A history of the CSIRO Division of Soils: 1927 - 1997

K. E. Lee

CSIRO Land and Water, Adelaide
Technical Report 43/98, November 1998

CSIRO LAND and WATER

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K.E. Lee

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Introduction

On 31 January 1997, after 70 years of scientific achievement and service to Australia's primary industries, the CSIRO's Division of Soils ceased to exist, when it became a part of the large new Division, CSIRO Land and Water. The new Division comprises the former Division of Water Resources and the Centre for Environmental Mechanics, together with the former Division of Soils. There are many who will regret the passing of the Division of Soils, but constant change is in the nature of scientific institutions, as of science, and the new Division opens up new possibilities for research and its application to Australian primary industries and to the better understanding of the Australian environment.

It is appropriate at this time to look back over the history of the Division and its achievements. It has not been possible to cover all that has been achieved, but I have tried to be even-handed in my assessment of the many aspects of the Division's work. My assessment of what are the significant contributions must be influenced by my own experience and if the history had been written by someone else, the interpretation may have been different.

Many of those who pioneered in the Division the development of the basic scientific disciplines that contribute to soil science are still available to contribute, and they have been generous with their help and advice. I am grateful to them and to present members of the staff who have read preliminary drafts and have given me their help. They are acknowledged in the front pages. The reputation of a scientific institution results from the quality of its staff and the work that they do. A notable feature of the Division throughout its history has been the large number of outstanding scientists who have been among its staff and have achieved recognition in Australia and internationally for the quality of their work.

I have not attempted to compile a bibliography because it would be a major publication on its own. I would refer those who might seek further information to the Annual Reports of the Division, of the CSIR and the CSIRO, and to the collections of the Division's publications held by the libraries of CSIRO and the new Division.

The earliest report of soil investigations in Australia was published in 1845 in Strzelecki's Physical Description of New South Wales and Van Diemen's Land. It included detailed descriptions of 41 soils from New South Wales and Tasmania, with the stated aim of 'contributing some fresh data to the important question relating to the causes of the fertility or sterility of soils in general'. Later in the nineteenth century, masses of analytical data, based principally on samples submitted by farmers to Departments of Agriculture, were published in Victoria, New South Wales and Queensland.

Regional soil surveys in Australia were first undertaken by Jensen, leading to the publication in 1914 of his book *The Soils of New South Wales*, which included a generalised soil map. The surveys, and others that followed, were based largely on surface soil characteristics and on the analysis of 'average' samples, although Guthrie, in 1906, described four classes of soils in the area now known as the Murrumbidgee Irrigation Area, in which he referred to subsoils.

Little attention was given in Australia to techniques of soil survey that had been established in other countries during the early years of the twentieth century, until a summary of soil classification methods was published by Prescott, in 1926. Prescott set out for Australian soil workers, in an ordered way, the four bases used at that time for soil classification: the geological, as used in Britain; the climatic, or zonal, developed by the Russians; the ecological, as practised by Australian land surveyors; and the physical, as developed by the U.S. Soil Survey. The stage was now set for the development of modern soil science in Australia.

The Beginnings of the Division of Soils (1927-1944)

One of the first tasks assigned to the Council for Scientific and Industrial Research (CSIR) when it was established by the Australian Government in 1926 was to undertake research on soils. In that year CSIR appointed a Committee chaired by J.A. Prescott, Professor of Agricultural Chemistry at the Waite Agricultural Research Institute, University of Adelaide comprising R.D. Watt, Professor of Agriculture at the University of Sydney and L.R. East, Chairman of the State Rivers and Water Supply Commission of Victoria. It aimed to investigate problems of soil deterioration resulting from waterlogging and increasing salinity in irrigated lands of the Murray Valley that had been allocated to service men returning from the First World War.

The Committee proposed that a soil survey should be made of the affected areas as a basis for further study. The recommendation was accepted by CSIR, leading to the establishment in 1927 of soils investigations at the Waite Institute, in Adelaide, under the leadership of Professor Prescott. It should be noted here that A.C.D. Rivett, who was the first Chief Executive Officer of CSIR, favoured university sites as headquarters for the organisation's fledgling Divisions, and Soils Division was well placed at the Waite Institute, associated with Prescott's university department. J.K. Taylor was appointed to CSIR in 1927 to initiate soil surveys under Prescott's supervision, and the beginnings of the Division are taken to date from that time. Soon after, in 1929, CSIR established the Division of Soil Resources (later Division of Soils), with Prescott as its Chief. Prescott held this appointment until 1947, jointly with his university post, and he and Taylor were key figures in the early development of the Division. From the beginning the Division matched its work to the needs of Australia's primary industries, extending its zone of interest until by the early 1930s it embraced the whole of Australia

Two main fields of research were established under Prescott's direction: establishment of accurate methods for the measurement of the chemical and physical composition of soils, a task to which members of his university department made important contributions, and field studies of soils at both local and continental scales. The first outcome was *Methods for the Examination of Soils* by Prescott and Piper (CSIR Pamphlet No. 8), published in 1928. A major step forward was made in 1931, with the maps published by Prescott in *The Soils of Australia in Relation to Vegetation and Climate*. Ten mapping units, based on the concept of Great Soil Groups, were recognised and, in a later publication, *A Soil Map of Australi*a (1944), 18 mapping units were recognised.

Prescott also vigorously pursued a strategy of enlisting as collaborators anyone outside his immediate circle of co-workers who had any interest in soils – for instance in the universities, departments of State governments, experimental stations – and he encouraged them to spread his message to others in their and other organisations. He particularly advocated the introduction of Russian-European concepts to soil science and the usefulness of soil surveys and soil classification in the study of soil-related problems in agriculture.

The Division's first soil survey publication was on the Renmark area, carried out by Taylor and N. England in 1927-8 and published in 1929. The basic principles of Taylor's surveys were drawn from the methods used by the U.S. Soil Survey, which he had learned during a period of work in the irrigation districts of California. Soil types were defined on the basis of detailed morphology of the soil profile, parent material, microrelief, crop response and field assessments of permeability. They served as a pattern for a long succession of surveys during the next 15 years of irrigable lands of the Murray and Murrumbidgee valleys. Soil surveys, some in conjunction with the Victorian Department of Agriculture, were in the 1930s the major preoccupation of the Division.

Taylor's group grew during the 1930s to include T.J. Marshall, G. Stephens, G.D. Hubble, J.G. Baldwin, R.L. Crocker, B.E. Butler, R.I. Herriot, R. Smith, R.G. Downes, E.J. Johnston and G.H. Burvill, seconded from the W.A. Department of Agriculture from 1937 to 1938. These soil surveyors were mainly graduates in agricultural science, whose duties included carrying out the soil analyses that accompanied their reports. Their reports were published as CSIR Bulletins, together with soil maps drawn by P.D. Hooper. Taylor was appointed Deputy Chief of the Division and Stephens Head of the Soil Survey and Pedology Section in 1941.

Photo 1 C.S. Piper, J.K. Taylor, C.G. Stephens, University Chancellor Sir William Mitchell, T.J. Marshall, J.A. Prescott, H.C. Stace, c. 1940

The great age of most Australian landscapes and the wide latitudinal extent of the continent provided the opportunity and the challenge for the outstanding group of pedologists that had been recruited to lead the way internationally in understanding many aspects of soil processes on the ancient, deeply-weathered and stable landscapes that characterise Australia. These ancient soils contrast with the young soils, that had been previously most studied on the weathered rocks and deposits laid bare no more than about 12,000 years ago by the retreating ice sheets in much of western Europe, Russia and northern U.S. The contributions of Prescott to soil classification were further developed, in particular by Stephens, and ideas about soil age were developed by Crocker and others.

In 1925, C.S. Piper had joined Prescott's department at the Waite Institute as Assistant Chemist. From 1944 to 1956 he held a joint appointment at the Waite and at CSIRO, where he was in charge of the Soil Chemistry Section from 1947; he was responsible for the establishment and development of soil chemistry in the Soils Division throughout his long career, until his retirement in 1963. His book, *s*, published by the University of Adelaide in 1942, was quickly recognised internationally as the definitive text on the subject. It was adopted as a standard, republished in the U.S. and in Poland, and is still to be found in soil chemical laboratories throughout the world. In 1956 he transferred fully to CSIRO. As well as establishing reliable methods for the determination of the major elements in soil and plant samples and for the particle size analysis of soils, Piper's book dealt with the estimation of trace elements. The use of arc emission spectroscopy, developed in the Division by A.C. Oertel from 1937, was particularly significant in the determination of trace elements.

In 1929 T.J. Marshall was appointed to the Division to work with Taylor on soil surveys of the irrigation areas of the Murray River valley. In the course of this work he made a particular study in the laboratory at Adelaide of the physical properties, water relations and salinity of the soils. In 1936 he was given the opportunity to develop this further- by working in soil physics at the University of California, where he graduated Ph.D. under the supervision of G.B. Bodman. At that time there was no Ph.D. training in Australia and it was CSIR's policy to send selected experienced research staff overseas to universities that could provide appropriate specialist training programs. Upon his return to Australia in 1938, the expertise he had acquired during his time in California was applied to the better understanding of the moisture-holding abilities of soils, their drainage characteristics and erodibility, soil structure, pore space and salinity problems. Soil physical studies were integrated with other research programs to throw new light on the dynamic relationships of water, either irrigation or rainfall, in soils.

Photo 2 Charles Stephens (Steve) in the laboratory at the Waite Institute, c. 1940

The Division's work, during the 1930s, was not entirely confined to irrigated or irrigable areas. Before 1933 soil surveys were undertaken of virgin lands and agricultural areas, in Southeastern South Australia and on King Island, Tasmania, and this attention to unirrigated soils continued through the decade, with studies for instance of agricultural lands susceptible to soil erosion north of Adelaide and in Victoria, and of the soils of pine plantations in South Australia.

Entry of Australia into World War 2 resulted in nearly all staff of the Division becoming involved in work related to defence and land settlement. This included mapping of selected areas, soil surveys and testing of the underlying materials for construction of airfields, dust control on unpaved airfields, design of soil-cement pavements for airfields, surveys, and analyses of soils and irrigation waters for the establishment of army gardens. The demonstrated practical usefulness of these activities led, in 1944, to the recruitment of a new group of young graduates in response to the need for surveys of projected land-settlement areas for returning servicemen.

During World War 2, with C.G. Gurr, Marshall studied the stabilisation with cement of soils used to make airfields and in 1942 he was associated with the U.S. Army on soils and soil stabilisation for airfields in Queensland and New South Wales. His interest in soil engineering, arising from his work on airfields, led to the appointment of G.D. Aitchison and the first measurements in Australia of the seasonal expansion and contraction of soils, with the aim of matching the foundation design of buildings to soil type, so that the severe cracking of buildings, especially in Adelaide, could be avoided.

Until 1944 Marshall was involved with irrigation projects, including work in association with G.A. Stewart in the Ord River region of the Northern Territory, army farms between Alice Springs and Darwin, and airfield construction. This latter work, together with research on soil cement, extended the scope of the Division's operations into the field of engineering. During World War 2 Aitchison was seconded for a time to U.S. forces and contributed to airfield construction in Guam and other Pacific regions.

Marshall was responsible for the establishment of soil physics as a strong component of the Division's work, as well as for much of the development of soil physics in Australia. At the time of his appointment, the significance of soil physics was little appreciated in agriculture and engineering.

Photo 3 Sgt. Mason (USA) and Geoff Downes (Division of Soils) working on runway construction at Bourke, NSW, 1942

Development of the Adelaide Sections and the Regional Laboratories (1945-1959)

In 1947 J.K. Taylor replaced Professor Prescott as Chief of the Division and continued in that position until his retirement in 1963. Prescott's policy as Chief had been to strike a balance between fundamental studies of the nature of soils and the more applied work required for applications to land-use problems. Taylor was more inclined towards the applied aspects, and his policy was appropriate to the largely technological demands on the Division's services that continued through the immediate post-war years of land settlement programs. By the mid-1950s the demand for such surveys had waned. Taylor at first resisted the wishes of the staff to devote more attention to the more fundamental aspects of soil science, but he was soon convinced of the need for better understanding of the origin and development of Australian soils and became an enthusiastic supporter of such work. For example, he encouraged work on the soils of the arid regions of Australia, with extensive surveys especially in South Australia and around Alice Springs, where a soil survey centre operated during the 1950s-60s.

Photo 4 John Taylor and David Rivett, early 1940's

Notable Soils Division contributors to the work were E.A. Jackson and M.J. Wright. Wright maintained his interest in the arid zone and continued to contribute part of his time to improving knowledge of its soils until he left the Division in the 1990s. Stephens, and in later years A.R. Milnes, also contributed, especially on the nature and origins of silcretes, calcretes and associated deposits. Taylor was pleased to recognise the Division's contributions in this field as a worthy contribution to world knowledge of arid regions rather than for national advantage.

With the knowledge that had been acquired over the early period of surveys as a foundation, and the high quality of research staff that had been recruited throughout the Division's history, it was not long before the Division of Soils had acquired an international reputation as one of the world's leading soil research organisations. International recognition of the Division's work was greatly helped by the success of Taylor in persuading CSIRO to establish the Australian Journal of Soil Research, in 1963.

Adelaide Sections

Pedology Section

In 1941 C.G. Stephens had been appointed Head of a newly formed Soil Survey and Pedology Section. Its activities then extended from the headquarters in Adelaide to include work based on the regional centres in Western Australia, New South Wales, A.C.T., Tasmania and Queensland. So the Division, within 10 to 15 years of its establishment, had acquired a truly national presence. The basic motivation always was to support Australian primary industries, but the scope of the surveys widened to include, for example, studies of erosion problems, soil-forming processes, relationships between soils and vegetation, and with important contributions to the development of Australian geomorphology and its relationships with soils.

The years 1945 to 1955 were described by J.K. Taylor as the peak of activity in soil surveys in Australia. Extension of irrigation areas near the Murray and Murrumbidgee Rivers was facilitated by preliminary soil surveys, with at least 12,000 ha of newly irrigated horticultural land being planted following soil surveys and much more surveyed prospectively. The soils of about 15,000 km^2 of the Riverine Plain of southern NSW and northern Victoria were mapped and their potential problems if water were applied were defined. The soils of more than 7,500 km^2 of southeastern South Australia were mapped by G. Blackburn and others, before their first settlement, while in Queensland a survey by G.D. Hubble and C.H. Thompson covered about 3,000 km^2 of the Burdekin River valley where a new irrigation scheme was proposed. About 10,000 km^2 of virgin land in South Australia were surveyed before post war land development, as well as large areas of agricultural land in the southern Flinders Ranges, Barossa valley, Adelaide metropolitan area, and around Lake Alexandrina. In Western Australia soil surveys covered 4,000 km^2 of the Swan coastal plain and 7,000 km^2 of virgin land in the south west with potential for farming. In Tasmania the soils of about 4,000 km^2 were surveyed.

Photo 5 Partial view of the camp at Gladys Lagoon, used during the Lower Burdekin Valley Survey, 1948

The Division had not been much involved in surveys in the north of the country, and its survey methods were best suited to arable soils in eastern and southern Australia. In 1946 the Commonwealth Government called for a study of land resources in northern Australia. Work in the north was better carried out through reconnaissance surveys, giving attention to topography, vegetation and soils and such surveys were carried out by expeditionary teams of the newly established CSIRO Land Research & Regional Survey Section. This Section subsequently became CSIRO Division of Land Research.

Relations between the new Division and the Division of Soils were close: G.A. Stewart transferred from the Soils Division and W.H. Litchfield was seconded to the new Division. Their broad-scale reconnaissance surveys eventually covered most of Australia north of latitude 26°S and much of Papua-New Guinea. New techniques were developed, based on units that were called 'land systems'. A land system was defined as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation. The land system concept was particularly suited to the rapid mapping of large areas of virtually undeveloped land and the surveys that were done made a valuable contribution to knowledge of the broad agricultural resources of northern Australia. The concept was also widely used in preparing basic surveys of the resources of other countries in the developing world.

Photo 6 George Burvill (standing), Alan Stewart and unknown involved in infiltration tests for the Cununurra survey, 1944. This site was very impermeable requiring overnight readings. Note the water tank used at right of photo

The soils of plantation forests had received some attention in South Australia in the late 1930s and some early work was done in Western Australia. In the late 1940s Stephens was approached by Southern Australian Perpetual Forests Ltd, which had problems with slow growth rates of young pine trees that had been planted on areas around Mt Gambier, replanted after clear-felling of earlier plantations. Stephens was able to demonstrate that there were trace element deficiencies, particularly of zinc, as well as phosphate deficiency. The use of suitable fertilisers resulted in spectacular increases in tree growth and the initial investigation led to a long series of research projects on soils and tree nutrition, under the leadership of M. Raupach, who had joined the Division as a soil chemist in 1948. Raupach's research made a very significant contribution to the resolution of nutrient problems of softwood plantations in southern Australia.

Photo 7 Roy Brewer and Bruce Butler at Jerilderie, 1947. Ned Kelly made the town famous a short time before they arrived

A major project of the late 1950s and the 1960s was the preparation of a new map of the soils of Australia. This project was led and coordinated by K.H. Northcote; it was a collaborative effort, involving the Division's regional pedologists and others in the preparation of 10 map sheets, the *Atlas of Australian Soils,* that covered the whole country at a scale of 1:2,000,000. There were major logistical problems to be overcome in the field work for the atlas project. For example, in the Cape Yorke Peninsula region of northern Queensland the only road was a track along the line of the telegraph line and there were no petrol suppliers. The survey work was supported by helicopter and it was necessary to arrange for depots of helicopter fuel to be landed on beaches along the coast of the peninsula. It is of interest that soil boundaries could be identified from the air in some areas by the colour of the numerous termite mounds, which characterised red earths, brown earths and yellow earths.

Map sheets and explanatory data were published over the period 1960-68 and the project was completed in time for the ninth International Congress of Soil Science, which took place in Adelaide in 1968. A new soil classification was developed by Northcote as a basis for the mapping project. This classification, *A Factual Key for the Recognition of Australian Soils*, was first published by Northcote in 1960, and later editions incorporated additional information derived from the soils atlas project. The Northcote Key, as it is widely known, is based on the concept of profile form: a term used to denote the overall visual impact of the physical properties of the soil that are capable of observation

and record, together with changes in soil pH with depth, to provide a means for the rapid recognition of soil profiles in the field. It has been widely used in Australia as a basic tool for soil surveys and land use projects. The atlas and key were supplemented by the publication in 1975 of *A Description of Australian Soils* (Northcote, Hubble, Isbell, Thompson and Bettenay), which provided general descriptions of all important soils defined by the key and identified during the mapping of Australian soils for the atlas. It also included information on the distribution, land use and analytical data for the soils.

Soil Chemistry Section

Soil Chemistry in the Division began as a service function for the early soil surveys. A standard set of analyses, consisting of particle size determination, pH, soluble salt content, carbonates, total nitrogen, phosphorus and potassium content of soils was developed, with exchangeable cation analyses as an additional test for some soils. The intention was that these analyses would establish the chemical identity of the surveyors' soil types, recognised in the field on morphological grounds. The number of profiles that could be analysed for each soil type was small, rarely more than three, and for less important soil types, only one. The information provided to pedologists was used to good effect, although there were difficulties because this number of profiles was too few to characterise some of the more variable soil units.

From the beginning, C.S. Piper, although he was a member of the Waite Institute's staff until 1944, provided strong leadership, with an emphasis on research as well as on providing an analytical service in the development of soil chemistry in the Division.

Notable among others who contributed in the early years of the Section were:

- M. Raupach, on soil pH and silica in the soil solution; .
- B.M. Tucker, on ion exchange equilibria and exchangeable cation chemistry (he also developed the first method for determining the exchangeable cations in soils containing carbonate);
- J.T. Hutton, on cyclic salts (that is, salts brought in by rain) and on methodology for particle size analyses;
- R.S. Beckwith, on trace element/organic matter complexes, and later on low grade phosphate sorption;
- R.D. Bond, on the nature and causes of water repellence in sands and its cure (to add about five per cent clay);
- K.G. Tiller, on the geochemistry of trace elements and the sorption of heavy metal cations;
- A.W. Fordham, with K. Norrish, using a combination of autoradiography and electron probe analysis to identify the sites in the clay fraction where phosphate is fixed.

The Soil Chemistry Section became known internationally as a leading research centre, both for its basic studies of soil chemistry and for its application of soil chemical analyses to practical problems of land use and plant growth. The analytical work, originally in support of pedology, increasingly supplied support to the newer Adelaide sections; it remained as a subunit of the Chemistry Section, supervised by A.R.P. Clarke, through to 1976, when it became a separate unit, with Clarke as its head until his untimely death in 1977. The present leader of the Analytical Group, T.A. Beech, was appointed in 1979.

Photo 8 John Hutton and Janet White discuss clay structure with the aid of a model, c. 1960's

Soil Physics Section

When the Soil Physics Section was formed in 1944, with T.J. Marshall as its Head, a vigorous attack was made on basic and applied problems in agriculture, hydrology and soil engineering. Among early recruits to the Section were J.P. Quirk, G.B.S. Stirk, A.V. Blackmore, D.S. McIntyre, J.W. Holmes, E.L. Greacen, C.G. Gurr, K. Norrish and G.D. Aitchison. All of the Division's recruits in soil physics spent some time with Marshall, with some of them then going from Adelaide to develop soil physics in the new regional laboratories that were opened in other States, for example, Stirk to Brisbane, Blackmore to Perth, McIntyre to Canberra.

Methods for measuring the amount of water in soil and how strongly it is held there were needed. Hence tensiometers, adsorbent blocks, neutron moisture meters and lysimeters were critically examined and adapted for extensive use in the field. Work by J.W. Holmes ensured the success of the neutron moisture meter, which was a novel method at that time, and a new gamma ray method for measuring water content and bulk density was developed by C.G. Gurr.

Seasonal changes in water content, resulting in swelling and shrinking can, in some soils, especially clays, cause building foundations to fail. G.D. Aitchison and J.W. Holmes measured the water regime and also the vertical movement of soil at various depths down the profile to determine suitable depths of footings for foundations on clay soils. Vulnerable areas in the suburbs of Adelaide and Melbourne were identified and the research of Aitchison and Holmes had a large impact on the design of foundations of houses. Further evidence on the behaviour of soil in shrinking and swelling was gained by Holmes using remoulded blocks and by Stirk using naturally structured soil.

By measuring the gains and losses of water in soil, Holmes, M.W. Hughes and J.S. Colville were able to estimate the annual rate of recharge of certain ground water systems, enabling limits to be set on the exploitation of aquifers for irrigation in South Australia. Holmes also used the naturally-occurring isotope tritium to measure the residence time of water in aquifers.

The entry, distribution and retention of water in soils were central aspects of the Section's research. D.S. McIntyre showed how hydraulic conductivity of surface soil was reduced by impacting raindrops. Marshall proposed a relation between hydraulic conductivity and the size distribution of the pores and also another relation between gaseous diffusion and the porosity of soil. Gurr and Marshall showed that the movement of water under the influence of a thermal gradient was much greater than could be accounted for by diffusion of water vapour alone. In other work on fluid movement, the effect of wind on vapour transfer was shown by D.A. Farrell, Greacen and Gurr to be considerable in surface soils.

The size, arrangement and bonding of particles affect the movement of fluids in the soil, and they also affect its behaviour under stress. Particle size distribution is represented qualitatively in soil surveys by a description of texture and relationships between such descriptions and water movement were examined critically by Marshall. The arrangement of soil particles is readily changed by management practices and the stability of the soil when wet depends on bonding factors such as organic matter and exchangeable cations. Marshall and J.P. Quirk worked on a number of aspects of stability.

W.W. Emerson replaced Quirk in 1957, working on the bonding between clay particles in soils and how this affects water entry and movement. Piping failures in earthen structures such as runoff dams had long been a puzzle and Emerson showed that they were due to clay in the soil used to build the dams dispersing in the water as the dam filled. Later he showed that having Mg-ions on exchange sites instead of Ca-ions weakens the bonds between clay particles in a similar way to Na-ions, although to a lesser extent. This last discovery is important in soil drainage in Australia, for in many soils there are more exchange sites occupied by Mg-ions than by Na-ions. Simple visual tests based mainly on the reaction of soil with water were developed to classify subsoils according to their suitability for forming water retention structures (Australian Standard, 1980). Subsequently the classification was extended to include surface soils. The class number helps to identify the causes of poor structural conditions for crop growth, such as clods or compacted layers.

Soil strength and its effects on growth of roots were studied very successfully by Greacen, and with Farrell he worked out the mechanics of probes to simulate root growth in soil. In other work on strength, Marshall and Quirk developed a method for measuring the energy expended in breaking up soil, as in tillage.

The significance of the Division's soil physics group to Australian soil science is perhaps best illustrated by subsequent events. Quirk went on to become Head of Soil Science and Plant Nutrition at the University of W.A., then Director of the Waite Institute. Aitchison established soil mechanics in the Division, and was the first head of the Soil Mechanics Section; he then became the first Chief of the Geomechanics Division of CSIRO. Norrish became Head of the Division's Mineralogy Section. Holmes was appointed foundation Professor of Earth sciences at Flinders University. G.B. Allison, who was appointed later to work with Holmes in his field of hydrology, was appointed Chief of the Water Resources Division of CSIRO when it was established in the 1980s.

Some of the many advances in soil physics that were made by Marshall and his colleagues were included in two notable books: *Relations between Water and Soil by Marshall* (1959); and *Soil Physics* [first and second editions by Marshall and Holmes (1979, 1988), third edition by Marshall, Holmes and C.W. Rose (1996)]. The latter book has achieved recognition as an outstanding text on soil physics and is widely used by students and researchers around the world.

A similar dispersion of talented soil surveyors from the Division of Soils included the move of R.L. Crocker to the Waite Institute and R.G. Downes to the Soil Conservation Authority of Victoria.

Marshall led the Soil Physics Section from its inception in 1944 until he retired in 1972, serving for several years before his retirement as Assistant Chief of the Division, in addition to his role as Head of Soil Physics. His contribution to the development of soil physics in Australia has been extraordinary and he achieved a leading international reputation for his own contributions to the physics of soil water.

Soil Mineralogy Section

In 1947 K. Norrish was appointed to the Soil Physics Section. He came from the University of W.A., where he had worked for his M.Sc. on X-ray crystallography. With E.W. Radoslovich and J.G. Pickering, Norrish began investigations of soil minerals. From 1950 to 1952 Norrish had a CSIRO Studentship, and worked at Rothamsted, where he obtained a Ph.D. On his return in 1952 a Mineralogy Section was formed, with Norrish as its Head and L. Rogers was appointed as a mineralogist. While Norrish was in England Radoslovich designed and constructed a curved crystal X-ray spectrograph for the chemical analysis of minerals and soils. This instrument was subsequently fitted with an electronic counting chain and was used with great effect by Norrish for about 10 years.

Soon after Norrish returned, in 1952, Radoslovich went to Cambridge, where he completed a Ph.D. on the crystal structure of the feldspar anorthite. He went from Cambridge to Pennsylvania State University, where he worked on the weathering of feldspars and returned to the Division in 1956, where he began a long period of work on the structure of micas, especially of muscovite. He was an early user of computers, working with a very early digital machine at the Weapons Research Establishment in South Australia and also with SILLIAC at the University of Sydney. He became the Division's expert on advanced computing, and in particular developed an extensive library of crystallographic programs that have now been modified for smaller computers and are still used by the Division.

Space in the Waite buildings was a problem, so the Mineralogy Section moved, in 1954, to the basement of the Geology Department at the North Terrace Campus of the University of Adelaide, where it remained until moving back to the Waite Campus in 1961, to the newly completed Division of Soils laboratories.

The Section's staff grew during the period at the North Terrace Campus, with the appointment of R.M. Taylor and T.R. Sweatman, and was further increased in the new laboratories, with the addition of the Geochemical (optical spectroscopy) group, previously attached to the Soil Chemistry Section and comprising A.C. Oertel, R.M. McKenzie and J. Giles. J.T. Hutton also transferred from the Chemistry Section and worked with Norrish to develop X-ray fluorescence spectrographic techniques for the analysis of mineral and soil samples.

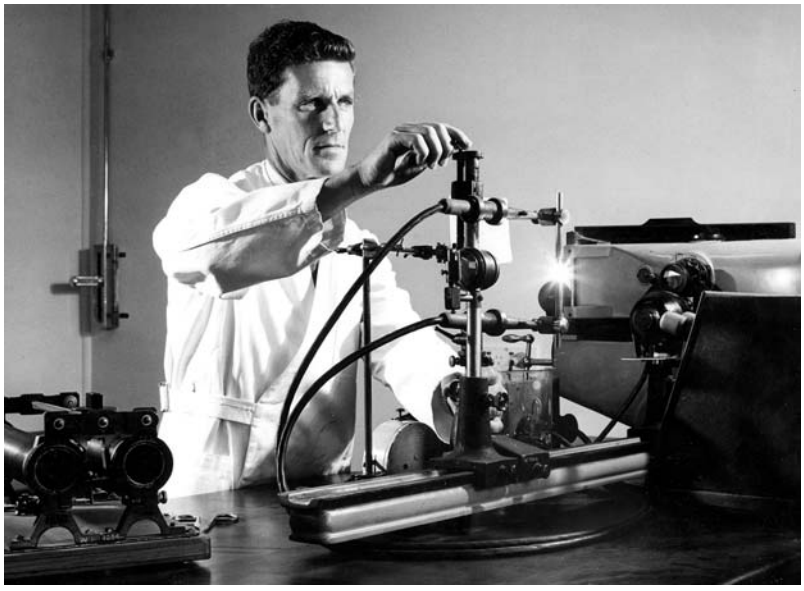

Photo 9 Reg McKenzie, c. 1970's

The Mineralogy Section, over, the years, has embraced many other physical techniques, including transmission and scanning electron microscopy, and electron probe micro-analysis, and has adapted these to the determination of the structure and composition of the minerals in the soil environment. Much attention has been paid to oxide minerals, especially by Taylor, McKenzie and A.R. Milnes in the Mineralogy Section, but with substantial contributions also from A.W. Fordham and, in recent years, from R.W. Fitzpatrick.

Soil Mechanics Section

In 1943 G.D. Aitchison was appointed to the soil Physics Section, and for the first few years was concerned mainly with the testing of soils and application of soil mechanics principles to the construction of war-time airfields.

The group's activities widened, particularly to include the interactions between building loads and the settlement of their foundations. This led, during the 1950s, to collaboration between the Division and the South Australian Department of Mines in the publication *The Soils and Geology of the Adelaide Plains*, in which the mechanical reactivity of soils was related to pedological differences. This book was for many years the standard reference used by Australian building consultants in the field of foundation design.

In 1955 Aitchison provided a stimulus to the study of soil mechanics in Australia when he established a Soil Mechanics Group in the Civil Engineering Department of the University of Melbourne.

The diverging interests and applications of agricultural and engineering soil physics in the Division led, in 1958, to the establishment in the CSIRO of a Soil Mechanics Section, with Aitchison as Section Head. This arrangement continued until 1967, when the Section became the nucleus of the Division of Geomechanics of CSIRO, with its headquarters in Melbourne and with Aitchison as its first Chief.

A small group of staff of the Division of Geomechanics remained in Adelaide, where the work was at first supervised by I.B. Donald, with the assistance of R. Martin. In 1957 P.O. Morris became head of this group, in accommodation supplied by the S.A. Department of Mines, until the early 1960s, when P.L. Newland became the group's leader and laboratories were provided at Division of Soils. From 1966 to 1979 the Adelaide group operated outside the Division of Soils, but then returned to become a Section within the Division, with B.G. Richards as Section Head and P. Peter, who had joined the Adelaide staff in 1969.

Soil Microbiology Section

The beginnings of soil microbiology in the Division date from the appointment of T. Strong, who joined the Division's staff in the early 1930s, although a P.M. Rountree worked at the Waite Institute on a CSIR project concerned with *Thiobacillus* during 1932-34 as a research student under the Science and Industry Endowment Fund (equivalent to the later CSIRO Studentships). Strong demonstrated the importance of strain selection of *Rhizobium* for the successful establishment of pasture legumes on Kangaroo Island. As a result of Strong's findings the Waite Institute established an inoculation service for South Australian farmers. J.R. Harris, who was appointed to the Division in 1946 after Strong's departure, continued to provide the service until 1955, while at the same time establishing field trials and investigating the process of nodule formation by *Rhizobium*.

In 1953, R.J. Swaby was appointed to the Adelaide laboratories as Head of the Soil Microbiology Section and from that time there was a steady expansion of research into many areas of soil biology. Swaby's own research was in the areas of sulphur oxidation by soil bacteria and the solubilisation of phosphate by sulphuric acid produced by *Thiobacillus* spp. This led him to develop 'biosuper', a fertiliser that consisted of particles of ground rock phosphate, coated with sulphur and a culture of *Thiobacillus*, so that water-soluble phosphate is formed in the soil as the sulphuric acid produced by the thiobacilli dissolves the rock phosphate.

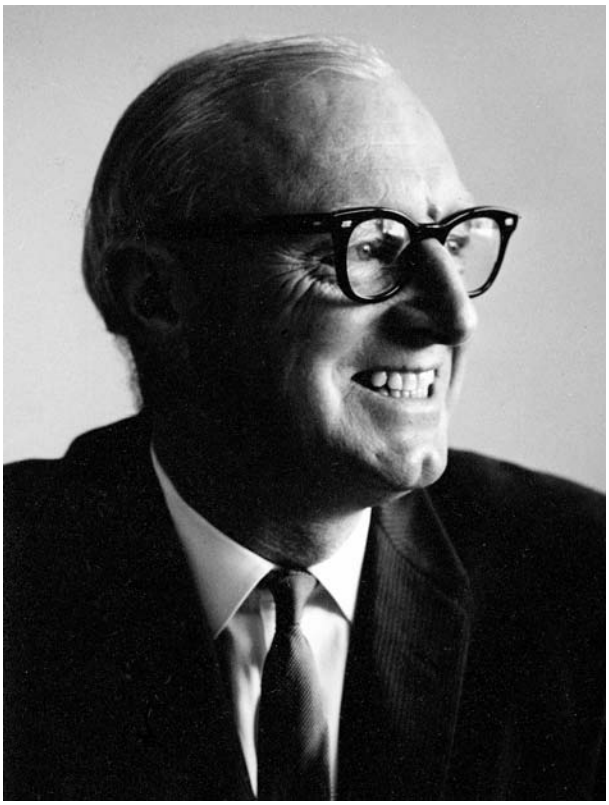

Photo 10 Ray Swaby, Assistant Chief, 1960's

During the next few years Swaby recruited the nucleus of what was to become one of the world's leading groups of soil microbiologists and the Soil Microbiology Section grew to become the largest of the Division's sections. It did not, as had the Chemistry and Physics Sections, establish a strong presence in the other regional laboratories of the Division. K.C. Marshall was active in the Perth laboratories, and A.W. Moore in the Brisbane laboratories, each for a few years.

In 1955 J.N. Ladd was recruited to the Microbiology Section to study biochemical processes in the soil. His early work concerned the oxidation of hydrocarbons in the soil and its possible significance for oil exploration. This was followed by studies of bacterial decomposition of the phenolic compounds that characterise humic substances in soils, that led to Ladd's recognition as a world leader in this field.

In 1956 A.D. Rovira returned to the Microbiology Section from a two-year CSIRO overseas Studentship, to begin a distinguished career working on the rhizosphere – the zone of soil adjacent to plant roots where many bacteria and fungi are stimulated by the release by plants of sugars, amino acids, organic acids and vitamins to multiply at the root surface, and mediate the cycling of nutrients essential to plant growth. He established himself as a world leader in this field of research and went on to concentrate on the plant pathogenic organisms that share the rhizosphere with beneficial organisms and are important antagonists to plant health and crop production.

In 1958 G.D. Bowen joined the Microbiology Section to study mycorrhizal organisms, particularly those associated with *Pinus radiata*. With C. Theodorou he studied soil factors that affected the growth of mycorrhizal organisms through the soil, the importance of selection of mycorrhizal inoculants, and they demonstrated and developed practical methods to optimise the beneficial effects o these fungi on the growth of pine trees. He and Rovira worked together on the effects of microorganisms on the uptake and translocation of plant nutrients.

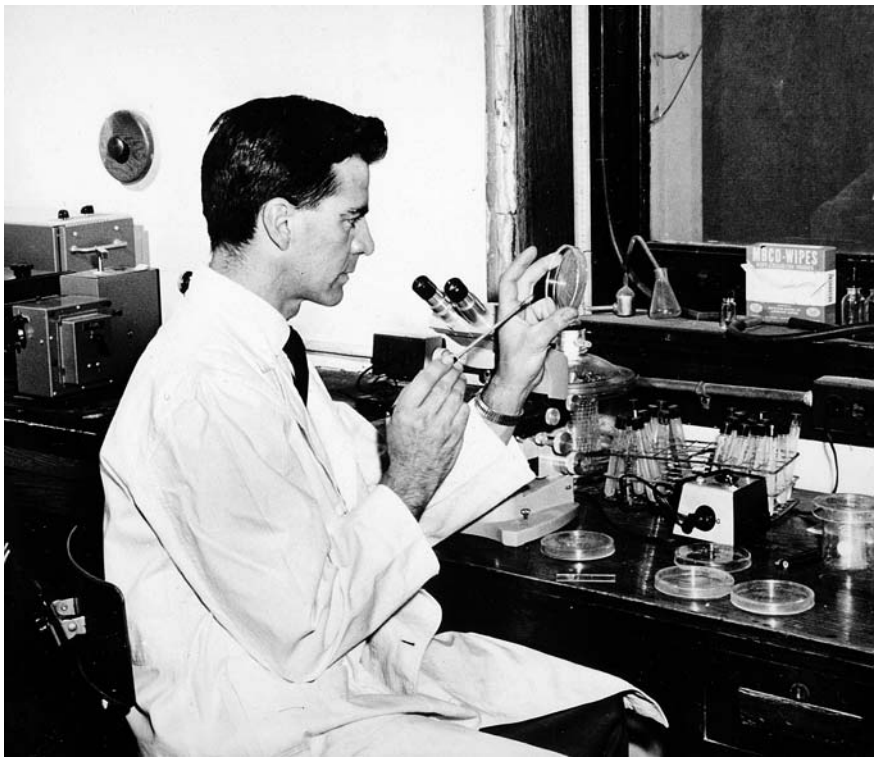

Photo 11 Albert Rovira studying bacterial colonies on agar plates at the Cornell University, USA, 1962

Headquarters Accommodation in Adelaide

As the Adelaide Sections were established and grew there was increasing pressure on laboratory space at the Waite Institute. Space on the Waite campus was allocated to CSIRO for the construction of laboratories for the Division; the first building was commissioned in 1958 and was occupied by the Pedology and Chemistry Sections and the administrative staff of the Division. An integral part of the Pedology Section at that time was the Draughting Group, under the leadership of P.D. Hooper, and this group moved with the pedologists into the first of the Division's Adelaide buildings. By 1962 the Division's accommodation on the Waite campus was completed and all Adelaide staff were housed in new laboratories.

The Regional Centres

The first regional centre of the Division was established by R. Smith in Perth in 1945. Similar centres were developed, mainly in the period after 1947 when Taylor became Chief, with one or more soil surveyors being located at each of a number of centres around Australia to service requests for soil surveys from various State authorities. B.E. Butler established the Deniliquin centre and R.G. Downes the Canberra centre in 1947, G.D. Hubble the Brisbane centre in 1948, and K.D. Nicolls the Hobart centre in 1949, although C.G. Stephens had done soil surveys in Tasmania from 1929 to 1938 and G.D. Hubble had also been stationed in Hobart from 1943 to 1948, working on soil surveys. The Townsville regional soils centre was established much later, in 1963, by R.F. Isbell, mainly in response to the interest of the Division of Tropical Crops and Pastures in having a soils research centre in northern Queensland.

By the late 1940s the Division had established a physical presence on a national basis. At first, all decisions concerning work in the outposts of the Division were made in Adelaide, but it soon became clear to Taylor that this was not efficient, and not sufficiently sensitive to the needs either of the scientists on the spot or of those who could make practical use of the survey data. So more responsibility was given to the senior soil surveyor at each centre and they became the first Officers in Charge of the regional laboratories.

Subsequent staff appointments at each centre were decided after discussion between the regional Officer in Charge and the Chief. In those days there was no problem about getting Treasury funding for new positions! The first new appointment the Officers in Charge requested was always a chemist, not necessarily at Research Scientist level, but more commonly at Experimental Officer level. This was because the primary task was not to do research in soil chemistry but to provide an analytical service in support of local soil surveys, thus avoiding delays involved in sending samples to the Adelaide laboratory and enabling close links between the chemist's and the soil surveyor's assessments of soils and landscapes. The next requests for professional support staff were for soil physicists, reflecting the critical importance of soil water and the high incidence of sodic and saline soils in many parts of Australia.

Perth

Robert Smith was the first Divisional Officer based in Perth, immediately after World War 2. Until the early 1950s broad (and later detailed) soil surveys of the southwestern parts of the State, with routine chemical analyses by A.G. Turton, constituted the core of the Division's work in Western Australia. Additional appointments of W.M. McArthur, T.J. Poutsma, E. Bettenay, F.J. Hingston and L. Pym, under the leadership of M.J. Mulcahy from 1954, greatly increased the strength of the W.A. group.

A major extension into research in soil physics, chemistry and microbiology followed the appointments or transfers to Perth around 1960 of A.V. Blackmore, J. Keay, K.C. Marshall, H.M. Churchward and D.R. Williamson. There followed a period of great progress in soil science in W.A. Soil surveys and pedological research were expanded, including in particular Mulcahy's fundamental contributions to knowledge of laterites. Bettenay and Blackmore led important work on salinity problems in the wheat belt, and a variety of projects were initiated by other members of the Division's Perth-based staff on boron, phosphates, nitrification, *Rhizobium*/clay interactions, and plant nutrition and water relations in pine forests. The Perth staff, especially Mulcahy and Keay, were much involved in the National Soil Fertility Project.

In the mid-1960s Blackmore, Marshall and Keay left the regional laboratory, but important contributions continued to be made by the Division to primary industries in W.A. until 1973, when the 12 professional and 12 technical staff were moved from Division of Soils to become part of the newly-formed CSIRO Division of Land Resources Management. Loss of the Division's group in Western Australia was a serious blow to Australian soil science. Mulcahy had built up a first class group of scientists, especially strong in pedology, and had established excellent relations between the CSIRO and State authorities. In their new Division pedology was not supported and the pedologists were forced to move into other fields of work or seek posts outside the CSIRO.

Canberra

R.G. Downes was transferred to Canberra in 1947 as soil surveyor and Officer in Charge of the southeastern region of the Division. The Region originally included ACT and all of New South Wales except the Riverina region, where B.E. Butler was OIC from 1947, and the Western Division. Downes' objectives were first to map the whole of the southeastern region quickly, using as mapping units combinations of Great Soil Groups that characterised geographic units, to be followed up as required by more detailed mapping of representative areas within each of the larger units. The Macquarie Region was the only area mapped in this way.

The initial stage of Downes' plan was somewhat similar to that developed by the Land Research and Regional Survey Section of the CSIRO to evaluate the little-known plant and soil resources of the vast area of tropical Australia.

Downes was joined in Canberra by J.R Sleeman (soil surveyor) in 1948 and R. Brewer (soil surveyor/soil microscopist) in 1949, and these two took part in the initial survey work, continuing after Downes left in 1950 to join the Soil Conservation Authority of Victoria, when Brewer became acting Officer in Charge of the Southeastern Region. The regional unit was originally housed in a single room provided by CSIRO Division of Plant Industry, but it moved in 1953 to a prefabricated building on the Black Mountain site that included laboratories for A.D. Haldane (soil chemistry) and A.V. Blackmore (soil physics), accommodation for a microscopy and thin-section laboratory and offices.

From about 1950 Brewer progressively changed the emphasis of his work towards experimental pedology, in association with Haldane, and then into full-time study of soil microscopy, developing techniques of soil micromorphology to expand knowledge of the genesis, classification and use of soils. His associate in this work was J.R. Sleeman and he was also assisted by P. Green, a mineralogist. The work in soil micromorphology led in 1964 to publication of Brewer's book *Fabric and Mineral Analysis of Soils,* which summarised the methods employed in micromorphology and provided a complete system for the description of micromorphological features of soils. The book established Brewer as the world leader in the field.

B.E. Butler was appointed in 1954 as Officer in Charge of the Canberra laboratory. Butler's view of field pedology was oriented towards land-use and he considered that the traditional soil maps of the time were not useful for this purpose. He moved the emphasis of field studies to encompass edaphic (soil/plant relationships), geomorphic and pedological aspects of soils. His interpretations of soils in relation to geomorphological history, especially his emphasis on the importance of prior stream patterns and climatic changes during Tertiary and recent geological times, to the development of modern landscapes and soils, was an important contribution to pedology and geomorphology in Australia.

Other pedologists were appointed in 1954 to the Canberra laboratory, including P.H. Walker, who worked initially in eastern coastal regions of New South Wales and contributed much in subsequent years to the understanding of relationships between soils and geomorphology; H.M. Churchward and D.C. van Dijk, who did similar work in the Riverina region; and J.A. Beattie, who made soil surveys of the Western Slopes of New South Wales. The Canberra staff was further strengthened in 1956, with the addition of D.S. McIntyre to study water infiltration and J. Beatty to take charge of an analytical services unit, and in 1957 with the move of R.W. Jessup, a plant ecologist/pedologist from Plant Industry Division to Soils Division. Blackmore subsequently moved to the Division's Perth laboratory, while Beattie left the CSIRO to lecture in soil science at the University of Tasmania, and R.W. Jessup transferred to the Pedology Section in Adelaide.

The operating area of the Canberra laboratory was extended in 1957 when McArthur transferred to Armidale to study edaphic and pedological aspects of local soils. He remained there until 1962, when he moved to Perth. Work in the Riverina region was reinforced by the transfer of J. Loveday to Griffith in 1959, to study edaphic and pedological aspects of local soils, mainly water entry characteristics, surface sealing and the effects of gypsum on soil structure. He remained in the Riverina until 1966, when he was transferred to Canberra, and during his time in Griffith contributed much to knowledge of soils and land management in this productive region of irrigated soils. A handbook, largely written by D.S. McIntyre, on methods for analysis of irrigated soils, was published in 1974 and sold throughout the world, and there was an edition translated into Chinese.

Work on the chemistry of soil phosphorus, including its absorption and the measurement of its availability to plants, was initiated with the appointment in 1960 of J.D. Colwell. He was subsequently to become the leader in the Canberra region of soil chemical aspects of the National Soil Fertility Project, and went on to take part in foreign aid projects, especially in Brazil. I.R. Willett contributed an outstanding study of P-deficiency in rice, showing that it was due to uptake of the phosphorus on iron that was precipitated after growing rice.

Deniliquin

When the CSIR Regional Pastoral Laboratory opened at Deniliquin, B.E. Butler was transferred there (in 1947) to coordinate soil surveys undertaken jointly by CSIR and N.S.W. authorities. His training of novice soil surveyors inculcated attention to soil profile morphology, which led to improvement in profile description throughout the Division. An important contribution of Butler's during this period was his proposal in 1955 for the description of soil structure and consistence, for which he coined new terms, notably subplasticity, a condition present in the subsoils of certain soils of the Riverina and later the subject of research in the Division.

The surveys carried out under Butler's guidance covered 4,000 km^2 in N.S.W., adding considerably to early knowledge gained by Butler in northern Victoria and by others in the Wakool and Berriquin districts of N.S.W. All this field work provided him with the basis for his important later contributions on the evolution of the soil cover.

Hobart

The Division's work in Tasmania dates from 1929, when C.G. Stephens accepted a CSIR postgraduate studentship to work at the University of Tasmania, investigating some chemical characteristics of apple-growing soils of the Huonville district, south of Hobart. During the course of this work he became interested in soil survey and in 1930 moved to South Australia for six months, where he gained field experience with T.J. Marshall in the Renmark and Barmera Irrigation areas. He then returned to Tasmania and made a soil survey of King Island, aimed at defining areas affected by `coast disease', and a reconnaissance survey of Flinders Island. This was followed by a period when Stephens was based in Hobart, making a reconnaissance survey of the soils of Tasmania, which was published in 1934, and more detailed surveys of other apple-growing and pine-plantation soils. In 1938 he was transferred to Adelaide and for a few years the Division had no staff in Tasmania.

In 1943 G.D. Hubble was released from service in the Air Force and was sent to Hobart to undertake soil surveys for post war soldier settlement areas at Waterhouse Estate, and the Dismal, Montague and Mowbray Swamps in NW Tasmania. During the five summer seasons of Hubble's surveys, new appointees and some other soil survey staff were sent to Tasmania to work with Hubble and to benefit from his accumulated knowledge. Among these were R. Sprigg, J.R. Sleeman, J. Shepherd, K. Nicolls, D. Suter, D. Perry. G. Cochrane, C. Thompson, A. Stewart, K. Northcote and, for a short time, B.E. Butler when he returned from service in the army. These surveys continued until 1948, when Hubble was transferred to Brisbane.

In 1949 K.D. Nicolls moved from Adelaide to Hobart, to establish a regional group in Tasmania. Nicolls worked especially on a survey of the Launceston Tertiary Basin, at the same time extending the broad scale survey of accessible areas of the island. In 1949 G.M. Dim mock joined Nicolls and worked mainly on the surveys of Flinders Island. In 1951 J. Loveday moved to Hobart and worked on the krasnozems of north western Tasmania until he left for postgraduate studies in 1956, before being transferred to Griffith in 1959. A.M. Graley and J.L. Honeysett joined the Hobart staff during the 1950s to provide chemical and plant nutrition support to the resource surveys. For a number of years following, there was a considerable research effort on the potassium status of soils in northeastern Tasmania, centred on the Frodsley Estate, and further surveys were carried out in the Launceston Basin and on Flinders Island.

In the mid- to late-1960s emphasis was placed on broader scale soil association mapping, with contributions to the Australian Soil Resource map as a priority.

Brisbane

G.D. Hubble was seconded in 1940 to the Queensland Department of Agriculture and Stock and for rather more than two years he did soil survey work to assist efforts to expand cotton production in that State. He then served as a pilot in the Royal Australian Air Force until 1943, when he was released, at the request of CSIRO, to undertake soil surveys in Tasmania. There was no further sustained involvement of the Division in Queensland until 1948, when Hubble transferred from Hobart to Brisbane to establish a Regional laboratory

In the first few years the small soils group was a part of the CSIRO's Plant and Soils Laboratory, of which T.B. Paltridge of CSIRO Division of Plant Industry was at that time the Officer in Charge. The initial task was to survey and assess the area in the Burdekin Valley proposed for irrigation from the Burdekin Dam scheme. C.H. Thompson transferred from Deniliquin to Brisbane in 1949 and G.G. Beckmann was appointed in 1950 to assist Hubble with the pedological work. Physical assessment of the soils was initiated in 1949 and continued by G.B. Stirk when he was relocated from Adelaide to Brisbane in 1950. A.E. Martin was appointed Soil Chemist in 1949 and established in Brisbane in 1950 with R.R. Reeve, to provide chemical and analytical support to the field program.

A soil survey of the Darling Downs was commenced in 1951 and continued for some years, with clay soils becoming an important focus of the pedological program. R.F. Isbell joined the pedology group in 1958, continuing the mapping of brigalow soils on which he had previously worked with the Queensland Bureau of Investigation.

From the mid-1950s there was increasing pressure from the newly established Division of Tropical Pastures (formerly Plant and Soil Laboratory) to coordinate the Soils Division's research program with their objectives. As a result, soil surveys were initiated of the Gympie area and of experimental areas in the Coastal Lowlands, a chemical study of groundwater podzols was completed, and water use and fertiliser efficiency of pasture species were examined. R.S. Beckwith was transferred from Adelaide in 1957 to work as a soil chemist, while Martin became head of a Soils Division-Tropical Pastures group that began isotopic nitrogen and phosphorus studies of plant nutrition, and included I.F. Fergus and P.J. Ross, who joined the Division at this time.

In its close collaboration with the Division of Tropical Pastures, the Brisbane staff of the Division established for themselves an important role in research for the developing rural industries of northern Australia.

Townsville

During the 1950s and 1960s there was increasing interest in Australia in the development of the tropical northern regions of the continent. The Division, up to this time, had not had a permanent presence anywhere in the tropics, so in 1963 a small regional soils group, led by R.F. Isbell, and augmented by B.G. Crack and G.G. Murtha, was established in Townsville, jointly with a small group of CSIRO Division of Tropical Pastures scientists led by L.A. Edye. Mapping of tropical Queensland for the Atlas of Australian Soils project was a major part of the Soils Division's work for some years. Collaborative projects with the Division of Tropical Pastures became a feature of the Townsville work, with Isbell, for example, providing soils and environmental data in support of a program aimed at introduction of legumes into unimproved grasslands, widely used for cattle grazing in northern Queensland.

The 1960s and 1970s

In 1963, when J.K. Taylor retired, the Division, for the first time in its history, was subject to an external review. Taylor had been Chief of the Division for 16 years, and had given great emphasis to soil surveys. The CSIRO Executive (the committee of senior scientists that controlled CSIRO's destiny) questioned whether the emphasis on surveys was appropriate to a Division in the scientific and research-oriented organisation that CSIRO had become. E.W. Russell, then Reader in Soil Science at Oxford University, and E.G. Hallsworth, then Professor of Agricultural Chemistry and Dean of the School of Agriculture and Horticulture at the University of Nottingham, were invited by the Executive to review the Division. The two reviewers were not able to come to Australia at the same time, so their reports, though they agreed on many points, were made individually. Their recommendations included increased attention to plant nutrition aspects of soil science, including trace element work, investigations of soil organic matter, rhizosphere biology, and Hallsworth particularly emphasised the need to develop soil zoology, which was not studied in Australia, and the surface chemistry of soil particles, making use of the newly-developing electron probe.

Hallsworth was invited to accept appointment as Chief, which he did, and took up the appointment in 1964. He had much experience and knowledge of Australian soils, having been a lecturer in soil science and animal nutrition at the University of Sydney through most of the 1940s. He had in the first place come to Sydney from England with a Ph.D. in animal nutrition, but with wide interests in soil science, especially in pedology and soil biology, and was responsible for the training of many who subsequently became leaders in soil science in Australia, including J.P. Quirk, E.L. Greacen, A.B. Costin, P.H. Walker, H.M. Churchward, J.E. Beattie, J.D. Colwell, and H. Waring. He had returned to England in 1949, to the Chair at Nottingham, and had again lived for a year in Australia in 1960, as Visiting Professor of Soil Science at the University of Western Australia.

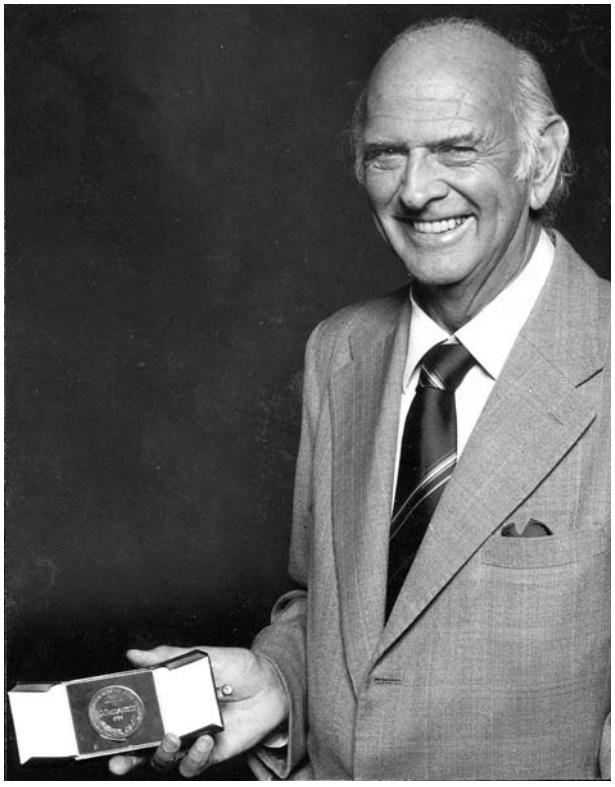

Photo 12 Gordon Hallsworth, third Chief of the Division of Soils, holds the Prescott Medal, c. 1971.

In 1966 Hallsworth initiated the National Soil Fertility Project, which continued until the mid-1970s. This was a group of projects that aimed to obtain good analytical data on a large number of soil profiles in each of a variety of soil groups and to define the limitations of soil fertility that prevailed in croplands and pastures of the temperate zone of Australia. Much support was provided by fertiliser companies and State Departments of Agriculture in Victoria, South Australia and Western Australia, who provided funding to purchase equipment such as trucks and tractors for the field work, and salaries for a group of technical staff who were involved in the field and laboratory work.

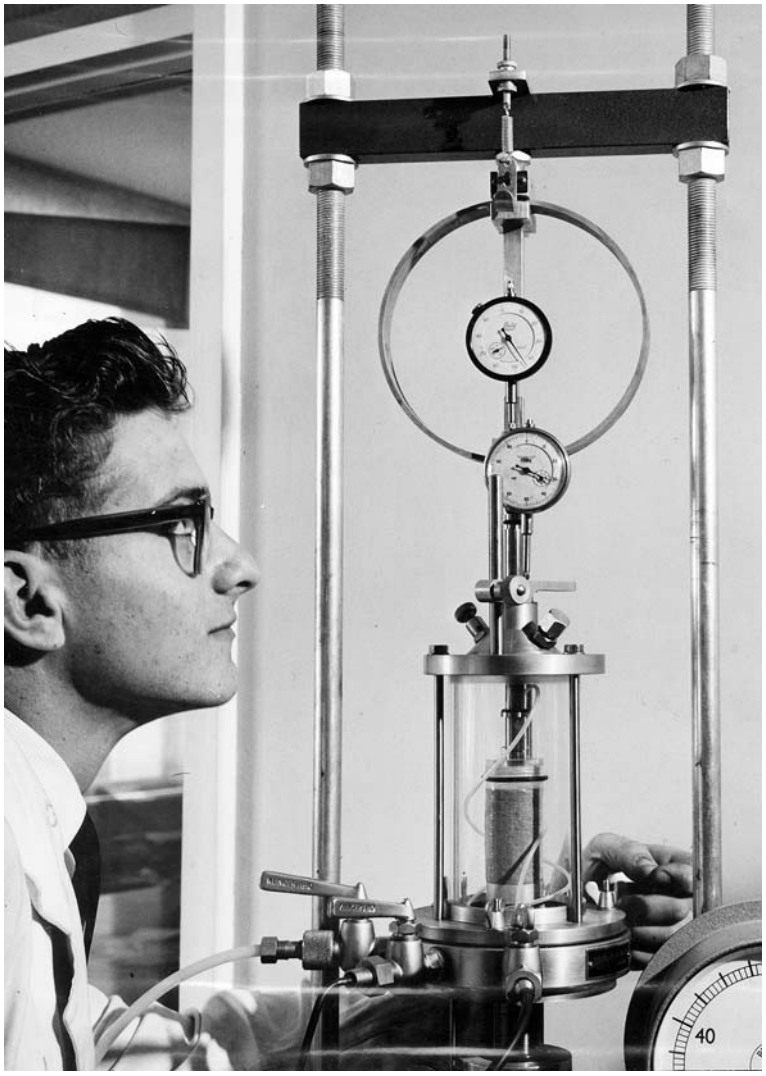

Photo 13 Cliff Hignett measuring soil strength for its effect on root growth, c. 1965

Large-scale plot experiments, using wheat as the experimental crop plant, were set out in many localities from Queensland to Western Australia to study the effects of various physical, chemical and morphological features of soils on plant growth and production. Using regression analyses and modelling techniques it was anticipated that soil factors influencing plant production could be identified and that the knowledge so obtained could be used to develop a more objective method of assessing the capabilities of soils for plant production. Colwell, in the Canberra laboratory, contributed much to the mathematical analysis of the data and as a result, was subsequently called on several times by the Food and Agriculture Organisation as a consultant to apply his techniques in countries of the developing world.

J.N. Ladd moved from his studies of humic materials in soils, a field in which he had become a leading international figure, to examine the pivotal role of microbial biomass in the turnover of soil carbon and nitrogen. He built up a small team whose studies, using ^{14}C and ^{15}N to follow carbon and nitrogen through the economically important wheat-soil system, earned him a well-deserved place among the world leaders in this field, as well as in his former field of humus biochemistry.

A.W. Moore was appointed as a microbiologist to the Brisbane laboratories in 1963. He did some work on nitrogen fixation, but developed an interest in Adansonian theories of classification and the application of numerical methods, like those that at the time were central to studies in biological taxonomy, to the classification of soils. R.J. Gilkes was appointed in 1967 to do research on clay minerals, and to establish an X-ray crystallography service in support of the pedological projects in Queensland. Gilkes left the Division in 1969, but the X-ray service work was continued by J. Drinnan, who had been appointed as Gilkes' assistant.

Following the transfer of R.F. Isbell from Brisbane to Townsville, W.T. Ward was transferred in 1963 from Melbourne to the pedology staff in Brisbane, and C.J. de Mooy moved from Canberra. Collaborative work with the Division of Tropical Pastures included a soil survey of the Narayen Research Station (Division of Tropical Pastures) and a hydrological project at Narayen, aimed at assessing the impact of pastoral development.

In the late 1950s X-ray spectrometers became available commercially and some mining companies became interested in using the new technology for their analyses. The Mineralogy Section in Adelaide had by the early 1960s about 10 years' experience with X-ray analyses of soils, and had developed methods that could readily be applied to mineral samples. Several of Australia's leading mining companies came to depend heavily on the Division's mineralogists, especially on Norrish, for advice and staff training, and in 1961 AMIRA (Australian Mineral Industries Research Association) made a grant to the Division to purchase a commercial X-ray spectrometer.

By the early 1970s, X-ray methods were widely used by the mining industry, but could not be used for contract assays, that is, for certifying the mineral content of ores for the market, because there were no recognised standard methods for X-ray analysis. Work was initiated with the industry and the Standards Association of Australia, and with the financial support of AMIRA, to develop standard methods and over the years this work has resulted in the mineralogists developing first Australian Standards, and later International Standards for X-ray analyses of ores and other materials of interest to the mining industries. The first standard, for the titanium ore ilmenite, has been published by the Australian Standards Association. The group's work, in a joint project with Japanese scientists, showed that the certified values for iron ore, based on certified reference samples, were inaccurate, and this led in 1995 to the initiation of a major international test program in which the Division's group is taking a leading part.

A Soil Zoology Section was established in 1965, when K.E. Lee was recruited from New Zealand. Lee had been the first soil zoologist in New Zealand, where he had worked mainly on the ecology of earthworms and their effects on pedogenesis and soil fertility. He now became the first soil zoologist appointed in Australia. T.G. Wood was recruited also in 1965 and he and Lee worked together for seven years on the ecology of termites and their relationships with soils, especially their effects on organic matter decomposition and pedogenesis. This work led to the publication in 1971 of their book *Termites and Soils*, which became the standard text on the subject and stimulated much further work in other countries where termites are an important component of the soil fauna. Termite work was further developed in the Townsville laboratories where A.V. Spain and particularly J.A. Holt continued to investigate the effects of termites on soil chemistry, nutrient cycling and organic matter decomposition in tropical ecosystems.

In 1968 P.J.M. Greenslade joined the Zoology Section in Adelaide and until 1990 he worked on the ecology of ants and their significance as indicator species for assessment of soil degradation.

Other projects in Soil Zoology initiated in the 1970s included work on the influence of soil mites and collembola on organic matter decomposition and nutrient cycling by T.G. Wood and especially by B.R. Hutson, ecological effects of bushfires and the ecology of the nematode *Heterodera avenae*, a parasite of the roots of cereals.

A.D. Rovira, in 1973, became Head of a Forestry and Rhizosphere Section in Adelaide that incorporated the rhizosphere and mycorrhizal biology groups, formerly within the Soil Microbiology Section. It was augmented by the transfer from the former CSIRO Forest Products Division in Melbourne of R.C. Foster, electron microscopist, R. Sands, a plant physiologist, and J.W. Nicholls.

The Forestry and Rhizosphere section became, by 1975, the Forestry Section, with G.D. Bowen as Section Head, while Rovira moved back to the Microbiology Section as he increasingly developed work on plant pathology of soil-borne root diseases of cereal crops. Initial work concentrated on *Gaeumannomyces graminis*, the fungus responsible for 'hay-die', or 'take-all', a widespread disease of wheat, the possibility of its control by suppressive organisms in the soil, and farm management practices to minimise the risks of severe loss. The work expanded to include parallel studies of the fungus *Rhizoctonia* and the cereal cyst nematode, *Heterodera avenae*, and occupied much of the resources of the Division's biologists throughout the remainder of the 1970s and the 1980s.

A high point in the Division's history was the ninth International Congress of Soil Science, held in Adelaide in 1968, while Hallsworth was the President of the International Society of Soil Science (ISSS). It was the first ISSS Congress to be held in the southern hemisphere; it focussed international attention on Australian soils and soil science and further enhanced the Division's international reputation as one of the world's leading soil research organisations. A meeting of Commission 1 of the ISSS, to discuss 'The Modification of Soil Structure' was also held in Adelaide in 1972.

The 1968 International Congress provided a stimulus to finalise the *Atlas of Australian Soils* and *A Handbook of Australian Soils*. The last sheet of the atlas was received from the CSIRO printer only a week before the Congress began. After that sheet had been sent to the printer, Northcote proceeded, at the request of the FAO, to prepare a preliminary map of Australian soils in terms of the FAO-UNESCO soil classification and this map was displayed, along with other sections of the FAO's world soil map, and with the atlas maps, at the Congress. In collaboration with the CSIRO Film Unit, Raupach and Northcote also prepared, in a short time and again in time for the Congress, an outstanding film on Australian soils.

The handbook was edited by a group of seven senior members of staff, coordinated by H.C.T. Stace, and published in 1968. It continued to use the Great Soil Group system of soil classification that had been the basis of three editions of Stephens' *Manual of Australian Soils*. The former generalised accounts of the Great Soil Groups, which were based on descriptions of 'modal' soil profiles, were expanded in the handbook to include the more important variants. Detailed descriptions were provided for all of the soil sites visited during the excursions associated with ISSS Congress, with chemical, physical and mineralogical data. A feature of the handbook was the inclusion, for 80 profiles representative of the major soil groups, of an account of soil micromorphology, based on the work of R. Brewer and J.R. Sleeman.

Both the atlas and the handbook have been well used and they have endured as basic references on the soils of Australia. Their use has, however, not been without problems for other scientists who work in environmental sciences, who have been faced with two of the most important general accounts of Australian soils, published in the same year, by the same organisation, using different and virtually incompatible soil classifications.

A notable new approach to soil science in the Division was marked by the appointment to the Canberra Laboratory in 1968 of J.M. Norris, an expert in the use and application of multivariate analysis, to work with Loveday and Butler on spatial variation of soils in the field. Norris's career was unfortunately cut short when he was killed in a car accident in 1971 and no further work was done in this field for some years.

The 1970s began as a period of growth for the Division. New laboratories were built in Canberra, opening in 1971, and for the first time providing high quality research facilities for the regional staff, which was previously housed in a temporary army-hut type wooden building. In the design of the Canberra laboratories Hallsworth took note of the possibility that some future Chief of the Division might prefer to be based in Canberra rather than Adelaide, so a Chief's office was included in the building. A notable feature of the Canberra building was its inclusion of a rain tower, in which natural rainfall could be simulated, giving Walker's Sediment Transport Group a powerful new technique for their research. Accommodation was also provided for Soils staff in a new building at Floreat Park, in Perth, for the Division's Western Australian staff.

There were plans also for new buildings in Adelaide, but these were shelved when, for the first time, the CSIRO as a whole came under serious pressure from the Commonwealth government to restrict the rapid growth that had begun in the immediate post-World War 2 period of enthusiastic support for science. From about 1972 and for the remainder of the 1970s the general trend in Australia was for decreasing government financial support and for reorganisation of the CSIRO. There began at this time a long series of reviews of government supported science, notably by the OECD, and including a number of internal reviews within the CSIRO. Pressures on CSIRO generated by the reviews resulted in attempts to reorientate research into areas that at the time were seen by the reviewers as being of high priority. The catch words of the times for CSIRO staff became 'redeployment', and for their research 'accountability'.

The effects of the reviews on Division of Soils were exacerbated by a period in the early 1970s of difficult times in the rural industries that reduced their ability to support research. Divisions that depended heavily on funding from the rural industries were left with insufficient resources, and funds were transferred to them from other Divisions, including the Soils Division, by the enforcement of a policy of not replacing Treasury-funded staff when they retired or resigned, and transferring their positions to the affected Divisions. The Division lost eight staff positions in 1972-73 and 10 in 1974-75 and the reduction continued in subsequent years. There were some gains for the Division from the pressures put on CSIRO, especially the transfer of R.C. Foster from Forest Products Division to the Division's Adelaide laboratories. Foster was an outstanding electron microscopist who was first to adapt staining techniques that were used in medical diagnosis to studies of ultra-thin sections of soils, revealing previously unknown details of sites of microbial activity, especially relevant to the rhizosphere studies of A.D. Rovira, and mechanisms of organic matter decomposition processes.

In 1972 G.M. Dimmock was transferred from Hobart to Perth, with the decreasing emphasis on soil surveys in Tasmania and the increase in Western Australia. The Perth group was much involved in the National Soil Fertility Project, but increasingly became involved also in problems of the relationship between increasing salinity affecting the quality of water supplies, and land use practices, including the extension of irrigation schemes. Similar investigations on salinity problems were associated with irrigation in the Riverina Region of New South Wales.

K.D. Nicolls, head of the Tasmanian Regional Laboratory, retrained in England, specialising in root nutrition and water use of apple trees, which were then important to the Tasmanian economy. A.M. Graley and J.L. Honeysett were associated with Nicolls in this work, but changes in export markets led to the collapse of the Tasmanian apple industry in the 1970s. Nicolls and his group then turned their attention to the forest industry, with some studies of water use in native forest, particularly in relation to a 'die-back' disorder. This work continued, in collaboration with the Tasmanian State Forest Service and the newly established CSIRO Forest Research group in Tasmania, until Nicolls retired in 1980. At this time Graley and Honeysett were transferred to the Forest Research Division and the Soils Division's Tasmanian Regional Laboratory was closed.

In 1973 G.D. Hubble gave up the position of Officer in Charge (OIC) at Brisbane and his place was taken by A.W. Moore. The Division of Soils group at the Davies Laboratory in Townsville remained small, with its work closely related to soil surveys until the early 1970s, when Hallsworth, as Chief, recognised a need for the Division to have a strong soil research centre in tropical northern Australia to complement the strong centres that had been built up in temperate southern Australia. Extensions to the Davies Laboratory were completed in 1974, and allowed a modest expansion of the work in northern Queensland. Isbell remained OIC of the Townsville Soils group, and there was an expansion of staff, including the appointment of soil zoologists A.V. Spain and J.A. Holt, physicist J. Williams, chemists M.E. Probert and G.P. Gillman and pedologist R.J. Coventry.

In 1973 the Division of Soils was incorporated into the Land Resources Laboratories of CSIRO, a new grouping of Divisions that resulted from the recommendations of the Underwood Report (1972) on CSIRO's agricultural research programs. The Land Resources Laboratories included also the Division of Land Use Research, based in Canberra, and the newly-created Division of Land Resources Management, based in Perth. The new Perth Division was made up of the local staff of Soils Division and several other Divisions that had a presence in W.A. For the first time since 1945 the Division was not represented in W.A., and the Division's overall research capabilities suffered a serious blow with the loss of the five pedologists, four chemists, two physicists, one biologist and 12 technical staff who made up the Perth-based staff. Hallsworth was appointed Chairman of the Committee of Chiefs of the Land Resources Laboratories, a position he held for a short time simultaneously with that of Chief of Division of Soils. Late in 1973 he relinquished the position of Chief to become full-time Chairman of the Land Research Laboratories.

A.E. Martin, who had been appointed as an Assistant Chief of the Division in 1971, and had acted as Chief while Hallsworth was overseas in 1971-72, moved from Brisbane to Adelaide when he was appointed to take Hallsworth's place as Chief of the Division in 1973. For the first time in the CSIRO, Chiefs of Divisions were appointed for fixed terms: in the case of Martin and the Chiefs of the other two Land Resources Divisions, for seven years.

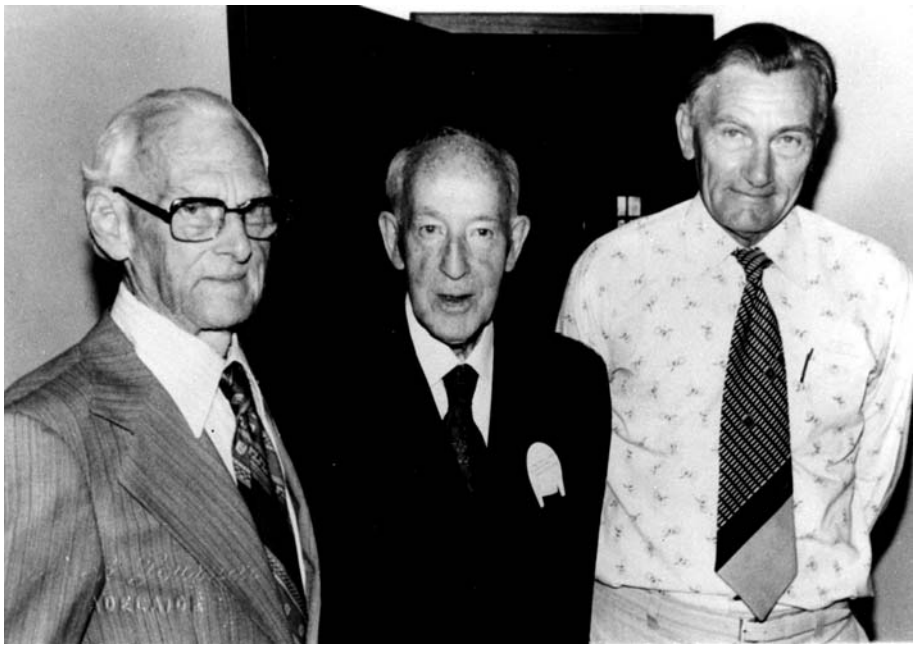

Photo 14 J.K. Taylor, J.A. Prescott and A. Martin, Apr. 1980

Field work for the National Soil Fertility Project was completed in the early 1970s. The project had occupied much of the staff and other resources of the Adelaide, Canberra and Perth laboratories since it began in 1965. Although it did not achieve the ambitious aims that had been set, it provided much information on the chemical and physical properties of soils that limit fertility and plant growth and their economic implications as they relate to fertiliser use, and provided a basis for subsequent projects on soil fertility. Lasting benefits to the Division were the provision of state-of-the-art equipment for automatic analyses and an electron microprobe.

A new program, Stability of Landscapes, was established in 1973. This program brought together groups in the Canberra and the Brisbane laboratories. In Canberra a Sediment Transport Group had worked since 1968, with P.H. Walker as its leader, A.J. Moss, a sedimentologist, and P. Kinnell, an engineer, studying soil erosion by water, especially the effects of vegetation cover and of raindrop impact on the mechanisms of down slope surface soil movement. The Brisbane group began work, with C.H. Thompson as leader, on the large coastal sand mass in the Cooloola area, as an example of similar sand masses that are important features of the southern Queensland coast. The Brisbane-based projects in this program came to occupy most of the Brisbane staff through the 1970s and into the 1980s, particularly at Cooloola, where a multi-disciplinary, ecological approach was taken.

To suit administrative convenience, especially new accounting methods, CSIRO Divisions were requested early in the 1970s to group their research projects into larger units, which were called programs. In response to this, and because there were concerns that in Division of Soils the disciplinary structure restricted interdisciplinary and inter-regional collaboration, the disciplinary structure was abandoned as a basis for grouping projects and the Division's research projects were regrouped in 1973 into a scheme of thematic programs, organised on a Divisional rather than a Regional basis. Project leaders were given more direct control over funding. Initially there were 11 programs and these were reduced to eight in 1974-75, but increased again to 10 by 1980. The new arrangements had most effect on the organisation of the Adelaide laboratories, where the former sectional structure had been strongest. Compounding the effects of the program structure, the frequent reviews of the Division's research and organisation and constant pressure for redeployment of staff resulted in increased stress and dwindling staff morale.

In 1979 the Geomechanics Division group in Adelaide rejoined Division of Soils to reconstitute a soil mechanics group, and in 1983 moved back to the Glen Osmond site. Studies on land use in engineering projects, slope stability and soil moisture status were continued by B.G. Richards and P. Peter, with emphasis, as computing power increased, on the use of finite element analysis procedures in a mathematical modelling approach to soil mechanics problems. Minesite rehabilitation work became an important component of the group's work in later years, with increasing awareness in the community and Divisional involvement in environmental conservation.

Soil biological investigations through the latter part of the 1970s were mainly directed at studies of soil-borne plant diseases in wheat growing areas of southern Australia, various aspects of the nutrition of pines, especially the role of mycorrhizal fungi, and the role of termites and other soil animals in pedogenesis, organic matter decomposition and nutrient cycling. G.D. Bowen was Assistant Chief of the Division from 1977 to 1980, with special responsibility for the Adelaide Regional Laboratories, but continued to supervise the mycorrhizal work. He became interested in the symbiotic nitrogen-fixing relationship between the actinomycete *Frankia* and the roots of *Casuarina* spp, and initiated a project that was to continue through the 1980s. Bowen left the Division in 1985 on a two-year assignment as Section Head for Soil Fertility, Irrigation and Crop Protection at the International Atomic Energy Agency, in Vienna. In 1986 he took early retirement under the ESIS scheme and the *Casuarina-Frankia* work was continued by P. Reddell. Reddell moved the project to Townsville, and later to Atherton, where he has broadened its scope to include mycorrhizal studies of tropical forest trees.

Beginning in 1977, a major publication *Soils: an Australian Viewpoint*, including contributions from 68 authors, was planned and written. This book was a comprehensive statement of the state of knowledge of Australian soils derived mainly from the work of the Division's staff in its first 50 years of operations. Its preparation was initiated and coordinated by K.E. Lee, and was provoked by the fiftieth anniversary of the Division's foundation in 1927, and by the impending retirement of many of those who had pioneered and developed soil science in the Division, to record what they knew. It was unfortunate that, although most of the writing was completed by 1979, there were publication delays and the book did not appear until 1983. It has, however, been accepted as a standard reference for research workers, students and extension workers.

And, of course, in 1997 the new division of Land and Water was born, comprised of the former Division of Water Resources and the Centre for Environmental Mechanics, together with the former Division of Soils.

Photo 15 Centre right: Ron Kimber acted as MC at the WAKE held for the Division of Soils on 31st January, 1997

Photo 16 Roger Swift (6th and final chief of CSIRO Division of Soils) discusses the old division with Gordon Hallsworth, 1997

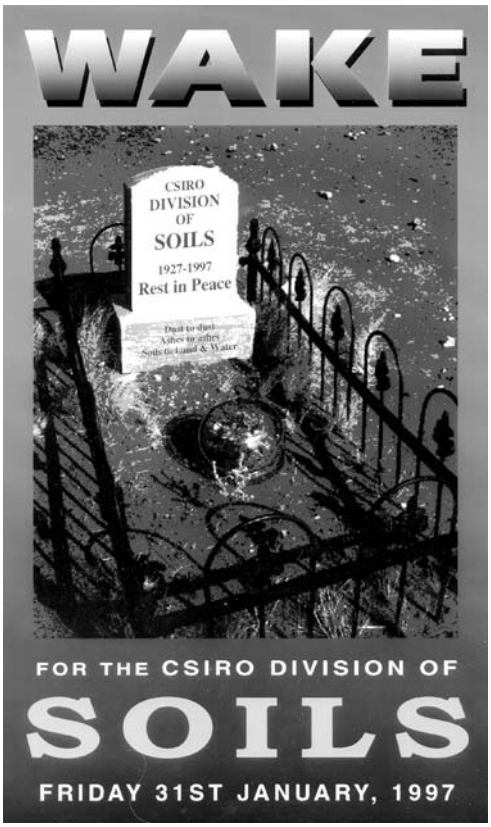

Photo 17 Poster prepared for Soils Wake

The 1980s and into the 1990s

Despite considerable reduction in staff numbers, the Division entered the 1980s with senior staff members in all of its disciplinary groups who were recognised internationally as leaders in their fields, with excellent buildings, comprehensively equipped, but with much of the equipment in need of updating.

A fundamental restructuring of the CSIRO had followed the implementation, in 1979, of the Birch Report, an external review of the CSIRO commissioned by the Australian Government. Divisions were grouped according to their major functions and research areas, into five Institutes. For each Institute there was a Director, to whom chiefs of Divisions were responsible, although the Chiefs retained the right also to deal directly with the CSIRO Executive, which continued as the central controlling body of CSIRO. Division of Soils, together with the Divisions of Land Resource, Management and Land Use Research, was first placed in the Institute of Earth Resources. The interests of the remainder of the Divisions in this Institute were closely related to the mining industries, and it soon became apparent that the three Land Resource Divisions were not well placed.

A.E. Martin's initial seven-year term as Chief of the Division ended in 1980, and a Review of the Division's research was commissioned by the CSIRO Executive. The Chairman of the Review was Dr J.R. Philip, Director of CSIRO's Institute of Physical Sciences, supported by a group of leading soil scientists and land use experts from Australia and overseas.

The Review Committee's report appeared in 1981 and it concluded that the Division, which had from its inception played a central role in the development and application of soil science in Australia, had declined so that it was no longer fulfilling that role. The decline was attributed to confusion of objectives, aggravated by contraction of its resources, an ageing and static staff, and by the recently-adopted emphasis on projects, often with only local objectives, at the expense of the encouragement of scientific excellence and coherent effort in the sub-disciplines of soil science.

The Review Committee recognised, however, the importance of an excellent national soil science research group with an obligation to develop principles for the application of soil science to dryland and irrigated agriculture, forestry, hydrology, engineering and conservation.

The Philip Review recommended that the thematic program organisation, with emphasis on projects, should be abandoned and that the Division should return to a structure based on the sub-disciplines, with the aim of developing principles for the application of soil science to practical problems. Also, on the Review Committee's recommendation the Division was removed from the Institute of Earth Resources to the Institute of Biological Resources, and a decision was made to close the Tasmanian Laboratory.

Overall, the Review Committee's report struck an optimistic note of encouragement of research for the benefit of Australia's primary industries and environment.

Soon after the report of the Review Committee appeared, applications were called for a Chief, to replace Martin, who was close to retiring age. The new Chief appointed was D.E. Smiles, who at the time was Chief of CSIRO Division of Environmental Mechanics; he was appointed in late 1982 and took over the position at the beginning of 1983. The new Chief chose to establish his office in Canberra because he considered that the Division at that time needed continuous representation close to the Institute office and to government.

Smiles was charged with the task of implementing the recommendations of the Philip review, specifically to restructure the Division with a strong disciplinary base, and at the same time to:

- maintain regional operational responsibility;
- redress the perceived imbalance between operational and salary funding of the Division;

- enhance the image and influence of the Division in the Institute of Biological Sciences, which regarded soil science as a support discipline for agriculture, and did not appreciate its wider environmental responsibilities;
- develop a strong international visits and visitors program; and
- reintroduce a system for annual reporting of the Division's activities, which had lapsed during the previous few years.

Restructuring into five discipline-based groups, Biology, Chemistry, Mineralogy, Pedology and Physics, each with a Discipline Leader, and strengthening of regional responsibility resulted in an effective 'matrix' structure of management, which was strongly supported by the staff. Very limited new resources were provided, however, to help correct deficiencies identified by the Philip Review and a long-term plan had to be instituted to ameliorate the salary:operating costs imbalance that had resulted from the Division's staff then having the oldest average age and the highest average salary of all CSIRO Divisions.

The Division's budget was realigned to allow the sponsoring of distinguished visitors to visit and work in the Division's laboratories, to fund overseas visits by the Division's scientists and, with the demise of the old CSIRO Postgraduate Studentship Scheme, to instigate Divisional Research Studentships. Several recipients of the Studentships subsequently became members of the Division's staff.

Despite the criticisms in the Review Report, especially those relating to the age structure of the staff, and perhaps as a direct result of that age structure and the large number of ageing but very able and experienced staff, the underlying strength of the Division was revealed when, by 1984, it was shown to be the most scientifically productive Division in the Institute of Biological Resources.

The Townsville Soils group was acknowledged by the Philip Review Committee as being highly regarded as a tropical soil science laboratory and to provide an example that the Division as a whole might emulate. The favourable comment on the Townsville laboratory derived from the excellent individual and collaborative research carried out between the early 1970s and about the mid 1980s. Particular aspects included the pioneering studies by G.P. Gillman on the charge characteristics of the high-rainfall, highly-weathered tropical soils, a study with world-wide implications for tropical soils. The soil fertility studies of M.E. Probert, initially on sulphur, then on phosphorus nutrition of the introduced pasture legume *Stylosanthes* spp in the semi-arid tropics, were also of importance. J. Williams was heavily involved with soil water balance studies in contrasting soils in the northern semi-arid tropics, based on neutron moisture meter measurement and analysis. He was able to show the potential for groundwater recharge through these soils in a dry tropical environment, possibly into the Great Artesian Basin. The associated pedological studies of R.J. Coventry in this environment underpinned both the hydrological and nutritional work done by Williams and Probert.

In 1983 major new projects were initiated: one in Perth, on dryland crops and soils, jointly with CSIRO Division of Plant Industry; and the other in Griffith, on management of irrigated cereal cropping soils, jointly with the CSIRO Centre for Irrigation Research. J. Loveday, who had been OIC of the Canberra Laboratory since 1975, was appointed Assistant Chief of the Division and remained in this position until his retirement in 1986.

In his preamble to the annual report for 1983-84, Smiles defined a focus for the Division's research on a restricted set of soils, selected with regard to the location of the Division's laboratories, that support significant agricultural enterprises and also present well-defined 'management' problems. Particular attention was to be directed towards the understanding of soil water relations, fertility and salinity, and this was of special interest in view of the subsequent developments in CSIRO research on Australia's water resources. The importance of continuing 'basic' research to underpin the more practical emphases detailed by Dr Smiles was recognised as also of paramount importance.

Work on the detail of water and salt movement in irrigated clay soils had been undertaken in the 1970s by McIntyre, Loveday and C.H. Watson. In the early 1980s much of the work of the Division's physicists aimed at gaining a better understanding of the dynamics of soil water and application of this knowledge to better land management. This included research led by G.B. Allison, who was the Discipline Leader for Soil Physics, on variations down the soil profile in concentrations of the naturally occurring isotopes ^{18}O and ^{2}H in soil water, which can be related to the rate of movement of water through the profile.

In Townsville J. Williams became more involved in runoff and erosion field experiments, before being transferred to Canberra in 1989. K.L. Bristow, who joined the Division in 1983 as a soil physicist, began studies on the thermal properties of soils and the movement of water and solutes. Meanwhile, P.J. Ross, who had moved to Townsville following the closure of the soils laboratory at Brisbane at the end of 1988, was working on a soil water modelling approach and, together with Williams and Bristow, produced the software package SWIM (Soil Water Infiltration and Movement) which is now extensively used both in Australia and overseas. A notable feature of the Townsville soil physics work during this period was the innovative instrumentation skills of the group, particularly of P.J. Ross.

During the 1980s and into the 1990s there were some major achievements in pedology. The publication in 1984 (second edition in 1990) of the *Australian Soil and Land Survey Field Handbook*, in which R.F. Isbell was second author, established for the first time in Australia a standard terminology for the description of soils and the characterisation of landform and vegetation. A related development was the establishment of the Australian Collaborative Land Evaluation Program (ACLEP), based in Canberra under the leadership of N.J. McKenzie. In the area of soil surveys, an important milestone was the completion of the medium-scale surveys of the wet coastal region of north Queensland by G.G. Murtha and M.J. Cannon of the Townsville soils group in collaboration with the Queensland Department of Primary Industries. In 1996 a new *Australian Soil Classification* was finally completed and published. This had been a project of R.F. Isbell for almost a decade, with much assistance from pedologists in a wide range of State and Federal agencies.

From 1990 to 1995 a project was funded jointly by Telstra and CSIRO to develop new methods to minimise the impact of soil properties on Telstra's Australia-wide optical fibre cable network. A multi-disciplinary CSIRO team led by R.W. Fitzpatrick in Adelaide developed techniques to determine the best routes along which to lay the cables. These new techniques were described in a *Soil Assessment Manual* and explained in training courses before testing by Telstra engineers and final acceptance for routine use. The end result has been enhanced performance of the national telecommunications system, with savings of millions of dollars.

In 1995 M.J. Wright retired from the pedology group in Adelaide, having over many years studied the nature, distribution and origin of red-brown hard pans (duripans) in Australia and having accumulated a database of great national and international interest on these features of arid zone soils.

Publication by Lee in 1985 of the definitive text *Earthworms: their Ecology and Relationships with Soils and Land Use* opened the way for the establishment of projects on the ecology of earthworms and their significance in soil fertility in southern Australian pasture and crop lands. G.H. Baker (CSIRO Entomology Division) and B. Doube (Soils Division) jointly led this work, which has the potential for great economic benefits to farming industries. Conservation farming systems with minimum soil disturbance and retention of plant residues promote earthworm activity. Research on earthworms, some of it done jointly with CSIRO Division of Entomology, has included studies of:

- the effectiveness of various earthworm species at burying and transporting plant residues and fertilisers;
- effects of earthworms on growth and yield of wheat growing on heavy clay soils at Kapunda, in South Australia, which demonstrated their ability to increase plant weight by 35 per cent and wheat yield by 29 per cent, and similarly, on sandy soils in Victoria, where plant growth was boosted by up to 50 per cent;
- beneficial effects on fruit production in orchard soils.

Photo 18 Rob Fitzpatrick, Reg Taylor and Jock Churchman at the 10th International Clay Conference held in Adelaide, July 1993

Research in soil chemistry, led by B. Cartwright, revealed widespread and previously unsuspected boron toxicity in southern Australian wheat crops, in soils derived from old marine sediments. A long-term interest of the Division, dating back to the chemical work of Piper and others at about the time of the Division's foundation, has been in trace elements and heavy metals in soils, which had been re-emphasised by the Russell Review of 1963. K.G. Tiller, who joined the Division in 1955, was responsible for a long series of investigations of these elements in soils and landscapes in southern Australia.

With increasing public concern in the 1970s about the health risks associated with heavy metals in the environment, Tiller, together with B. Cartwright, R.H. Merry, M.P.C. de Vries and others, initiated studies in 1972-73 of the environmental effects of heavy metal contamination in and around Port Pirie, where lead smelting has occurred since 1889. Other projects undertaken by members of this group included a study of long-range dispersal of lead carried eastward by prevailing winds from Adelaide, and investigations of lead, arsenic and copper contamination from sprays formerly used to control pests in apple orchards when the orchards were cleared and the land was redeveloped for housing. Results from the Port Pirie project showed widespread contamination, with levels of lead unacceptably high in some places, in home-grown vegetables, farm crops, pasture plants, and in bottom sediments of the adjacent waters of Gulf St Vincent.

The work at Port Pirie established Tiller's research group as authorities in the field of heavy metal contamination of the environment, with the result that demands on the Division for assessment of such problems and advice on treatment methods have increased, so that the group, despite Tiller's untimely death in 1995, has come to play, an increasingly important part in the Division's activities. The Port Pirie project had important implications for human health and was basic to further investigations and remedial measures that were undertaken in subsequent years by the South Australian health authorities.

Associated with the work on heavy metals in the environment were studies by de Vries on the land disposal of sewage sludge, its heavy metal content, fertiliser value, and effect on plant uptake of contaminants.

The Division began to be recognised not only as a leader in research on heavy metals in the landscape, but more widely as a source of authoritative advice and investigation on a variety of problems of environmental pollution. Tiller's group was increasingly consulted by companies, at first in Australia and subsequently internationally, on the rehabilitation of polluted mining and other industrial sites. The international standing of the Division's work on environmental pollution was recognised and enhanced by the organisation of the first Australasia-Pacific Conference on Contaminants and Soil Environment in the Australia-Pacific Region. This conference was held in Adelaide, in 1996, organised by a committee led by R. Naidu, a member of the Division's research group on problems of soil pollution. It was strongly supported by many countries in the region, and it was agreed that it should be the first of a series of conferences on this important topic.

The mid-1980s were a period of increasing political and financial pressure on the CSIRO. `Management by objectives' was a catch phrase at the time. It became CSIRO policy to ensure that science was seen as providing tools for the resolution of national problems and Divisions were directed to define clear objectives that related to politically and economically-defined national goals. In 1986 all CSIRO Divisions were directed to adopt a thematic program basis for management, so the Division was forced to revert to a management style very like that that had provoked criticism from the Philip Review Committee of 1980.

G.B. Stirk, who had been Officer in Charge of the Adelaide Laboratory since 1983, retired at the end of 1985 and his place was taken by K.E. Lee, who became Assistant Chief of the Division in 1986 on the retirement of J. Loveday, and Deputy Chief in 1989. P.H. Walker replaced John Loveday as OIC in Canberra and in 1987 he became an Assistant Chief, continuing in this role until his retirement in 1989, when J. Williams moved from Townsville into this post and was designated a Deputy Chief.

Constant reduction through the mid-1980s in Treasury resources allocated to the CSIRO forced the Division to seek grant funds to support an increasing proportion of its research. In the six years to 1988 there was a 30 per cent reduction in Treasury funding. It became necessary to reduce staff, resulting in the initiation by the CSIRO in 1986 of an Early Separation Incentive Scheme (ESIS), an early retirement scheme that resulted in 10 staff leaving in 1986 and eight more in 1987; these included some of the Division's most senior and experienced staff.

McKinsey's, an American management consulting company with much experience in reviewing large-scale commercial and government organisations, was commissioned in 1986 to undertake a review of the CSIRO's structure and operations. Its report, presented in 1987, resulted in the most far-reaching reorganisation in CSIRO's history. The whole organisation was remodelled and 'corporatised' on the lines of a hierarchical commercial enterprise which, though it did not readily suit the management of scientific research, accorded well with the political-economic views of the time.

Throughout its existence the CSIRO had been under the overall management of the CSIRO Executive. This consisted of a full time Chairman and four full time members, all senior scientists and employees of CSIRO, and a small number of part time members from business and university backgrounds. On the recommendation of the McKinsey report, the Executive was abolished and CSIRO came under the control of the CSIRO Board, whose membership was drawn largely from the business world, With a Chairman, appointed by the Governor General, and a Chief Executive Officer, who was the only full time CSIRO staff member. The first CEO was Dr John Stocker, who was previously the Research Director of a large international pharmaceutical company.

The five Institutes established in 1979 following the Birch Report were abolished and were replaced by six Institutes, related to sectors of the national economy. Soils Division argued most strenuously for inclusion in the new Institute of Natural Resources and Environment, on the basis that the use of soils is not restricted to plant growth and that the Division was increasingly involved and had an obligation to contribute to other areas of resource assessment, conservation and land management. This argument was lost, largely because the Institute of Plant Production and Processing and its large plant science Divisions were loath to relinquish territory.

A new Division of Water Resources was established, combining most of the staff of the Divisions of Groundwater Research (derived from Land Resources Management) in Perth, Land Use Research in Canberra, and most of the Soil Physics staff of Soils Division in Adelaide. G.B. Allison, who had been the Discipline Leader of Soil Physics in Division of Soils, was appointed Chief of the new Division. Strong arguments were put forward by Smiles and others in Division of Soils that the loss of key soil physicists who worked in the Division on hydrological aspects of soil physics would result in serious damage to the Division's research capabilities, and that if research on water resources was to be expanded it would be best done by expanding the existing Division of Soils. The Division of Water Resources was, however, constituted and was further dissociated from Division of Soils by its placement in the Institute of Environmental Resources.

It was further proposed by the McKinsey Report that the CSIRO should find more of its research funding from non-Treasury (industry) sources, and in 1988 the Board decreed that Soils Division should aim to find 30 per cent of its total funding, not just its research funds, from non-Treasury sources. This requirement was subsequently reduced to 25 per cent, but it was to prove not to be an easy task and was to have far reaching effects on the Division's research and staff. It is of interest to note here that in the financial year 1983-84, when there was little pressure on the CSIRO to obtain non-Treasury funding, grants and external funds amounted to $243,318, or 3.2 per cent of the total Divisional budget of $7,567,618. By 1987 external funding reached $1,304,000 or 13.6 per cent of the total budget of $9,554,700 and, by 1991, $3,579,500 or 25.7 per cent of the total of $13,915,000.

The necessity to raise so much of the Division's funding from non-Treasury sources placed new pressures on the Division's scientists. It increasingly became essential for them to design and work on projects that related to the interests of organisations that would pay some or all of the costs of doing the projects. Although staff with skills in various aspects of business management and public relations were recruited, and their inputs were valuable, the planning and preparation of research grant applications and reports to granting bodies on the research they funded depended mainly on inputs from all levels, especially the most senior and most experienced of research and technical staff.

Many staff were obliged to seek paid consultancies. Most of these were arranged by the participating staff within Australian industries and semi-government organisations, but considerable numbers have involved contracts in other countries, some supported by the Australian international aid organisation ACIAR, while others have been arranged directly with foreign organisations. The pressures that resulted from these changes in the research emphases of the Division became increasingly apparent through the 1990s. Although the Division had always aimed to produce work that had practical applications in the use of Australian soils, it now became necessary for the research to be more obviously 'applied' than had been the case through much of its history. Although some of the scientific staff at first had some difficulty in adapting to the changes in research directions and emphases, it is to their credit that most were able to cope with the demands of the new situation.

Through the 1980s and into the 1990s there was a steady loss by retirement and redundancies that removed nearly all of the remainder of the Division's most experienced senior research staff. It is in the nature of grant-supported research that most projects are problem oriented and have a short life, so that appointments must be for short terms, usually not more than three years. The loss of so many experienced staff coincided with a lack of assured funds that could support long-term projects in basic science. It was the Division's capability to support such research that had enabled the recently-retired or retrenched generation of research scientists to acquire the expertise that had brought many of them recognition as leading international authorities in their fields. The loss of research staff is well illustrated in the case of pedology, which has always been recognised as the basic discipline of the Division. In 1960 there were 28 pedologists in the Division; by 1981 there were 19, with no presence in Perth or Hobart; in 1996 this number was reduced again by almost half, with the majority based in Canberra.

The CSIRO Board and the Institute Directors appointed as a result of the recommendations of the McKinsey review pressed for the establishment of Divisional Advisory Committees, with the intention that they would provide advice to the Chief from users of the Division's research. Dr Smiles set up an Advisory Committee in 1987, with D.I. Blesing, a farmer, business consultant and at that time Chairman of the Wheat Industry Research Council as its Convenor, and four other distinguished members. In subsequent years the Advisory Committee's role expanded so that in the 1991 Divisional Annual Report it was reported that it was contributing more to Divisional management, advising the Chief on strategic planning, policy development and corporate management, as well as continuing in its original role of providing links with industry and advising on proposals that involved major shifts in the Division's research directions.

R.J. Coventry, who had succeeded John Williams as Officer in Charge of the Townsville Laboratory was recognised as an Assistant Chief in 1990. At the end of that year K.E. Lee withdrew from the position of Deputy Chief and Officer in Charge of the Adelaide Laboratory, before his retirement in early 1992. His place was taken by D.J. Reuter, who had previously had a long and distinguished research career in the South Australian Department of Agriculture. The structure established in 1988 included five research programs but by 1991 three other programs, Communication and Policy, Technical Development and Analysis, and Administration were added, each with a Program Manager. The Division's Management Committee at this time comprised the Chief, two Deputy Chiefs, an Assistant Chief and eight Program Managers, an extraordinarily large group to manage a Division with only about 40 Research Scientists.

At the Adelaide Laboratory in 1988, a large water supply pipe in the roof space of the main laboratory building burst during the night, at a weekend, when no one was in the building. Water ran down through service ducts, ceiling spaces and other openings, to flood all floors of the building, apparently picking up corrosive materials as it moved down. The result was damage to the building and to equipment exceeding a million dollars. The CSIRO had not previously experienced such an event and, in the absence of any policy precedent, replaced the damaged facilities and equipment from corporate funds. It was subsequently decided that this would not be done for any similar event in future. The resultant upgrading of some major but aging facilities provided a fortuitous benefit to the Division's capabilities, although offset against this gain was the substantial damage to stored experimental data and the loss of research time while repairs and replacements were in progress.

Budgetary strictures and a need to strengthen other laboratories, particularly Townsville, forced the closure at the end of 1988 of the Brisbane Regional Laboratory, which had contributed much to the Division's work in its 40 year life. Eleven of the 16 staff were retrenched and the other five were transferred to the remaining Divisional laboratories. With the closure of the Brisbane laboratory the Division much reduced its coverage of Australia and was represented by laboratories only in Adelaide, Canberra and Townsville, although a small Soils Division presence was later (1992) restored in Perth.

In 1990 the Commonwealth Government, through the Prime Minister's Science Council, provided funds that were open for competitive bidding, to facilitate the establishment of Cooperative Research Centres (CRCs), in the first place to number 50, but with more Centres to be established in subsequent years. These Centres were to bring together university, CSIRO, State government and industrial partners, with each partner contributing staff and physical resources to add to the Commonwealth's CRC funding, and they were to be financed in the first place for seven years.

Following early discussion between Dr Smiles and the Chief Scientist, Dr Ralph Slatyer, a proposal was developed jointly by the Division of Soils, the Waite Institute's Department of Soil Science and the SA Department of Agriculture for a CRC for Soil and Land Management, to be housed on the Waite campus. This proposal was submitted to the Prime Minister's Science Council. It was successful and the new CRC was established in 1991 with A.D. Rovira appointed for three years as its first Director. The aims of the CRC were to do research on the development of sustainable land management systems, to contribute to biological control of soil-borne plant pathogens, and to provide scientific support for the rehabilitation of soils contaminated with toxic elements. These aims were aligned with some of the major research aims of the Division of Soils, whose Adelaide staff provided much of the expertise, supervision of post-graduate students and collaboration with post-doctoral fellows who were appointed using the CRC's funds. From the Division's point of view, the major benefit of having the CRC on its Adelaide site was in enabling the appointment of a group of young scientists who brought new enthusiasms, ideas and techniques to the campus.

From about 1989 there began a series of developments on the Adelaide campus, which for many years had been shared by the Waite Institute (Faculty of Agriculture, University of Adelaide), the CSIRO, and the Australian Wine Research Institute. In 1989 the Premier of South Australia and the Vice-Chancellor of the University of Adelaide formally agreed on the relocation of some of the research units of the Department of Agriculture to the Waite campus.

Collaboration between the three research organisations, which had resulted in the establishment of the CRC, was carried further in 1991. There was a proposal for co-location of research facilities, so that for instance the soils and water research facilities of the three organisations would be physically grouped together in planned extensions and additional buildings that would be necessary on the Waite campus. This proposal was put to the staff of the three organisations and was agreed, and as a result a joint agency Planning Committee for a Soil and Water Environs Capital Works Program was established, to consult with the architects on the construction of the new facilities.

Construction work began at the beginning of 1993 and by the end of that year extensions to the Water Resources Division's laboratories, the larger of the Division of Soils' buildings (now named the Taylor Building) and the construction of a new laboratory block (the Prescott Building) were completed. These buildings were occupied by the end of that year by staff and research students of the University of Adelaide Department of Soil Science, the CSIRO Divisions of Soils and Water Resources, CRC research staff, and soil research staff of Primary Industries South Australia (PISA). By mid-1994 other Soils Division buildings had been refurbished and were occupied by sustainable resources staff of PISA, soil research staff of the SA Research & Development Institute (SARDI) and CRC research and administrative staff.

A brief review of the work of Division of Soils was undertaken in 1991, by a committee that included representatives of farming and other industry, as well as scientists. The chairman of the Committee was Prof. A.H. Chisholm, Professor of Agricultural Economics at La Trobe University. The Committee was generally satisfied with the Division's performance but raised some concerns about the proliferation of research managers and the increasing encroachment on research staff time in preparing research funding proposals, writing reports and similar tasks.

Following this review, Dr Smiles' appointment as Chief was confirmed for a further three years, but in mid-1992 he was forced by ill health to step down from the position. He had been Chief for nearly 10 years and had provided a high standard of leadership through these difficult years of radical change in the role and functioning of CSIRO. J. Williams was Acting Chief until the beginning of 1993, when Dr R.S. Swift, who was Professor of Soil Science and Dean of the Faculty of Agriculture at the University of Reading, took up his appointment as Chief and re-established the Chief's office in Adelaide.

Soon after his appointment Dr Swift moved to establish a new and less complex management system. The Divisional management team was reorganised, to comprise the Chief, J. Williams, as Assistant Chief in Canberra, the program managers, whose number was reduced to three by a revision of the program structure, K.G. Tiller, who was included as representative of the sciences that underpin the Division's programs, and the Divisional Secretary, J.B. Sleigh, as secretary of the Management Committee.

When Dr Smiles had taken the reins of the Division, in 1983, about 130 projects were listed in the Division's research program; he was responsible for reducing this number to 34. Many that had achieved their major objectives, or were considered no longer relevant to the Division's or the CSIRO's now more closely defined aims, were wound up; others were reorganised and combined into larger more thematic units, while some new projects were also established to bring the Division's research more into line with the now more industry-oriented emphases of CSIRO policy.

Photo 19 Divisional Management Committee members of the CSIRO Division of Soils, mid 1980's.
Back row (left to right) Geoff Stirk, Ian Fergus, Kevin Tiller, Ray Isbell, Pat Walker and Albert Rovira.
Front row (left to right) John Loveday, David Smiles (5th Chief, Division of Soils), John Sleigh, Keith Norrish & Bill Greacen.

This process was continued under Dr Swift's direction, with the number of projects being reduced to 16, grouped into three programs, Soils and Environmental Quality (Program Manager A.R. Milnes), Soils and Land Resources (Program Manager C.J. Chartres), and Soils and Rural Production (Program Manager C.A. Pankhurst, then D.J. Coventry). Increasing the breadth of projects enabled more flexible allocation of staff and resources within the projects and this was an advantage in the prevailing climate of reducing resources.

The financial stringencies were exacerbated by a substantial level of debt, accumulated over several years. A financial recovery plan was formulated and it resulted in further reduction of staff through redundancies.

In 1989, the Prime Minister of Australia had committed the Australian government to the development and adoption of national strategies of ecologically-sustainable development. Following this commitment, nine Working Groups, each relating to a sector of the Australian economy, and several Intersectoral Groups were established, to report to the Government on suitable strategies and practical means for their implementation. The Division was directly involved in the development of strategies through the participation of K.E. Lee as Convenor of the Intersectoral Group on the Conservation of Biodiversity as it relates to Sustainable Development. Other members of staff contributed to the findings of many of the Working and Intersectoral Groups. By the time of Dr Swift's appointment these Working Groups' recommendations were completed. It was an opportune time, following on from the development of the recovery plan, to look ahead and to prepare a strategic plan for the Division's research.

The strategic plan was based on an evaluation by the Division's staff and major clients of the Division's current work and its research opportunities and priorities, and it outlined objectives and strategies for the period 1995-2000. It recognised that although the development and use of land has played a major role in shaping contemporary Australia, some production systems have resulted in damage to the soil. The role of the Division was to help to arrest and reverse these effects and to ensure, as far as it was able, that the production systems used should be sustainable in the long term. While soil management practices that promote sustainable farming systems should continue to be a major area of research for the Division, the plan proposed an equally significant commitment to work related to land rehabilitation and ecosystem reconstruction, with particular emphasis on the mining industries.

Following on from the preparation and adoption of the strategic plan, a Divisional Business Planning Workshop identified priority research areas, and within the framework thus defined, program managers and managers of support areas prepared an integrated Business Plan for the Division. The plan identified priority research areas, within which research projects were grouped to define eight research themes, as follows:

- sustainable soil management for plant production systems;
- indicators of soil health and quality;
- production of contaminant-free food;
- sustainable disposal of waste on land;
- management of coastal zone soils for urban and tourist use;
- environmental repair and rehabilitation;
- sustainable soil management for catchment care;
- improved methods for land resource assessment.

From about the beginning of the 1990s there was increasingly an expansion in collaborative projects with other CSIRO Divisions: Multi-Divisional Projects (MDPs) and with Cooperative Research Centres (CRCs).

A Divisional project had been established by A.R. Milnes to provide advice to Energy Resources Australia, owners of the Ranger uranium mine at Jabiru in the Northern Territory, aimed at the environmentally-acceptable management of spoil heaps and tailings dams. This project led, in 1987, to the establishment of a Minesite Rehabilitation Group, including staff from Divisions of Soils and Water Resources, with Milnes as Group Leader. Rehabilitation techniques at the Ranger Mine included a study of a revegetation project at Gove, in the Arnhem Land region of the Northern Territory, where selective planting had resulted in the establishment of plant communities closely similar in structure and composition to local native forest; similar techniques were successfully extended to waste deposits at the Ranger mine.

Further consultancies, with Ranger and with other mining companies, underpinned the growth of the Group, which progressively involved contributors from all of the Division's disciplinary groups and from other CSIRO Divisions. This led in 1992 to the establishment of CSIRO Minesite Rehabilitation, an MDP offering multidisciplinary research for mining and environmental management, with scientific input from seven CSIRO Divisions. A.R. Milnes was the leader of this unit until he left CSIRO in 1996, and his place was then taken by P. Maconochie of the Division of Exploration and Mining, based in Brisbane.

An MDP was initiated on the conservation of biodiversity in Australia, involving divisional staff with staff of CSIRO Divisions of Entomology, Forestry, Plant Industry and Wildlife and Ecology. The Division's contribution to this program was to examine the impact of land-use practices on the activity and biodiversity of selected groups of soil organisms. It included the development of DNA probe and FAME (fatty acid methyl ester) techniques to characterise soil microorganisms.

Another MDP in which many Divisional staff became involved is the CSIRO Land and Water Care Program, in which the Division's role has included work to resolve soil production and protection problems, management techniques best suited for wheat growing on poorly structured soils in south-eastern Australia, a project in north Queensland in which soil and landscape information is combined with remote sensing data to predict areas that are likely to become saline if trees are removed, and an associated program funded by the Murray-Darling Commission on the prediction of soil properties using digital elevation models and remote sensing.

The use of limited field information for accurate assessment of the suitability of land for various uses remains a major scientific challenge. The Australian Collaborative Land Evaluation Program, coordinated by Divisional staff and supported by the CSIRO's Land and Water Care Program, addresses this problem and works closely with all the relevant State, Territory, and Federal agencies. The Division's input has aimed to develop new technologies for the prediction of soil properties at resolutions useful for land planning and management, to provide a coordinated and technically sound approach to soil survey and land evaluation in Australia. Several new protocols aimed at standardising soil databases, and a new soils software package, pcSITES, with full documentation, have been developed and distributed.

In 1996-7 R.W. Fitzpatrick and D.J. Reuter began a new project on soil indicators for land health in rural catchments, as part of a CSIRO Multidivisional Program on dryland farming systems for catchment care. They were major contributors to a book, *Indicators of Catchment Health: a Technical Perspective*, and to a national workshop where the book was evaluated for its practical use. The same two scientists are collaborating with scientists of the Chinese Academy of Sciences in an ACIAR-funded project that aims to define indicators to predict and manage risks of waterlogging, salinity and sodicity in two regions of China and three regions of southeastern Australia. It is planned to use hydro-pedological indicators, models and remote sensing to scale up and extrapolate site-specific data for regional analysis.

In Western Australia the Division's work has included a joint project with the State's Department of Agriculture that aims to develop a computerised soil-mapping system based on remote-sensing techniques that will predict the risks of acidification and soil structural decline in wheat producing soils. The system was tested in the 25,000 ha Yornaning catchment, where it proved more accurate than the best conventional maps. The availability of ground positioning systems, using a satellite network to accurately fix positions on the ground, integrated with the new techniques of soil mapping, has raised the possibility that soil management could be matched to accord with soil variation within paddocks. The idea has stimulated keen interest among farmers, and experimental sites have been established at three sites under lupin, barley and wheat in Western Australia, to pursue this possibility.

A variety of collaborative projects, involving inputs from staff of the three Divisional research programs, were developed with the CRC for Soil and Land Management in Adelaide; CRCs for Tropical Rainforest Ecology and Management, for Sustainable Management of Tropical Savannah, and for Sustainable Sugar Production, in Townsville; and the CRC for Catchment Hydrology in Canberra. An indication of the resources contributed by the Division to CRCs is evident in the commitment for the 1995-96 financial year to the CRC for Soil and Land Management in Adelaide of $1.33 m of the Division's funding, including inputs of staff time equivalent to 6.5 full time scientists (involving 17 individual scientists) and 6.5 full time technicians, in support of all four of the CRC's research programs.

In Australia's agricultural lands, farmers are increasingly facing problems of increasing acidity, sodicity, and deterioration in soil structure. Staff of the Division, in collaboration with staff of a number of other organisations in South Australia, Victoria, New South Wales and Queensland, have done soil analyses that show that acidification is a widespread and serious problem, especially in temperate regions of Australia, except where lime or other alkaline materials have been applied. Research has also been done on methods for measuring sodicity and structural decline and a significant outcome has been the development of a new technique for assessing the effect of agriculture on the stability of microaggregates in soils.

A major contribution of the Division to the CSIRO Coastal Zone Program has been in collaborative work on the identification, description, monitoring and methods for the management of acid sulphate soils. These soils are widespread in coastal zones and development projects that have led to exposure of ground water or runoff to contamination from underlying acid soil horizons have resulted in serious environmental damage, including massive fish kills in northern New South Wales and southern Queensland. The Division's contributions have included a lead role in establishing a network of reference sites, collection and interpretation of information for a database on coastal soils, and the development, in collaboration with Dr David Dent of the University of East Anglia, of a new expert system for assessing the risk posed by acid sulphate soils.

Common agricultural practices can sometimes result in accumulation of heavy metals or toxic chemicals in soils and plants. For example, long-term use of superphosphate has, in some cases, resulted in accumulation of cadmium, which is present as an impurity in the superphosphate. The Division's chemists investigated how trace elements, soil types, crop rotations, alternative farming methods and other factors have affected the amount of cadmium found in wheat grains and leaves. Similar research was undertaken into cadmium intake by potatoes, and the association between soil lead and lead content of grape varieties. Other work included research into soil contamination by arsenic and DDT around former cattle and sheep-dip sites, chromium from tannery wastes and, in collaboration with the CRC for Soil and Land Management, into the mobility of heavy metals in rural and urban soils. The work on tannery wastes has expanded to include a project, led by R. Naidu and funded by ACIAR, on large-scale pollution by tannery wastes in soils in India.

Using municipal sewage effluent to irrigate tree crops could help to alleviate two major environmental problems - sewage treatment and shortage of good land for plantation timber. An area of concern with using sewage effluent for irrigation is that heavy metals and nutrients may leach from the irrigation water to contaminate the water table. The Division's Canberra staff have been a major participant in a project based at Flushing Meadows, near Wagga Wagga in New South Wales, to test whether irrigation of trees with effluent is a sustainable practice. By tagging nitrogen in the effluent with the isotope ^{15}N, movement in the soil of this nitrogen could be traced. It was shown that, especially in winter months, much nitrogen from the effluent was leached down towards the water table rather than being taken up by plant roots or released into the air through denitrification processes in the soil.

Test wells were drilled at the Flushing Meadows site and it was shown that the water table, originally 10 metres deep, had risen to be as shallow as only 1.2 metres under one experimental plot. Irrigation practices were changed to alleviate this problem. At two other sites, at Canberra and Wodonga, where irrigation with effluent had been practised for four and 17 years respectively, it was shown that the level of contamination for six heavy metals was within the natural background range for Australian soils, and that it could take 50 or 100 years of continued irrigation before heavy metal contamination was likely to become an environmental concern.

The Division's mineralogists, over many years, developed a high level of expertise in the study of clays, and this has been applied to investigate major clay deposits, mainly in South Australia, and to match specific clay deposits to high-value niche markets. This research has, for example, revealed high-quality deposits of kaolinite clays, for applications in ceramics and paper making; of halloysite, for refractories; and of smectite which, following modification with some commonly-available chemicals, can be used to absorb organic contaminants from water. Progress was also made in making the clay magnetic, so that it can easily be separated from water along with the absorbed organic contaminants. A new infra-red process, suitable for commercial application, was developed for distinguishing kaolinite from tubular halloysite.

Work on mycorrhizal fungi associated with tropical trees was continued by a small group led by P. Reddell at the Townsville laboratories, and subsequently moved to the CSIRO Forestry Division's Tropical Rainforest Research Unit at Atherton, in northern Queensland. Glasshouse trials showed that many high-value tropical timber trees are highly dependent on associated mycorrhizal fungi and that early growth of young trees can be significantly boosted by inoculation with suitable mycorrhizal species. Research funded by the Wet Tropics Management Authority examined the mycorrhizal associations of 30 native tree species and led to recommendations on how the fungi might be used to help forest rehabilitation. Another study on mycorrhizal fungi in five different rainforest communities at different altitudes on northern Queensland's Windsor Tablelands showed a strong relationship between soils, roots and the fungi, with trees growing on the least fertile soils having the highest density of roots and the most mycorrhizal fungi.

In 1993 a large multidisciplinary team within the Division began a six-year joint program with the Sugar Research and Development Corporation and the Bureau of Sugar Experiment Stations to investigate the problem of widespread decline in Australia of yield of sugarcane. This team's aim was to identify soil-related factors that affect the productive capacity of the cane and to advise on the development of soil management strategies that would promote sustainable production. A survey was undertaken at a series of 'old land' and 'new land' sites to monitor crop growth and changes in chemical, physical and biological properties of soils that relate to long-term monoculture of sugarcane. The survey showed that the soils at 'old land', relative to 'new land' sites were more affected by soil acidity, had lower organic matter content and reduced microbial biomass, and commonly exhibited high soil strength, presumably due to compaction. Sugarcane grew more prolifically and produced more stalks on 'new land' than on 'old land', but the differences were not always evident in yields at harvest. The research is continuing, with studies of more specific soil and crop-growth factors associated with yield decline.

Soil organic matter is a major sink for carbon on a global scale, holding two or three times that held in the earth's atmosphere. Soil degradation results in the transfer of soil carbon to the atmosphere as carbon dioxide, thus contributing to the greenhouse effect and the possible acceleration of global warming. Reversing soil degradation results in movement of carbon from the atmosphere to the soil, so research on the cycling of organic matter and nutrients through the soil has assumed a new importance that stimulated research in the Division, led by J.O. Skjemstad, on the movement of carbon and nitrogen through Australian soils. An early finding in this research was that carbon that is estimated by chemical analyses of Australian soils exists partly as charcoal, probably the end product of bushfires and, in this form, unavailable to plants. In Australian soils that have been cultivated for more than 25 years charcoal accounts for most of the measured organic carbon, and this has tended to disguise the very low fertility of many Australian soils.

Research Support Groups

This brief history has dealt primarily with the activities of the research staff, whose quality of work and ideas and willingness to apply their knowledge to the solution of practical problems gave the Division an outstanding reputation in the Australian community, while at the same time assuring its recognition as one of the world's leading soil research institutions. A major reason for the successful outcome of many of the research projects and application of their findings to practical problems has been the quality of research support staff.

From the beginning, the Division has been fortunate to have had highly-motivated technical support staff, most of whom were recruited as school-leavers and were trained 'in house'; many stayed and developed their skills for periods of 20 years or more. Technicians were often associated for long periods with the same research scientist, so that they became highly expert in the technical support that underpinned that particular scientist's research and often contributed valuable ideas to research projects. Many also achieved university degrees and successfully made the transition from the status of technician to that of Experimental Officer (later known as Experimental Scientists), while a few progressed to join the ranks of Research Scientists. In the later years of the Division's history, with more school-leavers continuing their education at universities or other tertiary institutions, some technicians had achieved first degree or diplomate qualifications before they joined the Division.

The technical staff included not only technicians who directly supported scientific projects but, as time went by, a substantial number who provided support for the Division's research in specialist Research Support Laboratories.

Analytical Services

Until the 1960s, soil survey work dominated the Division's scientific program. In the earliest years, the pedologists, as well as mapping and sampling soils in the field, did their own analytical work. Subsequently, soil samples were sent to Adelaide for analysis, but as regional offices were developed, chemists were appointed and, although they were encouraged to pursue their own research projects, they were also responsible for the provision of soil analyses and advice on soil chemistry in support of the pedologists. Much of the chemists' research during these years was concerned with the development and refinement of analytical techniques to improve the quality of analytical support. Technicians were appointed to assist the chemists in both the research and routine analysis aspects of their work, and some of them became increasingly involved in routine analyses of soil samples.

As time went by and the demands for analytical and other research support services grew, groups of technical staff were designated in each of the Division's laboratories, with the specific responsibility of providing these services.

Adelaide

Analytical Chemistry

Preparations for the International Soil Science Congress in Adelaide in 1968, which included the completion and publication of the *Atlas of Australian Soils* and the *Handbook of Australian Soils*, together with the establishment in 1965 of the National Soil Fertility Project (NSFP), resulted in a great increase in demand for analytical services. In 1966, a subsection of Routine Analytical Services (RAS) was established, at first supervised by R.D. Bond and subsequently by A.R.P. Clarke, and by 1968 seven additional technicians had been appointed to satisfy the demand for analyses. This demand stimulated investigation of methods that would speed up the analyses.

S. McLeod, from the Adelaide analytical group, was attached to B.M. tucker and they developed a technique for the simultaneous measurement of pH, electrical conductivity and chloride in soils. Equipment necessary for this technique was made in the Division's workshop in Adelaide and sent to each of the regional laboratories. H.C.T. Stace and McLeod then collaborated with Walsh and Sullivan from the Division of Chemical Physics and developed methods for the use of atomic absorption spectroscopy (AA) in soil analysis. At this time autoanalysers specifically designed for soil and plant samples were not commercially available but equipment could be developed from a range of modular units.

In 1969 J.Keay, a chemist in the Division's Perth laboratories, developed a continuous flow analyser for determining phosphorus and nitrogen in soil and plant samples; Hallsworth recognised the potential of such techniques and McLeod was assigned to work again with Stace to develop, in collaboration with the Adelaide workshop staff, a more versatile autoanalyser. By 1970 their efforts resulted in a facility that became known as the autolab; it could simultaneously determine six constituents from a suite of 14, at a rate of 30 soil or plant samples per hour. Smaller versions of the same equipment were built in the Adelaide workshop and by 1972 these were installed in the Division's Brisbane and Townsville laboratories.

With a steadily reducing soil survey component in the Division's research and the winding back and conclusion of the NSFP, the RAS was increasingly involved in support work for research in the other Research Sections. By 1975 some of the RAS technical staff had moved to directly support the chemical research projects of Tiller, Cartwright and Merry. The original autoanalysers were eventually replaced by purpose-designed equipment produced by scientific supply companies; the original Adelaide facility was in use for 15 years and produced more than 20,000 analyses per year.

Following the death of A.R.P. Clarke in 197A the Adelaide RAC was managed by McLeod until the appointment in 1979 of A. Beech to supervise the analytical service; the RAC was renamed the Analytical Chemistry Unit (ACU) and became independent from the Chemistry Section. Services provided by the ACU expanded to include ICPS analysis, ion chromatography, total and organic carbon, physical analysis and surface area measurement. In 1997, when the Division was incorporated into CSIRO Land and Water, these services continued to be provided by the ACU.

Inductively Coupled Plasma-Atomic Emission Spectrometry (ICPS)

The first ICP spectrometer in the Division was installed in the Adelaide laboratories in 1979. This was new technology and the instrument was only the fifth ICPS in Australia. Its initial purpose was to provide `ground truth' analytical data on soil and plant samples for what was then known as the Eyre Peninsula project, which had as an aim to use aerial photography to establish infra-red spectral signatures of poor crop growth. The capability of the ICPS to simultaneously determine, quickly and accurately, up to 32 elements in one digest solution, made it the instrument of choice for this project.

The instrument was commissioned by B.A. Zarcinas, to whom fell the task, which occupied much of his time for about 18 months, of establishing the instrument's capabilities for soil and plant analyses. Zarcinas collaborated with the manufacturers, Labtest, in Melbourne, who made many modifications to the design of the spectrometer, the nebulisation system, electronics and software, on the basis of his advice. At the same time, as he learned to use the ICPS effectively, he added much to the literature on soil and plant analysis, and was called upon to give advice on procedures and analytical techniques to government and industrial organisations in Australia and elsewhere, who wished to make use of the ICPS technique.

When the instrumental problems were overcome and appropriate soil and plant digest and soil extraction matrix techniques had been developed and calibrated, the ICPS became the most versatile and most used of the Division's elemental analysis instruments. Zarcinas's development of appropriate techniques made it possible for the ICPS to evolve from use by a specialist operator to a general purpose analytical facility with a number of operatives, in the same way as atomic absorption spectrometry had progressed in the Division about 10 years previously.

X-ray Spectrophotometry

Techniques of X-ray diffraction (XRD) for determining the clay constituents of soils, and X-ray fluorescence for chemical analysis had been developed in the Mineralogy Section by K. Norrish and E.W. Radoslovich, and these were made available during the 1960s as a service and were widely used in many research projects. The XRD service was provided by J.G. Pickering until he left the Division in 1986, and then by P.G. Fazey, while the XRF service was provided by M.D. Raven.

Brisbane

A routine chemical analytical service was first established at the Brisbane laboratory in 1949, when R. Reeve was appointed to carry out chemical analyses under the supervision of A.E. Martin, `in support of the field program'. Reeve was joined by J. Cox in 1950, and when Cox left in 1953 his place was taken by H.J. Beatty; Beatty was transferred to the Division's Canberra laboratories in 1956. From 1957 to 1962 R.S. Beckwith was in charge of the routine laboratory and he was followed by Reeve who, with one technician, then from 1965 with J.O. Skjemstad as an additional technician, continued the analytical service.

During this period the laboratory provided analytical services for a number of large soil surveys, including the Burdekin survey, NW Estates survey, Darling Downs and regional survey, and the Boonah/Beaudesert, Brigalow, Munduberra/Gayndah and Beenleigh surveys, and data for the sites that were included in excursions related to the ISSS Congress in 1968. Apart from routine soil and water analyses, using classical methods, the laboratory staff contributed chemical skills to a variety of research projects and Reeve had his own project on the chemistry of surface waters.

In 1974 control of the routine laboratory was assumed by Skjemstad, and in the same year an Adelaide-designed and constructed autolab was installed. J. Dellaway, who had joined the laboratory as a technician in 1969, moved out in 1977 to establish an electronics laboratory in support of Brisbane research projects. The Cooloola project began in 1974 and continued until 1984; samples associated with this, together with those from major surveys at Narayen and Narrabri, were the analytical laboratory's main undertakings right through to the closure of the Brisbane Regional Laboratory in 1988.

During 1967 an X-ray diffraction service facility was established in Brisbane. This was associated with the appointment of R. Gilkes as a research mineralogist, and he and J. Drinnan, who was appointed as a technician, provided service until they both left the Division in 1971. Gilkes was replaced by A. Veen, but he left In 1972. An XRF/XRD service, without its former research component, was then set up, with two technical staff, J. Drinnan and D. Williams, who continued to provide this service until the closure of the laboratory in 1988.

Canberra

H.J. Beatty moved from the Brisbane laboratories to the Canberra laboratories in 1956, to provide analytical support for the region's projects. Prof. A. Wild, a visiting scientist, headed the analytical group until he left in 1958, and his work on phosphorus in Australian soils generated many samples for the group. An additional technician was appointed to the group during that time. After Wild's departure, phosphorous analyses continued as a substantial part of the group's work, as J.D. Colwell continued work on soil and plant Phosphorus. P. Colwell became head of the Canberra soil chemistry group In 196O.

In the mid 1960s a commercial automatic segmented flow analyser was purchased to cope with the increasing demand for analyses, much of which was generated by the Canberra laboratory's participation in the National Soil Fertility Project. This was the first such instrument to be installed in any of the Division's laboratories and it generated much initial work for Beatty to change and check the previously used colorimetric methods for soil, plant and water analyses and to calibrate them against the new autoanalysis methods.

From 1967 to 1972, when the NSFP work was at its maximum, this project generated a huge number of analyses on top of those required for other projects; two additional technicians were appointed to handle the extra work load.

Up to 1971 the analytical services were managed as a part of the Chemistry Section, but in that year A.E. Martin, who was then acting-Chief of the Division, separated the analytical service group to establish a separate unit, with Beatty as its head and two technical assistants. At this time the unit expanded its scope to include particle size analysis as well as chemical analyses of soil, plant and water samples.

After the NSFP work concluded, the analytical unit was involved in the support of a variety of projects, especially the determination of cations in soil and water samples. The unit's equipment was upgraded in the late 1980s with the purchase of new instruments for atomic absorption spectrophotometry and automatic carbon analysis. These instruments allowed the calculation of results to be done automatically by computer, so that the output, efficiency and accuracy of results were increased. In the early 1990s the efficiency of the laboratory was again boosted by the installation of a new segmented flow analyser, capable of more accurate and faster analyses, with computer control of the whole analytical process; identical instruments were installed in the analytical service laboratories in Townsville and Adelaide, and it was then possible to check analyses and so to standardise results across the Division's analytical facilities.

Beatty retired in 1995 and the Canberra analytical unit was disbanded in 1996. Research staff then resorted to doing their own analyses or to sending samples to Adelaide, where the analytical services of the Division were concentrated.

Townsville

B.J. Crack, who was the first chemist appointed (in 1963) to the Townsville laboratories, established a RAS facility, staffed by two technical assistants. In 1968 G. Gillman was appointed to manage the RAS, and it was engaged for some years largely in processing the thousands of samples that were generated by reconnaissance surveys for the Atlas of Australian Soils project.

When new laboratories were built for the Townsville staff, in 1974, a new RAS laboratory was included and its facilities were augmented by the installation of a Stace/McLeod auto analyser that was built in the Adelaide workshop. Gillman moved more into research and the laboratory was managed for about two years by P. Bakker, until the appointment of W.S. Hicks as manager in 1984. The emphasis of the laboratory's work changed through the remainder of the 1980s, away from the processing of soil survey samples into the support of process studies in soil biology and physics. The work was done in close association with the research scientists and the laboratory took on an in-house consultancy role as well as continuing to provide analyses.

By the early 1990s the laboratory's focus changed again with a greater emphasis on environmental analytical chemistry. The purchase of a segmented flow analyser allowed the development of measurement of nutrients at levels in the low parts per billion. In 1995 a new, purpose-built integrated analytical laboratory was opened and this provided a high level of efficiency in work flow. During this period Divisional policy removed the laboratory from any role in research and placed it in competition with other consulting laboratories. S.D. Farr became the laboratory's manager and her role changed from that of a consulting analytical chemist to that of a resource manager.

Workshop Services

Innovative research often depends on the development of innovative instrumentation. Scientists may themselves design and build equipment and, all through the Division's history, there have been scientists who have built or at least contributed to the building of equipment to facilitate their research. Their efforts have ranged, for example, from modifications of simple soil sampling equipment to the construction of complex instrumentation such as the first X-ray spectrophotometer used in the Division. Well-equipped workshops were provided, first in Adelaide and later in Canberra and Townsville, to support the Division's research.

In Adelaide during the 1960s and 1970s there were up to seven workshop staff, for many years ably led by A.W. Palm. They provided expertise in instrument making, electrical and electronic work, welding, woodwork, the use of plastics, and their high levels of ingenuity and imagination could take the ideas of a scientist and produce elegant instrumentation that would enable the ideas to be translated into practical experiments. As a notable example of their achievements, the design and construction of the first autolab, largely by C. Eickhoff with the technical collaboration of S.McLeod, greatly increased the capabilities of the Adelaide routine chemical analysis laboratory. Further work by these two resulted in the construction and installation of similar autolab facilities in the Brisbane and Townsville laboratories. Much of the field equipment used in the National Soil Fertility project was designed and built in the Adelaide workshop.

Photo 20 Andy Palm (left) and Ken Farley test the 'Palm' seeder at the Waite Institute in the early 1950's

Workshop facilities were provided in the Division's laboratories outside Adelaide and though there were, from time to time, workshop staff who were available to help the scientific staff, the facilities were used mainly by the scientific staff themselves.

Changing emphases in the research programs and the increasing availability of ready made equipment from laboratory supply companies and the increasing sophistication of equipment with the increasing use of computer-managed control systems led, through the 1980s and 1990s, to progressive reduction in the need for in-house development of equipment. G.J. Blows came to the Division in 1990 to take charge of the Adelaide workshop, and in the last few years of the Division's existence many of the older members of the workshop staff retired and were not replaced.

Draughting and Publications

From the foundation of the Division in 1927 until about 1964, the main emphasis of the scientific work was on the mapping and classification of Australian soils. An essential part of this work was the preparation of soil maps. Among the first appointees to the Division after its foundation was P.D. Hooper, a draughtsman who prepared the maps that accompanied the first soil survey publications and continued to manage a small group of highly-skilled draughtsmen, until his retirement in 1960, when his place as senior draughtsman was taken by M.C. Coulls.

During Coulls' time as head of the group its responsibilities were expanded and it became the Publications Section, responsible for the preparation not only of soil maps but for the preparation of all manuscripts for publication in the scientific literature and for all other Divisional publications. Coulls left the Division in 1971 and was replaced by D.W. Wright, who had already served for some years as a draughtsman in the Division. Wright continued as head of the draughting group and supervisor of the preparation of publications, initially on his own but later under the overall supervision of H.L. Webster. Wright retired in 1996.

During Hooper's period with the Division and for some 30 years after, soil boundaries were plotted by pedologists in the field onto land survey maps and from these field sketches, using land survey maps as initial outlines, soil maps for publication were prepared by hand by the Division's draughtsmen. The draughtsmen displayed high levels of drawing skill and meticulous attention to detail in the preparation of the soil boundary outlines and colour separations that were required for publication.

There was not much change in methods until about the early 1960s, but from that time onward change was continuous and ever accelerating. The Division's draughting staff was quick to adopt and master new techniques as they became available. Much of their work was now done by photography and methods were developed for the preparation of high-quality slides to illustrate conference papers and other presentations, word-processing machines replaced typewriters in the preparation of manuscripts, and were themselves replaced by personal computers.

Sophisticated computer-based draughting programs became available and were continuously upgraded. There was increasing demand for posters for presentation at scientific conferences and the draughtsmen became expert at their design and preparation, first creating montages with photographs and printed text, then making use of colour copying machines to produce even more sophisticated posters. Desktop publishing and offset printing were adopted and used to produce high quality in-house publications. J.A. Coppi was appointed to the group in the 1970s as the Division's photographer, and like the draughting staff, he mastered many complex techniques and consistently produced photographs and slides of the highest quality.

These are only some of the many techniques that the draughtsmen mastered and made available to the Division's scientists. The success of the Draughting and Publications group resulted from the consistently high quality of the staff it attracted throughout its history. As an example, the combined efforts over the most recent 25 years of D.A. Wright, R.M. Schuster, G.E. Rinder and J.A. Coppi were responsible for the constantly improving and widely recognised quality of the Division's publications and presentations at national and international scientific conferences and meetings with industrial supporters of the Division's scientific work.

Communications

Increasing pressure on CSIRO to explain its research and its relevance to the Australian public and to promote communication within the organisation resulted in the appointment of K.A. Handreck, in 1974, in a dual capacity as technical secretary to the Chief and Divisional Information Officer. His most notable contribution as Information Officer was in the writing and publication, beginning in the late 1970s, of a series of nine booklets under the general title 'Discovering Soils'. These booklets brought many practical aspects of soil science to a wide audience that included home gardeners, horticulturists and others with no specialist knowledge. Their success is evident in that more than 1,000,000 copies of the booklets have been sold since publication began, making them by far the best selling of all CSIRO publications.

Handreck continued in the two roles until 1987, but after the retirement (in 1983) of A.E. Martin as Chief and his replacement by D.E. Smiles, the Chief's office was transferred from Adelaide to Canberra. Handreck stayed in Adelaide and he became increasingly involved in research on plant-potting media and other aspects of the growth and nutrition of nursery plants, a field in which he established a leading reputation and received strong support from the Australian horticultural industry. It was then decided that Handreck should be allowed to work full time in his new field and that the ever-increasing pressure on CSIRO to deal more directly with the public demanded the appointment of a full-time information officer with qualifications specifically suited to that task.

H.L. Webster was appointed to the Adelaide staff in 1987, initially as Information Officer to develop the Division's public relations, but her role was quickly expanded to include responsibility for administration of the Division's publications group, the library, and for the coordination and timely submission of applications for research grants. Her responsibilities were further extended to include assistance to the Chief and the Divisional Management Committee in the preparation of policy documents, the administration of business aspects of the Division's activities and liaison with external business organisations, so that the group developed into a Communications and Business Development unit. This unit was largely responsible for the success of the Division in attaining a high level of financial support from external grant agencies.

Library

The Division's library, based in Adelaide but with close support provided to the other regional laboratories, has always been a great strength. Among those who have been librarians in charge over the years, P. Dawe and A. Symons stand out as ardent supporters of the Division's research; their keen acceptance and application of new technologies and their overview of the collections provided a high level of service to the staff. From an early stage, it was accepted as policy that the Division's library should provide the national reference collection of international soils literature. The librarians kept to this ideal, even when shrinking funds and the proliferation of journals and texts made it increasingly difficult to maintain.

The new buildings erected in the early 1990s on the Waite campus to accommodate the co-location of CSIRO, Waite Agricultural Research Institute, and South Australian Research and Development Institute and Department of Primary Industries included a central library complex for the campus. The Division's library was rehoused in this complex, although it retained its identity in a special section of the new building.

Photo 21 David Smiles congratulates Librarian Anne Symons at the opening of the new CSIRO Division of Soils Library, February 1988

Administration

The Division has also been well served by its administrative staff, who have kept the support of the scientific work as their prime objective. In particular it is appropriate to record the long and conscientious service of two of the Division's senior administrative officers, F.W. Blanksby who served in that capacity from 1939 until the mid 1970s, and J.B. Sleigh, from the late 1970s until 1994.

Appendix 1 - CSIRO Land and Water predecessors

CSIRO Centre for Irrigation and Freshwater Research 01/07/1987 - 31/12/1987

CSIRO Centre for Irrigation Research 01/06/1982 - 31/05/1987

CSIRO Division of Irrigation Research 01/01/1967 - 31/05/1982

CSIRO Division of Water Resources Research 27/04/1987 - 31/12/1987

CSIRO Division of Groundwater Research 01/06/1982 - 26/04/1987

CSIRO Division of Land Resources Management 29/03/1973 - 31/05/1982

CSIRO Rangelands Research Unit 01/07/1971 - 02/09/1973

CSIRO Division of Water and Land Resources 01/06/1982 - 26/04/1987

CSIRO Division of Land Use Research 01/07/1973 - 31/05/1982

CSIRO Division of Land Assessment 29/03/1973 - 11/04/1973

CSIRO Division of Land Research 02/09/1965 - 28/03/1973

CSIRO Division of Land Research and Regional Survey 01/01/1957 - 01/09/196

CSIRO Division of Soils 01/09/1929 - 1997

Centre for Environmental Mechanics - 01/07/1971 - 31/12/1987