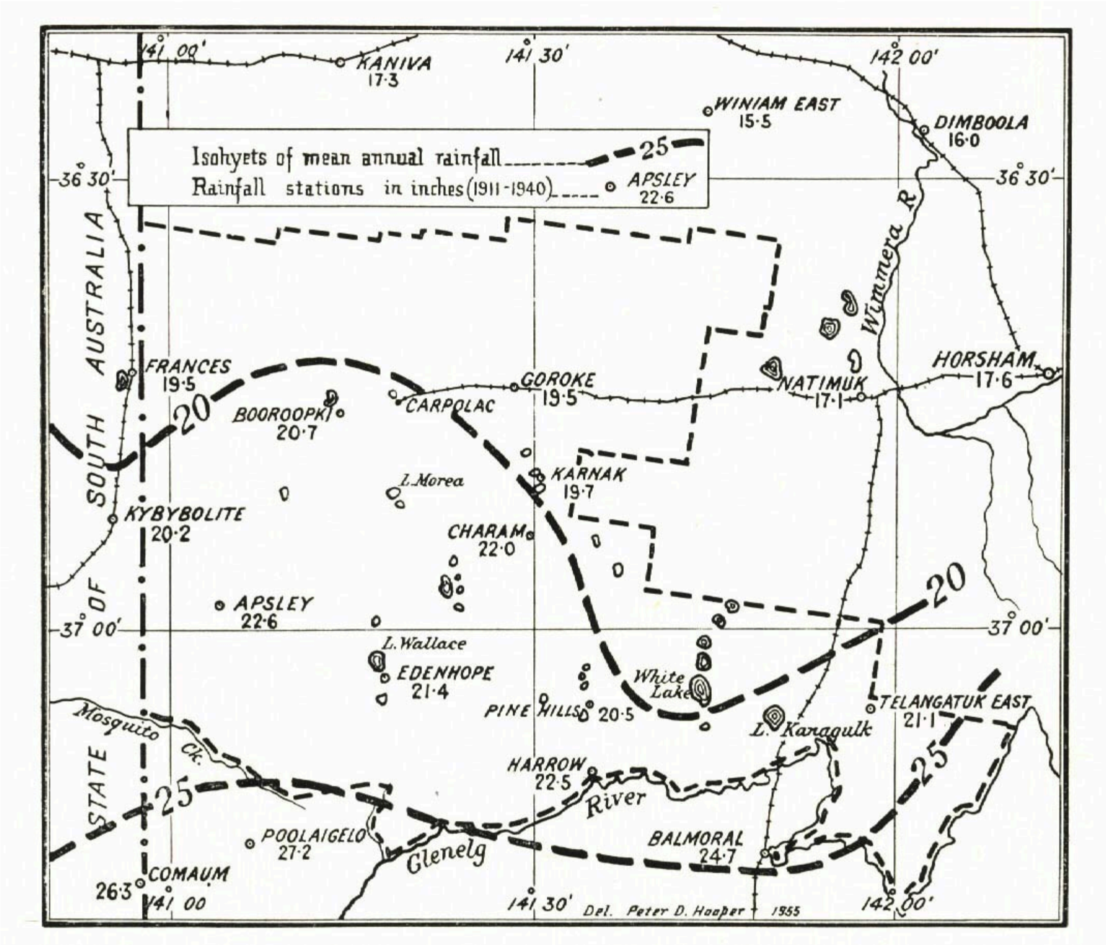

Fig 1 – Distribution of rainfall in the Shire of Kowree

There may well be significant variations in the Shire of Kowree in temperature incidence, particularly in some of the uneven country around Goroke valleys at the south of the Shire. The only meteorological records for temperature in the Shire refer to Booroopki, Lemon Springs, and to Apsley, but neither of these indicates any significant variation from conditions at Kybybolite.

(b) Topography and Geology

The Black Range, in the extreme south-east, and the Glenelg River valley, southern boundary, are distinctive features; apart from these the Shire lies on a fairly flat plain. The Black Range, capped by Mt. Byron, rises more than 600 feet above the plain and is made up mainly of sandstones similar to those of the Grampians, further east. The Glenelg River valley is 200 feet deep and contains the entrenched river below steep hilly country. The Rocklands Reservoir has been made in this valley by construction of a concrete dam at a point nine miles upstream from Balmoral; it supplies water by gravitation to the Wimmera and Mallee domestic and stock water supply system.

The extensive plain, constituting about 85 per cent of the Shire, slopes down very gently to the north and west. This slope is not at all conspicuous in comparison with the numerous basins and ridges throughout the plain, and is indicated only by the tendency of drainage water to move north-north-westward, except in the vicinity of the Glenelg River valley.

The outstanding topographic feature of the Shire, for which it is unique in Victoria, is the concentration of small lakes and swampy basins in parallel sequences. The largest basin slightly exceeds 1 000 acres and most of them do not exceed a few hundred acres, but they number hundreds. These lakes and swamps mainly lie in shallow parallel troughs, running south-south-east to north-north-west separated by more or less prominent ridges. In some of these troughs there is sluggish seasonal movement of drainage water northwards, but in others the basins are filled only by local catchment. In the western part of the Shire the parallel system is not well defined, owing to the gentle dissection of the area by four small west-flowing streams, the Mosquito, Koijack, Thompson's, and Morambro Creeks. In the south-eastern part of the Shire there are two troughs whose directions, departing from the general north-north-westerly trend, run irregularly north, and which are regarded by Hills (1939) as disused watercourses once occupied by tributaries of the Wimmera River. One of these troughs holds a number of salt lakes and the other is of some economic importance, as the water from the Rocklands Reservoir passes northwards in channels placed in this valley and is stored in it at the Toolondo Reservoir (Barton's Swamp).

The numerous depressions fill with water to a depth not exceeding about 12 feet. The deeper basins show a roughly circular outline and have on their eastern sides the conspicuous crescentic ridges, termed “lunettes” by Hills (1939), shown in Plate 1. The larger lakes are semi-permanent and with few exceptions their waters are fresh. These are a valuable asset in the Shire but so far the only notable diversion of lake waters occurs at Edenhope, where water from Lake Wallace is pumped, chlorinated, and reticulated for household use. The few salt lakes in the Douglas district (Fig. 2) lie in a trough referred to above. Samples of gypsum were obtained in the past from this locality.

The ridges lying between the lake and swamp systems vary in height from only a few feet, as in the north-west near Neuarpur, to 50 or 100 feet in the east and north-east, as around Gymbowen, where the parallel ridge system is most conspicuous. Many ridges have a sandy cover with forests of stringybark (*E. baxteri).*

The entire system of ridges and troughs ends abruptly to the north at the almost straight margin of the Little Desert. This is an extensive sand plain, characterised in places by east-west sand ridges, and separating the pastoral and agricultural lands of the Shire of Kowree from similar land in the Nhill-Kaniva districts. The sharp separation of the sandy scrub land from the better country north and south is not connected with any obvious differences in elevation.

Fig 2 – White Lake, a slat lake near Douglas. Viewed from the lunette on its eastern side. Samphire (Salicornia) grows on the salty fringe of the lake. A heap of salt harvested in summer lies in the foreground.

Rook outcrops are most common in the Black Range. Many different rocks outcrop in the Glenelg River valley, especially upstream from Balmoral where they have been important in construction of the new reservoir. Another rocky area in this valley occurs near Harrow, where there are small outcrops of granite, basalt and limestone. The remainder of the Shire is largely devoid of rock outcrops, the only exception of the parallel ridges, and the small areas with shallow beds of ironstone nodules (“buckshot” gravel) occasionally united to form boulders. The mottled sandstone has had restricted use as a building stone and the gravel is commonly used for the surface of roads. Limited use is also made of a basalt outcrop near Harrow as a material for surfacing roads.

The repetition of parallel rides, with intervening lines of swamps and lakes, has attracted attention from geologists but so far there is no satisfactory explanation of their origin. The concentration of iron oxide occurring in various formations at or close to the surface (ironstone gravels and sandstones) suggests that the formation of laterite has been a feature of the area, but research is required to elucidate this problem.

The southern part of the Shire is important as an intake area for the Murray artesian basin. The country to the south and east has an impervious rock basement and is drained by rivers, but the Shire of Kowree is underlain, at least to a considerable depth, by more permeable Tertiary deposits, including an extremely porous Miocene limestone. Surface water enters this formation, particularly through sink-holes, and moves north and west, to maintain a supply of underground water of good quality throughout an area of about 20 000 square miles in Victoria and South Australia. Accurate information is lacking both on the quantities entering the aquifer in this Shire and on the area of intake, but sink0-holes in the Apsley district are known to be important. The absence of well-defined streams in part of the Black Range, for example the western slopes of Mt Byron, suggests that underground drainage may be important there. The general absence of salt concretions in the numerous lakes and swamps also indicates that there is partial drainage to the underground, although evaporation is probably the main factor in the gradual disappearance of the water in dry seasons. The underground water is obtained at depths generally exceeding 100 feet, from limestone in the western part and from clay beds in the eastern part of the Shire. Large supplies are available, especially from limestone, but so far there is little use of the water for irrigation of farm crops.

Apart from limited areas of soils formed on crystalline and older sedimentary rocks the soils generally have formed either directly on post-Miocene sandy and clayey deposits or materials derived from them. Wind movement of material has been important in the formation of lunettes to the east of many lakes, and in the construction of sand ridges, although the origin of these sands is not certain. Wind movement of oceanic salts has furnished at least part of the soluble salts commonly occurring in subsoils throughout the plains of the Shire. The major component of these salts is sodium chloride, and its high solubility and movement in solution have led in a few places to salting of poorly-drained land. The appreciable amounts of free calcium carbonate occurring in or throughout many of the soils have as their source the weathering of the post-Miocene deposits, the underground water, or air-borne deposits originating from the ocean or seashore.

(c) Vegetation

On 800 square miles there is natural vegetation, comparatively undisturbed except by fire which has been used purposely in places to promote grazing of young growth. The greater part of the Shire has undergone considerable changes but it is still possible to indicate many of the original types of vegetation (Fig. 3).

Trees, mainly eucalypts, were widespread formerly but there was much native, grass among the trees and in open treeless areas (Figs. 4, 6). It is in these parts that many lakes occur, consequently areas of grassland convenient to good surface water were soon occupied for grazing and many trees were gradually killed to increase the grass area (Fig. 5). The greatest destruction of trees was required on land used for cultivation, mainly in the northern parts. Areas without grass, occupied either by a dense tree growth or by trees and shrubs, have had little interference because of the labour involved in clearing, the apparent poverty of the soils, and the frequent lack of surface water.

Fig. 3. - Although some clearing of trees has occurred, the original savannah woodland formation of river red gum* (Eucalyptus camaldulensis) *is indicated in this scene taken in the Glenelg unit.

Until about 20 years ago the vegetation had been changed mainly by removal of trees, encouragement of native grasses, and cultivation of cereals for grain or fodder. In recent years the natural spread or systematic sowing of pasture legumes, especially subterranean clover, and top-dressing with superphosphate have increased the fertility of limited areas of the soils.

The definite types of vegetation in the Shire are those consisting almost exclusively of rushes, grasses, shrubs, and trees respectively. They are:

(1) Swamps, consisting of rushes only, e.g. the numerous swamps to the west of Goroke.

Fig. 4. - Part of a forest reserve on plateau land near the Glenelg River showing condition and density of a virgin stand of river red gum* (Eucalyptus camaldulensis) *with ground cover of grasses and sedges.
Compare with Figure 5.

Fig. 5. - Pasture adjoining the virgin land in Figure 4. The complete destruction of trees in this paddock is unusual.

(2) Grassland, consisting of grasses only, e.g. the lunettes on the eastern edges of many lakes such as Ullswater.

(3) Heath and scrub, consisting of low shrubs only, e.g. the flats in the Little Desert.

(4) Woodland, consisting of an open cover of spreading trees and usually with grass, e.g. the red-gum country around Edenhope and the yellow gum and box around Goroke.

(5) Sclerophyll forest, consisting of a closed cover of trees and usually with an understorey of shrubs, e.g. the "stringybark scrub".

Fig. 6. - A specimen of black box (Eucalyptus largiflorens) on a roadside in the Minimay district, showing the characteristic spreading habit.

However, there are various common intermediate forms less readily named and classified. Some of these may be described as follows:

(1) Rushy swamps with scattered shrubs, e.g. lignum swamps, salt swamps.

(2) Savannah woodland consisting of the very open woodland with abundant grass as typified by the red-gum plains.

(3) Scrubby dry sclerophyll forest consisting of shrubs with stunted trees, e.g. the more poorly developed "string bark scrub".

There are at least 13 species of eucalypts in the Shire, including:

Eucalyptus camaldulensis (syn. *Rostrata*)	River red gum
E. leucoxylon	Yellow, blue or white gum
E. viminalis	Manna or white gum
E. ovata	Swamp or white gum
E. fasciculosa	Pink or hill gum
(This species occurs only near the South Australian border and was not seen)	
E. hemiphloia var. *microcarpa*	Grey box (Fig. 7)
E. largiflorens (syn. *Bicolor*)	Black or flooded box
E. melliodora	Yellow box
E. elaeophora	Long-leaf or bastard
E. baxteri (syn. *Capitellata*)	Stringybark, brown stringybark
E. macrorrhyncha	Red stringbybark
(This species has been reported near Balmoral but was not seen)	
E. incrassata	Mallee
E. leptophylla	Mallee

Some of the "peppermint" box trees in the Goroke district may be *E. odorata*

Fig 7. – A specimen of box in the Gymbowen district.
The upright growth habit of this tree is in contrast with black box (Fig 6) and it closely resembles grey box (*Eucalyptus hemiphloia*)

Other trees are:

Casuarina luehmanni	Bull oak (Fig 8)
C. pusilla and *C.* spp	Desert-oaks, oak-bush
Melaleuca pubescens	Dry-land tea-tree
M. halmaturorum	Salt-water or paper-bark tea-tree
Callitris glauca	Native pine
C. propinqua	Murray pine
C. tasmanica	Native pine
Acacia mollissima	Black wattle
A. pycnantha	Golden wattle
A. melanoxylon	Blackwood
Pittosporum phillyreodes	Native willow

The main shrubs, mainly those common in heath areas, are:

Xanthorrhoea australis	Yakka, blackboy
X. quadrangulata	Yakka
Banksia marginata	Honeysuckle
B. ornata	Honeysuckle
Leptospermum pubescens	Silky tea-tree
Leptospermum spp.	Tea-tree
Melaleuca uncinata	Broom-bush (tall)
M. oraria (?)	Broom-bush (low)
Dodonaea viscosa	Sticky hop-bush
Calythrix tetragona	
Hibbertia sericea	} Heath plants
Epacris impressa	
Brachyloma daphnoides	

The grasses include:

Danthonia caespitosa	Ringed wallaby grass
D. duttoniana	Wallaby grass
Stipa falcata	Slender spear grass
S. setacea	Corkscrew grass
Hordeum murinum sun. *leporinum*	Barley grass
H. hystrix	Sea barley grass
Amphibromus neesii	Swamp wallaby grass
Neurachne alopecuroides	Foxtail mulga grass
Poa bulbosa	Bulbous poa
Vulpia myuros	Silver grass
Bromus mollis	Soft brome
Distichlis distichophylla	Australian salt grass

Some of the rushes, weeds and other plants are:

Juncus polyanthemus	Common rush
Cladium filum	Thatching grass
Erodium botrys	Long storksbill
Cryptostemma calendulaceum	Cape-weed
Homeria collina	One-leaf Cape tulip

III. SOILS

(a) General Features and Classification

The prevalence of sand is a distinctive feature of the soils in the Shire. This is most noticeable in the many dunes and ridges where the depth of loose sand may be several feet. But even on the extensive plains the surface soils (A horizons) to 12 or 18 inches are mainly sandy with comparatively low amounts of silt, clay, and organic matter. Another important feature is the occurrence of tough clay subsoils DB horizons), especially on the plains. The deeper subsoil layers, at 30 to 40 inches below the surface, normally contain high amounts of carbonates ("lime") and appreciable contents of soluble salts, mainly sodium chloride. A third important feature is the extent of gilgai or "crabhole" soil patterns.

Table 1 – Popular names and scientific classification of main soils in Shire of Kowree

Popular Term	Scientific Classification
Sandy loams or reg-gum country	Solonetzic sandy loams
Sandy, heath, or stringybark land	Solodic or podzolic sand
Crabholey, heavy, or Wimmera soils	Gilgaied solonetzic soil complex
Loams or hummock soils	Solonetzic loams or red-brown earths

The soil terms most used by landholders in the Shire refer to the nature of the surface soil or to obvious features of the landscape, either native vegetation or topography. A scientific soil classification, based on the nature and arrangement of successive soil layers in the vertical section, is necessary for any assessment of soil problems. There is broad agreement between the scientific classification and local classification of soils, though the names are quite different, as shown in Table 1. Detailed descriptions, with references to soil pH and salt content, are given for typical soil profiles in Appendix 1. The different soil profiles named in Table 1 are discussed below.

Fig 8 – A typical example at Gymbowen of bull oak (Casuarina leuhmanni), with river red gum (Eucalyptus camaldulensis) in the distance.

Fig. 9. - The exposure of this solonetzic soil to 12 inches shows the compact sandy loam surface, the whitish subsurface layer, and the dense columnar clay subsoil. The hole is close to the site of gypsum trials near Goroke (Mullett and Scott 1923).

(i) Solonetzic Soils.-The surface soils are normally of fine sandy loam texture but sands also occur to a limited extent. The fine sandy loams are mainly compact when dry, except possibly in the first inch. The surface is grey, grey-brown, or brown in colour, depending on soil drainage and organic accumulation. Only a few inches of soil are darkened by organic matter and the subsurface layer is lightly coloured or off-white. This layer, above the clay subsoil, becomes semi-fluid in wet periods and is referred to as "spewy". Subsoil clay may occur at 2 to 18 inches below the surface, but generally at 6 to 12 inches. The colour varies somewhat with surface colours and local features: brownish subsoils occur with brown surfaces; yellowish, reddish, and grey mottlings may be found under grey surface soils. Mottled subsoil colours are common. The subsoils are invariably tough and cloddy and show the distinctive regular vertical cracks between columns of clay, as shown in Figure 9. Deeper subsoil layers are more friable and contain up to 10 per cent. of carbonates ("lime") and up to 0-5 per cent of soluble salts. The profile shows a gradual change from an acid surface to the strongly alkaline deep subsoil. Organic matter, estimated as 0-5 to 3 per cent, is most concentrated in the first few inches of soil but relatively appreciable amounts, I to 2 per cent, occur in the upper clay subsoil.

Solonetzic soils are noted for their distinctive subsoil features, usually associated with a compact surface soil. The physical and chemical properties of these soils are usually rather unfavourable for the entry of water and air, hence the soil profile features limit plant growth.

Fig. 10 - Soil variations in a virgin gilgai are near Neuarpur with scattered bull oaks (Casuarina luehmanni).
The further hole has friable clay soil on the puff or mound, and the nearer hole shows a thin bleached layer over cloddy clay. Depressions, or crabholes, are marked by rush growth. (See Profiles 6A, 6B, Appendix 1.)

In gilgai areas, with a marked variation of soils over very small distances, the term gilgaied solonetz may be used to cover the association of solonetzic soils on lower spots with soils on higher spots (puffs), which often have distinctive crumbly clays. The solonetzic soils have usually only an inch or two of sandier material over the subsoil clay. The puff soils are normally clay throughout, and show large cracks in summer. Some gilgai areas lack clay soils on the puffs. Typical soil variability in gilgai areas is shown in Figures 10-12. There is a great variety of soil features in areas referred to as gilgais or crabhole soils. Cultivation and levelling have almost obliterated gilgai features in some paddocks, but there is still a very large extent of undisturbed land with a wide variety of features, outlined below.

(1) Degree of unevenness.*-The vertical* interval between puff and depression is rarely more than 18 inches, but unevenness depends partly on the spacing of the puffs. The greatest irregularity occurs in sites that are quite swampy in wet seasons, such as the fringes of some shallow lakes, or low watercourse areas.

(2) Occurrence, of self-mulching soils.-Extremely loose, rather bare, self. mulching grey clays with visible lime occur on some puffs, as in the Toolondo district, but generally there is a range through self-mulching limy soils to cloddier, less limy types on the puffs. Some puff soils, as in the Kadnook and Fulham districts, are sandy loams, lacking lime, with cloddy clay near the surface (Fig. 13).

Fig. 11 - A close-up view of crumbly clay soil on the puff shown in Figure 10

Fig. 12 - A view of compact solonetzic soil in the rushy gilgai depressions shown in Figure 10.

(3) Proportions of shelf soils.-The soils of the shelf sites, that is, flatter sites between puff and crabhole, make up from 10 to 80 per cent of an area of crabhole land. Areas of shelf soils are least obvious in some swampy sites but are very noticeable in gently sloping sites with only a few puffs and crabholes, per acre.

(4) Profile features in crabhole areas.-Puff soils have grey (light and dark), yellow-grey, brown, and reddish brown colours. Apart from the non-limy sandy loam puffs seen only in the southern part, the textures are clays, generally showing cracks when dry.

Shelf and crabhole soils have only a thin layer of compact sandy loam over stiff clay. These are varieties of solonetzic soils.

Fig 13 – This view near the Glenelg River represents the uneven, gilgai soils without exposure of clay on the puffs.
The soil profiles on puffs and depressions are solodic.

Another variety of solonetzic soils occurs on some lunettes. The lunettes are banks or ridges, shaped like a new moon, on the eastern sides of lakes and swamps, They consist of wind-blown material and the soils vary with the type of material involved-sandy or clayey. Some lunettes are complex hummocky structures **with** grey sandy loams or loams over dark grey clay with marl from two to three feet. In other cases the soils are reddish brown and compare with red-brown earths near Adelaide. Some lunette soils have solonetzic subsoils under a depth of sandy material.

(ii) Solodic Soils.-These have some resemblance to the solonetzic soils of the area, as there is a sharp change from sandier surface soil to clay subsoil, but columnar effects do not occur in the subsoil and a conspicuous bleached layer, hard when dry, occurs above the clay (Fig. 14). These solodic soils generally have lower amounts of soluble salts and lack carbonates in the subsoils. There are intergrades between solonetzic and solodic soils, and they may both have similar surface soil features. However, the solodic soils in this area are mainly those with a much greater depth of sandy material above the clay subsoil. Ironstone gravel occurs above the subsoil in a number of solodic soils. The organic matter at the surface of these soils is estimated to be from 0 - 5 to 1 per cent and the upper subsoil contains similar amounts.

(iii) Podzolic Soils.-A degree of accumulation of iron and organic matter is shown in many profiles of deep sand, especially those in swampy areas with seasonal shallow water-tables. In these cases a rusty organic layer of "coffee rock" may be found near the water level.

These soils are acid throughout the profile and contain little organic matter near the surface. Few examinations only were made of these deeper sandy soils.

***(iv) Saline* Soils.-**These occur mainly near the margins of salt lakes, as in the Douglas area, and show surface-crusts of soluble salts in summer.

Fig. 14-Inspecting an erosion gully near White Lake. This profile shows the extremely compact bleached subsurface layer, a feature of solodic soils.

***(v) Miscellaneous Soils.*-**Small areas of black peaty soils occur in and near swampy situations in the headwaters of creeks draining to the Glenelg River. Black and reddish soils occur in small areas of special geological or drainage conditions in the Glenelg valley system.

***(vi) Distribution of* Soils.-**The solonetzic soils are most widespread in the Shire and show remarkable uniformity over great distances. Changes in topography and geology are associated with particular varieties of solonetzic soils: the brown solonetzic varieties found on freely-drained ridges in the Goroke district, and also on lunettes throughout the northern districts. Some lunettes, for example in the Maryvale district, have dark grey solonetzic soils.

Gilgaied solonetzic soils are extensive on flat and depressed situations conducive to swamping in the northern districts, but they also occur on sloping land. They were less extensive in the southern parts but may be seen even south of the Glenelg River**.**

Solodic soils occur sporadically in the long ridges extending north-north-west and south-south-east and also in other areas of stringybark scrub. Profiles intermediate between solonetzic and solodic soils occur on the extensive plains in the south of the Shire.

Podzolic sands are restricted to areas of deeper sand, and are mixed together with solodic sands.

***(vii) Laboratory Examination of Soils*.**-Soil samples were collected from more than 30 sites in the Shire and submitted for laboratory examination. Determinations were made for plant nutrients, except trace elements, soluble salts and soil reaction (pH), exchangeable cations, mechanical composition, and composition of carbonates and soluble salts. Reference is made in the section on soil fertility to the relevant data on plant nutrients, salinity, soil reaction, etc. The determinations on soluble salts have shown that these consist mainly of sodium chloride, common salt. - Small proportions of sulphates were found in areas of gilgaied solonetzic and solonetzic soils. The carbonates consist mainly of calcium carbonates, but magnesium carbonate may be present in amounts up to 10 per cent. of total carbonate in a sample.

(b) General Account of Land Use in Relation to Soils

Despite the low fertility of large areas in the Shire of Kowree, limited production has always been possible because rainfall is adequate for the growth of native herbage during at least six months of the year. The most prevalent grassland soils are sandy and are well suited to plant growth in months of moderate and regular rainfall; their clay subsoils ensure a reserve of water for drier periods. The gilgai clay soils mainly occur in broad depressions or valleys liable to collect some of the limited run-off and this circumstance offsets the usual disability of clay soils for plant growth in areas subject to dry periods. This efficiency of the soils with respect to the local annual rainfall of 18 to 23 inches has been the basis of pastoral activities since Major Mitchell's discovery of the region in 1836.

Wheat-growing for export became possible with the construction of railways near or in the Shire from 1880 to 1927. This industry became important mainly in the northern parts of the Shire where it was given scientific assistance by the Victorian Department of Agriculture. This government assistance occurred particularly in the Goroke district, probably owing to the existence there of an active Agricultural and Pastoral Society. It was from this locality that the major soil variations of the Shire were first recorded (Mullett 1918) and experiments were carried out there in an attempt to overcome the adverse physical properties of solonetzic sandy loams (Mullett and Scott 1923). The best soils for wheat-growing were found to be the darker soils of the hummocks, i.e. lunettes, bordering numerous lakes. The light sandy soils with clay subsoil, i.e. solonetzic or solodic sands, near the Little Desert were known to suffer waterlogging in wet years. The clay soils, occurring in gilgaied solonetzic areas, were known to be difficult to manage until levelled by cultivation. Interest in scientific agriculture led to the introduction of Wimmera ryegrass and subterranean clover to the Goroke district about 1920.

In the same period of activity near Goroke, there were similar developments in the Kybybolite district of South Australia, due to the establishment of the Kybybolite Experiment Station in 1905 and the existence of active local branches of the Agricultural Bureau. The value of subterranean clover as a pasture plant in this district had been established by 1920 on local farms. Subsequently the Experiment Station entered on a long period of investigation into top-dressing pastures of native species and of Wimmera ryegrass with subterranean clover (Perkins 1928; Cook 1939). These and other experiments on solonetzic soils at Kybybolite have had a great effect in the adjoining territory in both States, particularly in showing the production to be achieved by the use of these soils for improved pasture rather than cereal-growing as had been attempted in the earlier years at Kybybolite. Large areas of the Shire are now used for improved pastures based on subterranean clover and this development has also stimulated the industry of clover seed harvesting.

Fig. 15 - Portion of stringybark* (Eucalyptus baxteri) *vegetation in the Tallageira parish. The straggly low growth of these trees is characteristic for this Shire. Ground cover consists of low shrubs and sedges in a loose sandy soil (Profile 5, Appendix I).

Further extensions of pastoral areas can only occur now on the less fertile deeper sandy soils still covered by natural vegetation, usually heath or stringybark (Fig. 15). Some such development has already occurred but there is a high expense for clearing and subsequent growth of shrubs and bracken may be troublesome. Considering the low fertility of the deeper sandy soils they may not be as suitable for pasture as for timber production.

Introduced pasture plants other than Wimmera ryegrass and subterranean clover have not been widely used despite the experience at Kybybolite showing the merit of *Phalaris tuberosa,* a perennial grass. The main pasture grass, Wimmera rye, is not persistent in long-term pastures unless there is some cultivation for pasture renovation. The common clover is susceptible to attack by both red-legged earth mite *(Halotydeus destructor)* and lucerne flea *(Smynthurus viridis).* These two popular pasture plants are often incapable of completely dominating a pasture and it is common to find large proportions of less valuable annual grasses: barley gram**,** brome, and silver grass, or weeds such as cape-weed *(Cryptostemma calendulum)* and Cape tulip *(Homeria collina).*

Fig. 16.-Lake Charlegrark Booroopki, is one of the many shallow freshwater lakes in the Shire of Kowree.

Only a limited use has been made of other pasture plants although *Phalaris tuberosa,* lucerne, and veldt grass have proved useful. The area sown with *Phalaris tuberosa* probably does not exceed a few thousand acres. Perennial veldt grass *(Ehrharta calycina) is* used on some sandy land in the north of the Shire and could be more widely used on the sandiest soils. Lucerne is grown to a limited extent both with and without irrigation and there is no doubt that much greater use could be made of it, especially under irrigation on lunettes. Strawberry clover was seen only on one small area and probably could be used more widely in swampy sites. Evening primrose also probably has application to particular soils-the more and sandy sites.

Irrigation, especially supplementary irrigation with sprays, could be used to a greater extent, particularly in the western part of the Shire where large amounts of water can be pumped from the underground supply. Limited use might also be made of the surface water held in the many lakes (Fig. 16). There is little experience of irrigation in the Shire and advice is required on the possible drainage and salinity problems likely to limit the irrigation of cimmon soils-the solonetzic sandy loams and gilgaied solonetzic soils.

Some areas of improved pasture have been used recently for cereal cropping with very satisfactory results, indicating the merit of periodical cropping association with improved pastures.

Fruit-trees are grown commercially to a limited extent. Apricot plantings are mainly on better-drained deeper sandy soils fringing sand ridges, or on lunettes, whereas plums may be grown successfully on less well-drained areas of solonetzic. plain soils. Only a few vine plantings were seen in the Shire. Frost hazards, among other problems, are likely to limit any major horticultural extension at present.

Despite many changes in the past century, wool production still remains the main industry in the Shire. This is now more productive than ever, mainly owing to widespread use of superphosphate on improved pastures. Increased productivity is accompanied by a reduction in the size of holdings and the most intensive production is often found on the smaller holdings of less than 1 000 acres. Capital improvement, in the form of fencing, sown pasture, mechanical equipment, water supply systems for stock or for irrigation, and so forth, has assisted production. The rabbit problem, which had become quite serious on many holdings, is of minor importance since the spread of myxomatosis, and could be eliminated completely.

Wool production depends here mainly on Merino sheep. The difficulties in rearing sheep in this country have led to a wide preference for grazing of dry sheep, especially larger-framed types purchased from drier northern areas. The difficulty of rearing sheep is due mainly to “weaner unthriftiness”, an ill-defined but common complaint. Experiments intended to test the contribution of potassium deficiency to this disorder are now in progress at the Kybvbolite Experiment Station, following recent experience in Tasmania.

Beef cattle are grown on many properties, usually in conjunction with sheep. Dairy production is a minor industry in point of output and is probably only sufficient for local requirements.

Forestry occupies a minor place in land use if judged by the number of people actively involved, but the area of natural forest reserves is comparatively large. River red gum, *Eucalyptus camaldulensis,* has been most used for milling, but is not as abundant as stringybark. Commercial plantings of exotic forest trees such as *Pinus* are not noticeable, though a small plantation of *Pinus* at Kybybolite shows that climate and soils would not be unfavourable in the southern part of the Shire. Obviously any successful afforestation of exotic trees would entail considerable precautions against fires, an ever-present risk in this drier, sparsely settled district. The large areas of uncleared scrub and forest lands can scarcely be regarded as productive in their present state, except to a limited extent for apiarists, and might be used more for commercial timber production. Nevertheless, even in their present state these scattered areas are of value in breaking the force of winds in the extensive plains.

Many opportunities obviously exist for increased production by the use of modern techniques backed by adequate capital. There are several kinds of obstacles, not the least of which is the cost of certain measures in relation to market prospects. Thus economic considerations are likely to limit use of underground water for irrigation, or any extension of fruit-growing. But attention should be directed also to some of the more natural obstacles to greater production: the hazards of soil erosion, drought, frost, fires, and floods; accessibility; and damage by animals. These matters naturally have unequal importance in different parts of the Shire. Consideration is given to these questions in Section (e) below, where the discussion is summarised in Table 3.

Wide experience of soils and land use in the Shire has revealed that many avenues of primary production are feasible even though there has been little progress with anything but wool production. The earlier attempts, in the Kybybolite district, to exploit the solonetzic sandy loams for cereal production were given up in favour of improved pastures, partly because physical features of the soil, especially drainage, were found unsuitable for cereal production. Recent experience within the Shire has shown cereal-growing to be far more productive after years of soil improvement. This confirms the successes obtained in wheat-growing at the Rutherglen Experiment Station, in north-east Victoria, using rotations with clover pastures. It also indicates that there is scope for much more diversified and intensive production in the Shire of Kowree.

The major problems apparent after the years of local pasture improvement are:

(1) Eradication of persistent nutritive disorders in sheep, sufficient to discourage many graziers from breeding sheep.

(2) Determination of fertilizer treatments appropriate to different soils and systems of production, both for the period of pasture establishment and subsequently for pasture maintenance.

(3) Correct measures for maintenance of balanced pasture composition through management practices.

(4) Determination of land-use systems, appropriate. to different soils, involving rotation of pastures with grain crops.

Investigations dealing with some of these problems are in progress at the Kybybolite Experiment Station, S.A., but the problems involving soil variations, as between Gymbowen and Harrow or between Neuarpur and Edenhope, certainly cannot be dealt with at one centre alone. A keen interest is shown by landholders in some of these problems, especially the matter of appropriate fertilizers, and a number of observation plots were seen which used a standard system of various fertilizer treatments.

(c) Soil Fertility Problems

There are no areas of highly fertile soils and without chemical fertilizers the level of production remains very low. Phosphorus, supplied in superphosphate, has been necessary for increased cereal production and for growth of pasture legumes. The successes associated with superphosphate drew attention from other soil deficiencies until the recent interest in trace elements. These have not been shown to be essential for the present land use on solonetzic sandy loams and gilgai solonetzic areas, but copper and zinc are known to give responses for clover growth on sands, either solonetzic, solodic, or podzolic, as in the Miga Lake district (Newman, personal communication), Little Desert, and in adjacent areas of South Australia (Tiver and Crocker 1951). Zinc responses for cereals, clover, and flax have been obtained on gilgai soils in the Victorian Wimmera (Forster and Hore 1939) and for clover on similar soils in the Frances district (Tiver, personal communication). Pasture responses to potassium have been obtained on solonetzic sandy loams at Kybybolite Cook 1939) and at Apsley (Newman 1948), but the responses were comparatively small and the use of a potassium fertilizer has been regarded as uneconomic in these cases. Field experiments with calcium, either as agricultural lime or gypsum, have been conducted at Kybybolite and Goroke on solonetzic sandy loams and in both cases significant responses were obtained: comparatively uneconomic effects on pasture at Kybybolite (Cook 1939) but quite outstanding effects from gypsum with wheat growing in the Goroke district (Mullett and Scott 1923).

The experimental work at Kybybolite (Perkins 1928; Cook 1939) on the effects of top-dressing has been of great value in showing the marked improvement in soil fertility after application of phosphorus fertilizer. With both natural and improved pastures the use of this fertilizer increased the sheep-carrying capacity and increases were obtained in nitrogen and potassium contents of the surface soil. Typical analyses of soils from unimproved and improved soils at Kybybolite with typical virgin soils in the Shire of Kowree are given in Table 2, which also includes results for a fertile soil at Mt Gambier, South Australia, and an infertile soil in the Coonalpyn Downs, South Australia, in order to show the general deficiencies in the Shire of Kowree.

The data indicate that the soils in the Kybybolite experiments are comparable with the commonly used solonetzic sandy loams in the Shire. The grey puff soils from gilgai areas and the solonetzic brown soils from lunettes appear to be the most naturally fertile soils iii the Shire but they are quite inferior to the Mt. Gambier soil. The solodic sands with some depth of sand above clay subsoil are shown to be lacking in all major soil nutrients; deficiencies of trace elements are to be expected also on such soils.

Table 2 – Analytical data for representative soil of the Shire of Kowree and for fertile and infertile soils of South Australia

Soil Type	Sample		PH	Nitrogen (%)	Phosphorus (Acid-extract) (%)	Exchangeable Calcium (%)	Exchangeable Potassium (%)	Chlorine (as NaCl) (%)
	Depth (in)	Texture						
Solonetzic sandy loam, untreated natural pasture, Kybybolite (Plot 6)	0-3	Sandy loam	6.3	0.07	0.005	3.3	0.29	0.01
	10-18	Clay	8.3	0.07	0.005	10.5	0.80	0.03
Solonetzic sandy loam, improved (volunteer) natural pasture, lime and superphosphate treatment, Kybybolite (Plot 3)	0-3	Sandy loam	6.8	0.14	*	7.3	0.31	0.01
	8-10	Clay	8.1	*	*	9.0	0.86	0.02
Solonetzic sandy loam, untreated natural pasture with eucalypts, east of Apsley, Profile 3	0-3	Sandy loam	6.0	0.09	0.005	1.7	0.07	0.001
	10-13	Clay	6.6	0.08	0.006	4.1	0.47	0.01
Gilgai grey clay, virgin site, near Neuarpur, Profile 6A	0-3	Clay	8.6	0.09	0.009	*	*	0.007
	9-20	Clay	9.4	0.03	0.005	*	*	0.08
Brown solonetzic sandy loam, virgin site on lunette, Lake Karnak, Profile 19	0-3	Sandy loam	6.7	0.09	0.008	5.4	0.75	0.004
	3-6	Clay	7.2	0.12	0.011	16.9	2.0	0.005
Solodic sand, stringybark forest, west of Douglas, Profile 23	0-3	Sand	5.4	0.03	0.003	0.7	0.03	0.001
	36-39	Clay	5.5	0.02	0.005	0.2	0.17	0.02
Black soil on volcanic ash, Mt Gambier, SA	0-6	Sandy loam	8.1	0.35	0.175	28.1	0.84	0.02
	8-16	Sandy loam	8.0	0.13	0.150	20.2	0.44	0.08
Solonetzic sand (Buckingham sand), Coonalpyn Down, SA	0-2	Sand	6.5	0.04	0.004	2.4	0.12	0.004
	11-17	Clay	7.8	0.08	0.007	9.3	1.92	0.01

It is well known that the phosphorus deficiency can and should be remedied by top-dressing with superphosphate and that the nitrogen status can be raised by the growth of clovers and their associated bacteria. But potassium and calcium, although known to be present in rather low amounts in many of the inspected soils, have received relatively little attention so far. The question of potassium deficiency has come into prominence recently in southern Australia and Tasmania where major responses have been obtained in pasture growth on some soils while in other cases there has been mainly an improvement in the health of livestock, especially the reduction of “weaner unthriftiness”. Many of the solonetzic sandy loams, as at Kybybolite, have higher amounts of potassium in subsoils and plant activity is responsible for its transference to the surface. But in the solodic and podzolic sands there is a gross deficiency of potassium throughout a considerable depth of soil. Taking the arbitrary figure of 0.2 milli-equivalent of exchangeable potassium per 100 grams of soil, corresponding with approximately 80 lb of exchangeable potassium in the first 4 inches of soil over an acre of land, as the lower optimum limit for potassium, it was found that many surface soils are deficient. Seven solonetzic plain soils from scattered points showed potassium deficiencies in four of the surface soils although all subsoils within 18 inches from the surface contained much more than 0.2 milli-equivalent per cent of potassium. Four solodic sands all showed potassium deficiency at the surface and two of these were also deficient in the subsoil clay, 24 to 36 in, below the surface. The brown or grey solonetzic loams on lunettes are well supplied with potassium in the surface and subsoil, and a similar position holds for soils in gilgai areas. The level of potassium given above is quite arbitrary and the small potassium responses at Kybybolite may have been associated with slightly higher contents, as shown in Table 2; nevertheless, there is a suggestion from the soil analyses that potassium is deficient in many of the sandier soils.

The calcium status of this area has had little scientific investigation yet. Limited, field experiments and soil analyses indicate that calcium deficiency may be important in the less fertile soils. Many surface soils were found to have less than 2 m-equiv. per cent calcium, although pH determinations were not below 5.4. Responses to lime have been obtained with soil at Kybybolite containing less than 5 m-equiv. per cent calcium (Cook 1939). Similarly Harris (personal communication) has observed near Adelaide a lime response for subterranean clover in a soil with less than 5 m-equiv. per cent calcium. Neither of these soils is highly acid; the pH determinations were from 6.0 to 6.5. Soil pH is likely to be misleading in assessing a lime requirement in the very sandy soils of this and other areas. The soil analyses in conjunction with field experiments indicate that a probable calcium deficiency warrants detailed investigation. Such a deficiency would, of course, be remedied progressively by annual applications of calcium in superphosphate and through accumulation by pasture plants of calcium from subsoil layers. However, in such a case as the third profile in Table 2, the exchangeable calcium in the top 3 in. is approximately 350 lb per acre and an increment of, say, 75 lb of calcium per acre in the first two years from 3 cwt of superphosphate may be quite insufficient to remedy a deficiency which can limit pasture establishment through its effects on the legume bacteria, *Rhizobium.*

Plants vary in response to different amounts of particular nutrients and also to the different proportions between nutrients, as shown by Milliman (1953) and Tyson (1954) in the case of subterranean clover. This is the reason why treatment of soil deficiencies may be complicated and requires care so that treatment of one deficiency does not induce another deficiency, as in the case of a manganese deficiency induced by liming (Tyson 1954).

Soil deficiencies need to be assessed in terms of prospective land use. Certain deficiencies, especially of some trace elements, may not appear in the first years of pasture establishment on land where burning of native vegetation releases a small supply of mineral nutrients. In other cases the choice of land use is quite important; for instance, a long period of intensive dairy production is likely to diminish certain plant nutrients more rapidly than does wool production.

The results obtained from chemical analyses show that only limited areas may be regarded as moderately well supplied with nutrients and large areas are potentially infertile. Deficiencies are more likely to be exposed as higher production is sought from the soils of the area.

Other aspects of soil fertility include the presence of substances harmful for plant growth, soil structure, and the associated problems of supply of water and air. The investigations made on soil samples, show that many of the soils are quite highly charged with soluble salts in the subsoils, especially in gilgai areas. These salts consist mainly of sodium chloride, with only very small proportions of calcium or magnesium sulphate or bicarbonate. Such salt concentrations have various effects: disturbance of the balance of nutrients in the soil, limitations of moisture availability for crop plants, alteration of physical properties of soils giving cloddy subsoil clays. Provided that the salts remain concentrated only in the deep subsoil there is no obvious effect on plant growth, yet where the salts migrate to the surface, as in some wet, saline areas near Douglas, the land is most unsuitable for crop plants. This effect is very limited in area so far but could occur in other parts where there is much disturbance of natural drainage by clearing of higher country.

One important aspect of soil fertility is the poor aggregation or structure at the surface of many solonetzic soils. This is obvious on some areas in the Goroke-Gymbowen district which have been subject to cultivation for quite long periods, but it is to some extent a natural feature of these solonetzic soils which have a mechanical composition at the surface that is favourable to compaction, as well as insufficient surface growth and organic matter to aid aggregation. The compact nature of these soils hinders water entry on sloping ground, reduces aeration, and aids sheet erosion. Improvement can, however, be effected by improved pasture growth and possibly by the incorporation of lime or gypsum.

The looser, sandy soils do not lack aeration but their low water-holding capacity induces droughty conditions whenever rainfall is low.

Soil fertility in this and other areas tends to be regarded as a matter mainly of deficiencies of certain chemical substances, but occurrences of excessive salt concentrations, lack of aggregation in certain soils, and inadequate aeration all limit the soil fertility. The most effective agent of improved fertility is a dense productive mixed pasture, capable of incorporating organic matter in the soil and promoting aggregation. With the prevailing climate, the growth of such pasture depends firstly on an adequate supply of certain mineral fertilizers, especially phosphorus.

(d) Descriptions of Mapping Units

The mapping units attempt to subdivide the Shire into areas in which a uniformly-recurring pattern of topography, water supply, soils, and native vegetation, together with a uniform climate, make the agricultural potentialities and problems similar. They should allow further investigation to be conducted upon the basis of the units.

The survey has separated and listed 15 mapping units of varying extent, including one, the Little Desert unit, which itself would appear to be composed of four or five units. The units are listed in alphabetical order as follows:

(i) Apsley
(ii) Benayeo
(iii) Black Range
(iv) Edenhope
(v) Glenelg
(vi) Goroke
(vii) Kowree
(vii) Kybybolite
(ix) Little Desert
(x) Neuarpur
(xi) Powers Creek
(xii) Tallageira
(xiii) Telangatuk
(xiv) Ullswater
(xv) White Lake

The units are described, using chiefly a diagrammatic representation of the recurring sequence, upon the basis of topography, soils, native vegetation, parent material, together with some indication of the variation within the and their relationships to other units.