FOWLERS GAP ARID ZONE RESEARCH STATION

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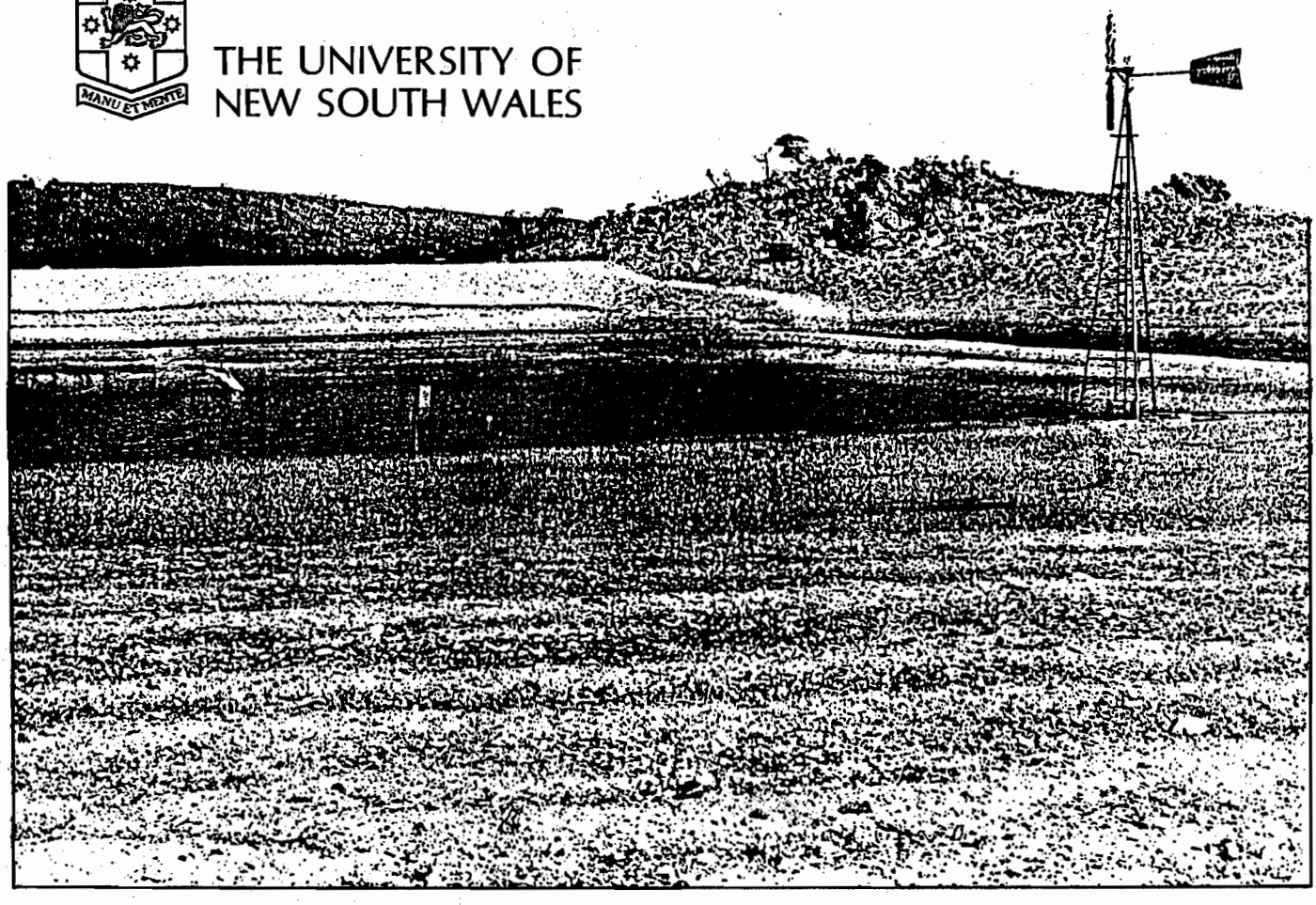
RESEACH AND RELATED ACTIVITIES 1966-1983

THE UNIVERSITY OF NEW SOUTH WALES



FOWLERS GAP ARID ZONE

RESEARCH STATION

RESEARCH AND RELATED ACTIVITIES

1966 - 1983

Compiled and Edited
by Rell Hannah

University of New South Wales 1984

A detailed Annual Report is submitted to the N.S.W. Minister for Lands.

The following Report identifies the research activities which have been undertaken at the Station over the last 17-18 years. It has been compiled with the assistance of researchers whose co-operation is much appreciated. Particular mention should be made of the Soil Conservation Service which provided a comprehensive report of S.C.S. projects at Fowlers Gap, included herein under category 33 (ppl29-154).

R.M. Golding,
Pro-Vice-Chancellor.

November, 1984.

PREFACE

Fowlers Gap Arid Zone Research Station is located 112km north of Broken Hill, New South Wales (latitude 31°S, longitude 42°E) in the Parish of Hulme, County Mootwingee. Occupying Western Lands Lease No. 10194, an area of 38,888 hectares, the property is held by the University of New South Wales as a "lease in perpetuity" for the purpose of study of the arid zone environment and its effects, particularly in relation to the pastoral industry. It is the only research station in the arid zone of New South Wales and is the only research station in the winter-rainfall arid zone of Australia. Areas have been monitored and data collected continuously, in some cases for over 30 years. The Station and its records form a unique facility for research and education.

The University of New South Wales, in taking over the lease, undertook not only to carry out research for its own use on the property but to also provide facilities for any reasonable research programme which might be proposed by other authorities, including government or university organizations. Research has been conducted by various schools/units of the U.N.S.W. including: Applied Geology, Botany, Zoology, Civil Engineering, Geography, Surveying, Wool and Pastoral Sciences, Architecture and the Centre for Remote Sensing. A number of other tertiary institutions have also conducted investigations at the Station, chiefly Macquarie University, the University of Sydney, the University of New England and Melbourne University. Government and government organizations which have utilized the facilities include the Soil Conservation Service, the CSIRO, and the N.S.W. and South Australian Departments of Agriculture. Amongst the funding bodies which have provided financial assistance for research projects at Fowlers Gap are the Australian Research Grants Scheme, the Wool Research Trust Fund, the Rural Credits Development Fund, the Water Research Foundation of Australia, the Australian Housing Research Council and a number of overseas governments and universities.

In addition to its use for formal research, Fowlers Gap is used for student field excursions from tertiary and other educational institutions. The Station also attracts many visitors from overseas and within Australia and has been the subject of television documentaries and newspaper articles.

The Field Station is administered by a Management Committee consisting of representatives from the U.N.S.W. Schools which use the Field Station. This committee is assisted by two advisory groups - the Graziers Committee, comprising a small group of pastoralists who supply support and advice at an informal level and the Consultative Committee, an advisory group representing organisations of the pastoral industry.

A fulltime Officer-in-Charge supervises the day-to-day operation of the Station, assisted by six support staff.

Over $1m has been invested in buildings, fences, yards and water supplies to provide the facilities needed for research and education. The revenue from the sale of wool and sheep is used to meet the running costs of the Station.

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OF FOWLERS GAP STATION

Reprinted with permission and some editing from "Lands of Fowlers Gap Station New South Wales", Fowlers Gap Arid Zone Research Station Research Series No. 3. ed J.A. Mabbutt, U.N.S.W. (1973).

I. EXPLORATION AND EARLY SETTLEMENT

Patterns of exploration and early pastoral settlement in this area, as elsewhere in the Australian arid zone, were determined by the availability of natural waters, specifically the Darling River and the smaller and often ephemeral supplies along local drainage in the Barrier Range. These provided permanent bases from which activities could temporarily be extended into the adjacent plains after rains. The first European explorer in the area, Charles Sturt, who experienced drought conditions on his journey in 1844-5, followed the Darling River to the point that gave the shortest plains crossing to the southern end of the Barrier Range. He then moved northwards along the west side of the Range to Floods Creek, named after one of his party, where he camped for three weeks on a waterhole about 25 km WNW of Fowlers Gap.

From this point Sturt made a short journey across the plains to the east of the Barrier Range between December 13th and 16th 1844, and gave the first report on the condition of the country near Fowlers Gap. He wrote (Sturt, 1849) "immediately on the other side of the range, there was a plain of great width, and beyond, at a distance of between 50 and 60 miles, was a range of hills running parallel to those near the camp. The first portions of the plains were open, and we could trace several creeks winding along them, but the distant parts were apparently covered with dense and black scrub. Descending to the eastward towards the plain we rode down a little valley in which we found a small pool of water; at this we stopped for a short time, but as the valley turned too much to the north I left it". This may well have been Fowlers Creek. His general direction was ENE and at 12 miles out into the plains he "crossed the dry beds of several lagoons"; at 16 miles he "entered dense brush of pine trees, acacia and other shrubs in pure sand". This is consistent with a traverse from Fowlers Creek, across the line of claypans that includes Nucha Lake, and through the sand dunes in the east of the plains to the north end of the Bynguano Range, identified by Sturt with Mt. Lyell. The description of the plains country on the map that accompanies Sturt's journal is appropriate to the floodout of Fowlers Creek on The Selection across the northeastern boundary of Fowlers Gap Station: " .... plains lower than those W fall of Wr to N - plains swampy in winter with pools of water, now dry - grass on the plains tho' barren soil". Periodically he referred to "barren" areas, or to areas with "some grass".

Sturt traversed the area at the onset of drought, and the periodic spareseness of vegetation in the area before European settlement is confirmed by the fact that when Sturt returned southwards a year later, when conditions were excessively dry, he found that all bird and animal life had gone, and his horses and bullocks could barely find enough fodder to sustain their emaciated bodies. It can be concluded that even before any pastoral occupation took place, the lower pasture layers were scanty on the hills, that on the plains there were grassy areas interspersed with claypans, and that little herbage of value persisted close to natural waters during dry periods. The tree cover was probably much denser than now.

In the interval between Sturt's return in 1845 and the departure of Burke and Wills from Menindee in 1860, a line of pastoral stations was established along the Darling River frontage, a pattern to be strengthened by the advent of river boats on the Darling after 1859. Under the Waste Lands Occupation Act of 1846, the West Darling area formed part of the Unsettled Districts beyond the Nineteen Counties, in which squatting licences could be granted for "runs" capable of supporting 4000 sheep at an assessed stocking rate, but in 1851 the new land district of Albert was formed, comprising all of New South Wales beyond the Darling River north to the 30th parallel. Systematic surveys and allocation of runs began here in 1854 and grazing licences were apparently already being issued by 1850, but settlement continued to outrun the extension of administration in this remote area, and many of the early settlers who took up land west of the Darling did so without licences. The pastoral leases under the 1846 Act were mainly of 32,000 acres for up to 14 years, and there was no limit to the area that could be held by one man provided he held the land in runs of standard size and paid his assessment on the number of stock held on each. In the absence of proper surveys, this led to a good deal of land speculation by middlemen, and a tendency to occupy strategic sites such as waterholes and pockets of better-quality grazing land. Behind the river frontages, back blocks were taken up for temporary occupation after rains; for instance Kinchega Station near the present-day Menindee extended back towards the Barrier Range along Yancowinna Creek and its soakages.

It was in the decade after 1860 that the main movement west of the Darling took place. By this time most of the frontage country had been secured, there was the additional attraction of good reports of pastoral potential from the parties which followed Burke and Wills in 1861-2, and also the stimulus given by the threat of selection in areas further east under the 1861 Crown Lands Occupation Act, which allowed the taking up of pre-emptive leases and small freeholds on land held on pastoral runs. Already before 1870, pastoralists had been exploring the country west to the Barrier Range, which was itself an avenue for travel northwards. For instance when Crawford journeyed to the Grey Range in 1859, chiefly with a view to the discovery of minerals, he found evidence of journeys in the area south of Fowlers Gap by pastoralists from the Darling stations. Among these pastoralist explorers were Wright and Stone, who later accompanied Burke and Wills, and a Robert Gow who was engaged by the Victorian pastoral firm of Clough and Co. to look for pastoral lands

west of the Darling, and who in 1861 travelled up Stephens Creek with local men and reported on the Corona area, where scrub cattle and wild horses were found.

The 1863-4 season was particularly favourable for pastoral expansion west of the Darling, for good local rains encouraged occupation of the back blocks at the same time as the exceptional flooding along the Darling frontage caused problems there. The first stocking of pastoral runs near Fowlers Gap dates from this time. In the south the Mt Gipps run, close to the main Darling settlements and favoured by soakages and waterholes along Stephens and Yancowinna Creeks, was taken up and stocked. A Darling River squatter, George Urquahart, was the first to travel sheep into this area. Further north, Abraham Wallace brought 1400 sheep across the Barrier Range from South Australia and took up Sturts Meadows on Caloola Creek, probably the first pastoral utilisation of the Fowlers Gap country. At first Wallace's settlement was nomadic only, and in times of water shortage he had to leave the area and move to water at Bancannia or Cobham Lakes, or even further afield. It was not until 1871 that a homestead was built at Sturts Meadows, by which time a flock of 18,000 sheep occupied the run. To the west and north Corona was also occupied in 1863-4 on behalf of Clough and Co, with Robert Gow as manager. It can be assumed that all the easily-watered country in the area of Fowlers Gap had been taken by 1870, even if not effectively occupied. At this time there were no man-made waters, and sheep were shepherded as protection against the dingo. There are many reports of attacks by aborigines on the first stations, including one on Corona in 1867.

II. EARLY PASTORAL DEVELOPMENT

The philosophy behind the 1861 Crown Lands Occupation Act and its subsequent amendments was that the "natural" carrying capacity of the land - already held over-optimistically as one sheep to between 9 and 10 acres - could be raised further through the provision of improvements such as fencing and watering points, and by "judicious stocking" and consequent trampling of the ground. The enormous areas of pastoral runs west of the Darling, large parts of them only temporarily occcupied, represented a challenge to this view and its aim of establishing closer settlement by resident graziers on medium-sized holdings. Faced with the threat of selection, the pastoralists were also being pressed to introduce improvements - in expectation of increased returns - through increased rentals, which were raised from 0.15d per acre in 1861 to 0.37d per acre in 1880. In the event, few Homestead Leases were taken up in the arid area west of the Darling River by bona fide selectors. However the burden of higher rentals and the high costs of providing water and fencing for permanent occupation put the individual squatter without capital at a considerable disadvantage. Many of them left the newly-occupied areas in the dry years after 1865, particularly during the period of depressed wool prices in 1868-70, among them Wallace from Sturts Meadows. Their place was taken by the extension of large company holdings such as that of Corona Station, which early in the 1870's

incorporated runs to the north and east to take in parts of Sturts Meadows and Cobham, and brought what is now Fowlers Gap Station within its area of more than one million acres.

The Fowlers Gap area was affected only indirectly by the wave of mineral prospecting and mining activity that followed in the region after 1870. In 1869-70 a gold strike occurred at Mt Browne and subsequently one at Tibooburra. Traffic northwards increased as a result, and the bullock track from Umberumberka through Euriowie and Fowlers Gap to Bancannia and Packsaddle developed in to a mail route. The mining episode was short-lived and was virtually over by 1895, but the route remained for coach traffic and for travelling stock. A stock route was gazetted in 1884, with a branch along the eastern foot of the ranges where it presumably used the natural soakages and waterholes. The Gap may well have received its name at this time. Hardy (1969) refers to a Fowler, "perhaps an early Murray squatter", who may have pioneered the Gap through the Ranges, and an alternative suggestion is that Fowler was a bullock-train driver who located the Gap on his journeys northwards. However local reports identify Fowler as a surveyor with one of the early exploration parties (K. Conners, pers.comm.). Certainly the name already existed in 1892, when Fowlers Gap Hotel was built on the route, on the left bank of Fowlers Creek about 3 km downstream from the Gap itself.

Unlike the 1861 Act, which had tried to impose a general formula for closer settlement which could apply throughout central and western New South Wales, the Crown Lands Act of 1884 recognized the need for more flexible tenure arrangements to meet the special needs of the more arid western part which was now constituted as the Western Division. The Act attempted to provide security of tenure for the squatter appropriate to his investment in improvements, whilst yet furthering the cause of closer settlement. The large agglomerations of pastoral runs were now legally consolidated and divided into two approximately equal parts knows as Leasehold Areas and Resumed areas. The holder was granted a Pastoral Lease of the Leasehold Area for 15 years with an option of further extension of five years; he was entitled to an Occupation Licence of the Resumed Area, which was renewable annually, but this area and any vacant Crown Land were available for the selection of Homestead Leases with terms similar to those of Pastoral leases. Subsequent amending Acts extended the terms of Pastoral Leases to 1918 and of Homestead Leases to 1930. The rent on both Pastoral and Homestead Leases was to be appraised for the first five years by a Local Land Board, the rents to be increased automatically by one-fourth for the second five-year period, and by one half for the remainder of the term, in the expectation of increasing returns following development.

Corona Pastoral Holding No. 105 was gazetted in July 1885, with a Leasehold Area of 828,820 acres in the south and a Resumed Area of 824,100 acres extending to the north. The holder was Dalgety and Co. Most of what is now Fowlers Gap Station was included in the northeast corner of the Leasehold Area, of which the eastern boundary is to be seen in the present eastern limit of Fowlers Gap Station; the old northern boundary survives in the present northern fences of North Mandleman and Sandstone Paddocks.

The improvement of pastoral leases proceeded during the 1870's and 1880's. Natural soakages had already been replaced by wells and earth tanks along stream courses, but after 1879 the mechanical drilling rig appeared. Bores could now be put down at a cost of about 11s. per foot compared with 4 per foot for well-sinking, and the increased range of depths allowed a more rational siting of waters. Sandy Creek No. 1 Bore near the stock route in the north of Fowlers Gap Station dates from 1893. The practice of shepherding disappeared, and the sheepfolds which had given rise to severe erosion and dust blowing were replaced by fenced enclosures. With the development of light-weight fencing costing as little as 5 per mile, the grid of five-mile paddocks began to extend across the country, and some of the oldest fences along the eastern and northern boundaries of Fowlers Gap probably date from the late 1880's. There was a general depletion of tree cover in the area to provide fence posts, both in the hills and along river frontages.

These investments were encouraged by an optomistic view of the carrying capacity of the country and by an official faith, expressed in sliding scales of increased rentals, that its potential could be more fully realized by station improvements. Fostered by high sheep prices during the early 1880's, and afterwards by good seasons, flocks of considerable size were built up. From less than 2 millions in 1880, sheep numbers west of the Darling rose to a peak of almost 8 millions in 1894. No figures are available for Corona Station at that period, but in 1877 Mt. Gipps carried 71,000 sheep on 540,000 acres, and Wonaminta Station, to the northeast of Fowlers Gap, sheared 92,000 sheep in 1892.

III. PASTORAL CRISIS OF THE LATE NINETEENTH CENTURY

The last 15 years of the 19th century brought increasing difficulties for the pastoral industry in the far west of New South Wales. The increase in sheep numbers had continued through and had in fact been provoked by a period of declining wool prices after 1884 and by the financial recession and further fall in wool revenues after 1890. This phenomenon of growing stock numbers combined with declining returns, whether from natural or economic causes, is so characteristic of the history of the pastoral industry in the Australian arid zone as to invalidate the use of stocking rates as an index either of grazing potential or of prosperity (Duncan, 1972).

The long drought that followed 1895 found the area severely overstocked at a time when there were few opportunities to transport sheep. Stock prices fell and a thriving boiling-down works was established at Menindee in 1891. Sheep numbers decreased sharply in the drought years after 1895, to less than 3 millions by 1901, but it is generally held that at this period much of the saltbush country and other perennial pastures underwent a deterioration from which they have not since recovered, particularly in holding paddocks, along stock routes, and near watering points. The southern part of Fowlers Gap Station, the frontages of Fowlers Creek, and much of the plains and foothill country to the east and north still reflect this degradation. Considerable soil erosion ensured, sand drifting was widespread, and dust storms were noted to be more common.

To this was added the problem of rabbit infestation from 1890 onwards. The rabbit had spread across the Darling River in 1884 and by 1886 had reached the Queensland and South Australian borders. Rabbits reached plague numbers several times in the following decades, and during drought they caused severe depletion of pasture grasses and widespread ring-barking of edible trees and shrubs. Damage was particularly extensive in the Resumed Areas, in which the pastoralists naturally took less interest and which therefore served as breeding grounds. The dingo population also increased, since the rabbit formed a new food supply. State Governments took action to construct netting fences along the border with South Australia in 1886 and with Queensland in 1887, but under the Rabbit Nuisance Act of 1883 much of the cost of rabbit control was levied on the pastoralist, particularly in the payment of bounties. After 1889 the landholder was faced with penalties for not controlling rabbits on Leaseholds. Rabbit depredation was particularly severe in areas of calcareous shale, as in much of the undulating country on Fowlers Gap Station; this may previously have carried perennial shrubs but no shrub cover survives today. In these areas some of the large warrens - now only periodically occupied - were originally those of the native bettong (Bettongia lesuri) which was driven from the area by the invading rabbit.

In its aim of bringing closer settlement, the Crown Lands Act of 1884 was a unsuccessful as that of 1861.

The Homestead Lease, initially of 5760 ac and increased to 10,240 ac in 1895, was entirely inadequate for most of the area, and only small parts of Resumed Areas were selected along the river frontages and near the market centres of the mining settlements. The Selection Station which borders Fowlers Gap on the northeast doubtless owes its name to the taking up of a Homestead Lease in the Resumed Area of Corona Station, on the favoured country of the Fowlers Creek floodout.

Although it did not serve the needs of the smaller grazier, the 1884 Act nevertheless succeeded in antagonising landholders, whose rentals were progressively increased from 2.23d per sheep in 1879 to 8.95d in 1900. Arrangements for compensation for improvements taken over by selectors were unsatisfactory, and led to the neglect of Resumed Areas at the cost of further overstocking of Leasehold Areas. Even on the Leaseholds, the conditions of tenure were not considered secure enough to justify the investments called for.

As in 1868-70, falling wool revenues after 1884 hit family squatters and smaller holdings hardest. The majority of family properties and many pastoral company leases passed into the hands of the foreclosing banks and mortgage companies at this time, among them Corona, which passed to Goldsbrough Mort and Co. Homestead Leases were even harder hit and Hardy (1969) reports that less than a quarter of the selectors who had taken up lands under the 1884 Act remained in the area by 1901. The critical situation led to the establishment of the Royal Commission of 1901 "to enquire into the position of Crown tenants in the Western Division". In its findings, the Royal Commission stressed the environmental problems of drought, rabbits, overstocking, and "sand storms" as principal factors in the depressed

state of the pastoral industry; nevertheless it also named as contributory factors, lower wool prices, depressed values of properties, and the comparatively short terms of pastoral leases which made finance hard to obtain.

IV GENERAL RECOVERY AND SUBDIVISION

Many of the recommendations of the Royal Commission were embodied in the Western Lands Act of 1902, which brought important changes to land tenure in the Western Division. It was now recognised that the harsh and unreliable climate and low productivity made the area unsuited for close settlement, as was apparent from the small extent of Homestead Leases taken up before 1901 (13.6 per cent of the Western Division) and the high rate of failure (Heathcote, 1964).

More realistic assessments of carrying capacity at one sheep to 15-25 ac were introduced for the far western country, based on inventories of land properties which took into account the degradation of the previous 20 years. Additional land was to be obtained by a withdrawal of up to one-eighth of the large pastoral leases. All leases were to continue to 30th June 1943 and there was to be no further alienation of land to freehold in the Western Division. Relief was also offered to a depressed pastoral industry in the form of lowered rentals, now based on the capacity of the land, on a sliding scale of 2d to a maximum of 7d per sheep area. The special problems of the Western District were recognised administratively, in that it was now removed from the Lands Department and placed under the control of a Western Lands Board.

In 1903 a new lease No. 243 of Corona of 827,738 ac restricted to the former Leasehold Area, was granted to Goldsbrough Mort and Co. for a term of 40 years. An early pasture map of Fowlers Gap which may date from that time shows that four paddocks had been fenced off in the Station area, namely:

Gap Creek Paddock
Fowlers Gap Paddock (including Sandstone, South Sandstone and Holding Paddocks)
North Mandleman Paddock (Salt Paddocks Nos. 4-6, plus Mantappa, now part of Rowena Station)
Mandleman Paddock (remainder of Fowlers Gap Station area)

Gap Creek Paddock was described as "only annual saltbush" and North Mandleman as "saltbush". In Fowlers Gap and Mandleman Paddocks there was open saltbush on the flats and rolling country, scrubby mulga, belah and saltbush, chiefly annual, on the hills north of Fowlers Creek, and saltbush, a little mulga and scrubby belah on the hills to the south. The poor condition of the country between the hills and Fowlers Creek which formed part of the stock route was noted, it being badly wind-eroded and containing only sparse annual saltbush and grass. Signs of degradation were also apparent in the absence of perennial saltbush from Gap Creek Paddock, but there was as yet no mention of copperburr. The assessed stocking rate was stated to be one sheep to 15 ac, compared with the present estimate of one sheep to 20-25 ac.

The original outstation on Fowlers Gap, a three-roomed stone cottage, had been built in 1892 on the left bank of Fowlers Creek just above the confluence with Homestead Creek. In 1895 a small hut was built in Mandleman Paddock, and it is likely that Mandleman Tank (now Saloon Tank) was built about that time. Other improvements followed after the granting of the new lease in 1903, for instance Sandstone Tank (Schmidt's Tank) in 1905 and Warren's Tank in 1910. Two of the series of Public Watering Points established along the Stock Route at droving intervals of about 20 km were sited on or adjacent to the Station; Fowlers Gap Tank (PWP 577) was approved for construction near the south boundary in 1906, and it is likely that Bald Hills Tank in the north of the property was excavated at about the same time. By 1910 the original homestead had apparently fallen into disrepair and a three-roomed wood and iron cottage was built to replace it; this was eventually dismantled in 1940 when the stone cottage was repaired and again brought into use.

In 1911 the Corona lease was transferred to Thomas Brown and Henry Dutton, but in 1917, as the Corona Pastoral Co., it passed to Sir Sidney Kidman and became the headquarters of the belt of large leases owned by him, which extended north almost to Tibooburra. At that time, Corona was reported to carry 50,000 sheep (1 sheep to 16 ac) and 1,200 head of cattle.

The Royal Commission had recognised the need to combat overstocking and the degradation of pasture lands, but control of stocking was not enforced under the 1902 Act. Protective measures were confined to requirements to control vermin and remove noxious scrub, and restrictions on the removal of timber or edible shrubs. Rabbit numbers, which had fallen markedly towards the end of the long drought of 1895-1902, were a recurrent problem and the Corona records of 1905 include an order to destroy rabbits. In 1912 the north border of Corona was netted against the rabbit-infested former Resumed Area, including the northern fences of Mandleman and Sandstone Paddocks. Dingoes were also a perennial problem on the border stations and a Border Fence Trust was formed in 1912, by which the Queensland Government was recompensed to render the former rabbit fence dog-proof. Kidman earned local disapproval by standing out from this arrangement, and had his own protective fences erected, for instance, the north-south fence along the western boundary of Fowlers Gap against Floods Creek Station was built in 1924. However, the Wild Dog Destruction Act of 1921 enforced dingo control through a general rate which is paid into a Fund and administered by a Wild Dog Destruction Board. The dingo is no longer a problem in the area, its place having been taken by the fox, which was introduced only too successfully into Victoria in the late 1870's. As with the dingo formerly, the number and range of foxes fluctuate with seasons in response to rabbit numbers.

The period from 1902 to 1924 was generally one of recovery following the severe droughts of 1895-1902. With better rainfall and more favourable leasehold conditions, the Western Lands Board reported in 1903 that the "pastoral industry in the Western Districts is now on a reasonably sound basis". Under the influence of rising wool prices sheep numbers in New South Wales west of the Darling recovered sharply to almost 4 millions in 1907. They continued to fluctuate

about this figure, for the decade 1910-20 was also one of drought, but although they exceeded 5 millions in 1925 they never again attained the peak of the early 1890's. This is generally attributed to the deterioration of carrying capacity of the natural pastures following the heavy stocking which continued into the drought years after 1895, and it has been claimed that such stability as has been achieved has been the result of man-made improvements, particularly the provision of additional watering points which have brought more land within the reach of stock (Perry, 1970).

Wool prices slumped badly during the depression years 1928-32, yet sheep numbers were generally maintained until late in the long drought period of 1940-45, again demonstrating that the high stocking rates encouraged by good seasons and favourable prices are maintained with falling prices, as a counter to diminishing revenue.

The records of Corona Station during the 1920's and 1930's reflect the state of the pastoral industry in the region generally, with periods of drought and occasional better seasons, rabbit plagues, stock losses and strongly fluctuating sheep numbers, and repeated requests for relief from rentals on the basis of diminished carrying capacity.

Apart from lower or deferred rentals, another form of relief requested was extension of tenure to give greater financial manoeuvre. In 1930 existing pastoral leases were offered an extension of up to 25 years, but in return for withdrawals of up to half their Leasehold Areas for further subdivision. Under the Western Lands Amendment Acts of 1932 and 1934 this was redefined as "one quarter of their land immediately, an eighth in 1943, and an eighth in 1948" (King, 1957). These areas were to be used to establish new Western Lands Leases and to build up smaller holdings to economic size. However the Corona Pastoral Company did not fully exercise this option, and the lease as gazetted in June 1932 was to continue only until October 1947.

The Amendment Acts were in response to strong pressure for land in conditions of high unemployment. They emphasised the concept of the home maintenance area - a rural equivalent of the basic wage - capable of supporting 3-5000 sheep in the more accessible parts of the Western Division and up to a maximum of 10,000 in the more remote and arid areas. They introduced the right to extend existing leases to perpetuity and to grant new leases, subject to a restriction to a home maintenance area in both cases. The majority of the large landholders accepted the offer of extended leasehold in return for giving up part of their area, but there was some resistance west of the Darling, notably from the Kidman group of companies, which preferred to retain interim control over its entire areas with the intention of eventually transferring its interests to Queensland and South Australia. The Corona holding was thus to remain intact until the termination of the lease in 1947, when it would become due for complete subdivision.

The Act of 1934 also established the Western Lands Commission under the direction of a single Commissioner. The closer supervision of land use which now characterises Western lease Holdings was instituted. Local Land Boards were set up to decide on lease allocations, and such allocations included for the first time a restriction on the numbers of stock that could be carried. The process of land subdivision, which had previously been relatively slow

west of the Darling, began to speed up after the 1934 legislation, but it was to be significantly advanced by a wartime Labor Government which in 1943 directed the simultaneous withdrawal from pastoral leases of areas which under the 1934 Act were to be ceded separately in 1943 and 1948. Complete enforcement of subdivision followed with the 1949 Amendment Act, which in the face of new demands for land from returned ex-servicemen fixed the maximum holding of further leases in the Western Division at two living areas. Heathcote (1964) records that 96 per cent of the Western Division had been divided into living areas by 1956, and that all the large old pastoral leases had been broken up. The 1949 Act reinforced the control of land use, in that it empowered the Minister for Lands to order the de-stocking of leases to prevent undue deterioration and to allow regeneration of pastures. A 1945 Amendment had also made mandatory a review of sale prices on transfer, in order to prevent undue increases in the price of land and its use for speculative purposes.

The Pastoral Lease of Corona was due to terminate in 1947 and pastoral inspections were carried out in 1945 in anticipation of subdivison and give the following picture of Fowlers Gap Outstation at that time:

Fowlers Gap Paddock - mulga, dead-finish, black oak and berrigan, good saltbush and copperburr. Carrying capacity, one sheep to 25 ac, or 843 sheep.
Mandleman Paddock - good saltbush and copperburr. One sheep to 22 ac, or 1230 sheep.
North Mandleman Paddock - one sheep to 22 ac, or 588 sheep.
Warrens Paddock - one sheep to 25 ac, or 660 sheep
Gap Creek Paddock - one sheep to 25 ac, or 242 sheep

This assessment makes the first mention of copperburr on Fowlers Gap, suggesting that deterioration of saltbush pastures had progressed since 1903. The average carrying capacity was rated as one sheep to 25 ac, which compared favourably with a number of other blocks in the area. Fowlers Gap block, Western Lands Holding No. 1236, with an area of 92,100 ac, was thus allocated a carrying capacity of 4100 sheep. No part of the block was indicated as showing severe erosion.

V. CONSERVATION AND RESEARCH IN THE WESTERN DIVISION

Although the 1901 Royal Commission had recognised the deterioration of pastures and consequent wind erosion as major problems of the region, there was not protective legislation until the Acts of 1934 and 1949. A visit in 1934 by E.A. Buttenshaw, New South Wales Minister for Lands, to the United States, then in the throes of the dustbowl years and in the early stages of its soil conservation measures, may have influenced the setting up of a New South Wales Erosion Committee in 1934, the passage of a Soil Erosion Bill in 1937, and the establishment of the Soil Conservation Service in 1938. The change towards a conservationist policy was certainly reinforced under the widespread move for planned postwar construction and development under the McKell Government, and a Department of Conservation was formed in 1946. Doubtless the need for soil conservation measures was given point by the drought that set in after the good seasons of the early

1930's and continued through the war years, again under the impact of rising sheep numbers, and which hindered considerably the progress of subdivision under the Western Lands Commission.

The problem of drought and soil erosion in arid Australia was surveyed scientifically for the first time in the late 1930's, notably by Ratcliffe for the CSIRO in South Australia and southwest Queensland (Ratcliffe, 1936, 1937). Morris successfully established a saltbush regeneration area around Broken Hill in 1937, to combat the nuisance of dust storms. However, the major contribution in the Western Division was the work of Dr N.C.W. Beadle, who as an officer of the Soil Conservation Service carried out a wartime survey of vegetation and pastures in the Western Division with special reference to their deterioration under grazing and resultant soil erosion (Beadle, 1948).

Beadle's work underlined the necessity for field experiments by the Soil Conservation Service, and negotiations were begun for the transfer of one of the Corona leases that contained suitable country. As a result, Fowler Gap Block No. 1236 of 92,100 ac, the smallest of the Corona blocks, was granted to the Conservation Authority of New South Wales* under Special Western Lands Lease No. 7318, for 20 years from January 1st, 1952, "for conservation purposes".

A first necessary step was to survey the pastures and conditions of soil erosion on the Fowlers Gap Rural Investigation Station, as it had now become. This was carried out later in 1952 by Dr Beadle, who had moved to Sydney University in 1950, and his students. Their surveys show annual pastures with bassias and copperburrs on the plains country in the east of the Station and also along much of the eastern footslopes, as well as on the continuation of the stock route south of the Homestead, short grass-forb pastures along the river frontages, and ephemerals on the light calcareous soils on the southwestern sector of the property. Much of these areas was characterised by severe to moderate wind erosion. It was noted that between 73 and 90 per cent of all the mulga on the Station was dead, with no evidence of regeneration.

Professor Beadle continued these studies from the University of New England, to which he moved in 1955. Seven kangaroo-proof enclosures were fenced off, across a characteristic range of country, and permanent quadrats were maintained in them to measure the progress of natural regeneration. Unfortunately their value was seriously diminished through their occasional use as holding pens for travelling stock! Postgraduate research from the Department of Botany, University of New England, continued into the 1960's and included the general ecology of the Station, patterns of soil salinity and vegetation and their modification by grazing, and studies of the root form and nodulation of Acacia aneura (mulga) and of the ecology of rhizobia of pasture and indigenous legumes in native vegetation communities. Unfortunately, some of the records of this work, including a small herbarium based on the Station, were destroyed in 1962 when the shearers' quarters, built in 1953, burned to the ground.

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* This consisted of the Commissioners of the various branches of the New South Wales Department of Conservation, together with the Under-Secretary of that Department.

Officers of the New South Wales Conservation Service began experimental work on the Station in 1954, when a regeneration area of about 1300 ac, now known as Conservation Paddock, was fenced off in the northwest corner of Warrens Paddock. This was kept free from sheep but was open to grazing by feral animals. The studies included the effectiveness of ponding banks in conjunction with water spreading, for the reclamation of scalds (Newman, 1966), and effectiveness of ripping and checkerboard furrowing in scald reclamation; the effect of contour furrows and trenching on the regeneration of bladder saltbush (Atriplex vesicaria); the progress of regeneration of cotton bush (Kochia aphylla) and also of bladder saltbush in degraded sites as shown in repeated measurements along permanent transects; measurements of the extension of scalds; the effect of animal repellants as a counter to attacks on tree seedlings, particularly by rabbits; dung sampling to compare grazing intensity in an unstocked and an adjacent stocked paddock (Warren, 1971); and the role of stone in stabilising surface soil.

In 1953 a sublease of the Station, other than the experimental areas, had been granted to O.J. Hayes, at first for a period of five years and subsequently for a further seven years. These were years of recurrent drought, and the lease records indicate periodic plagues of kangaroos and rabbits, particularly in the dry year of 1957, when trees were ring-barked and pine seedlings were killed. This was particularly unfortunate as these represented the first regeneration of pine in the memory of pastoralists in the Western Division. Sheep numbers accordingly fluctutated strongly; for instance permission was granted to raise the stocking to 4200 sheep temporarily in 1956. Hayes was eventually extended Permissive Occupancy through the year of 1965 because of general drought conditions on other leases in the area. Nelia and Homestead Lake (Gum Creek) Dams were constructed during the period of this sublease.

Towards the end of 1965, the Station was inspected in connection with the termination of the sublease. The Pastoral Inspector's report indicates that the pastures were in poor condition at that time. North Mandleman Paddock carried practically no feed, Warrens and Mandleman Paddocks were also grazed out, the area around Mandleman Tank was completely bare, Sandstone Paddock contained bare areas with incipient sand drifting, and East Bald Hills Paddock was also bare. The only signs of regeneration were in South Sandstone and Bald Hills Paddocks. This condition appears to have resulted from drought periods of heavy grazing.

In the period since the lease was granted to the University of New South Wales, there has been considerable investment in the development of the Arid Zone Research Station. This investment was recognised when the University of New South Wales was granted a Lease in Perpetuity early in 1972.

It is a condition of the University's lease that the facilities of the Station be made available to other organisations concerned with arid zone investigations, and there has been close collaboration with the New South Wales Soil Conservation Service, the C.S.I.R.O. and other educational institutions.

VI. ACKNOWLEDGEMENTS

Apart from the references cited, this history has drawn upon an unpublished manuscript "A short historical background of the Fowlers Gap area" by Dr I.L. Johnstone, formerly Director of Field Stations, University of New South Wales, and on information from the files of the Western Lands Commission in Sydney.

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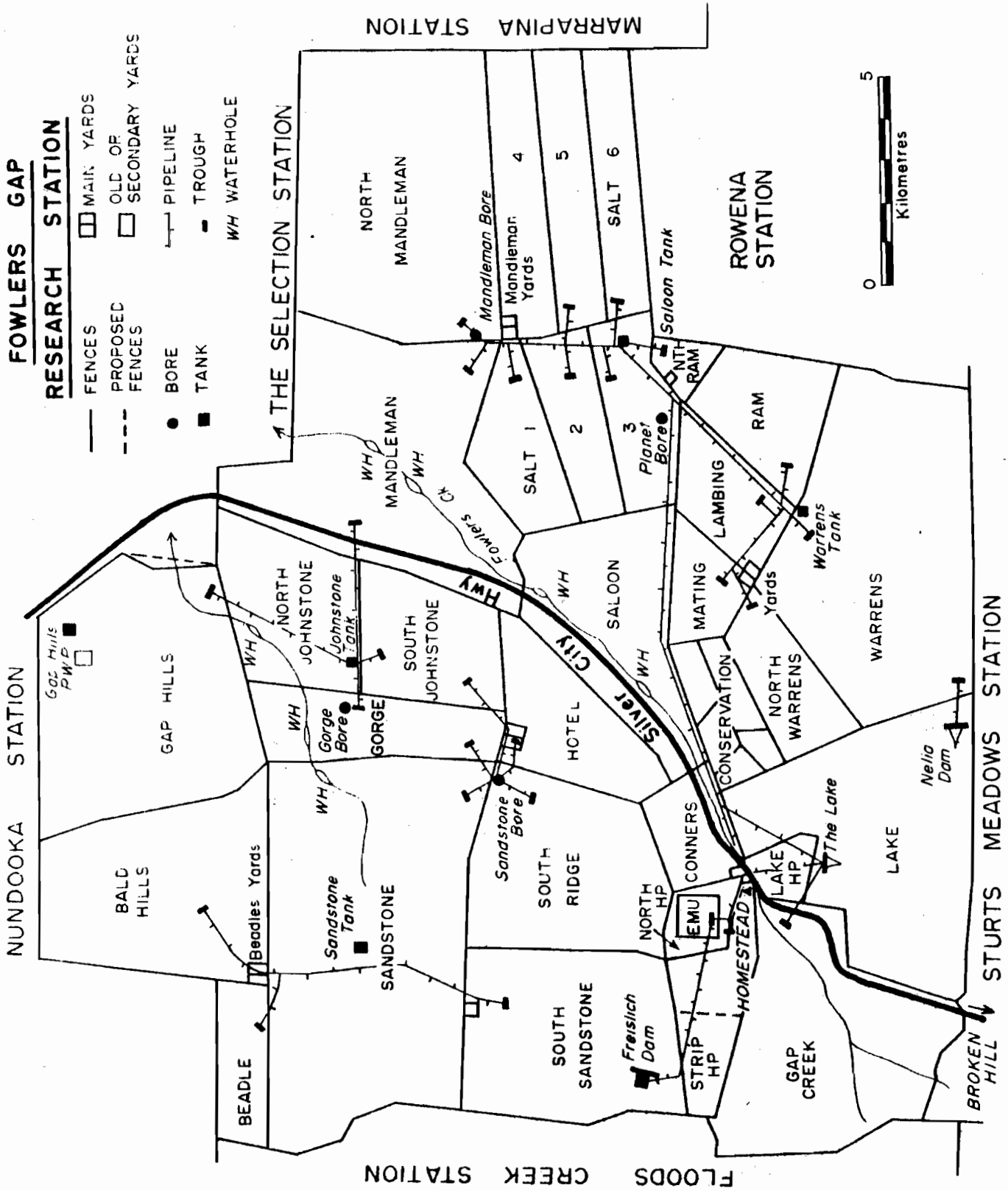
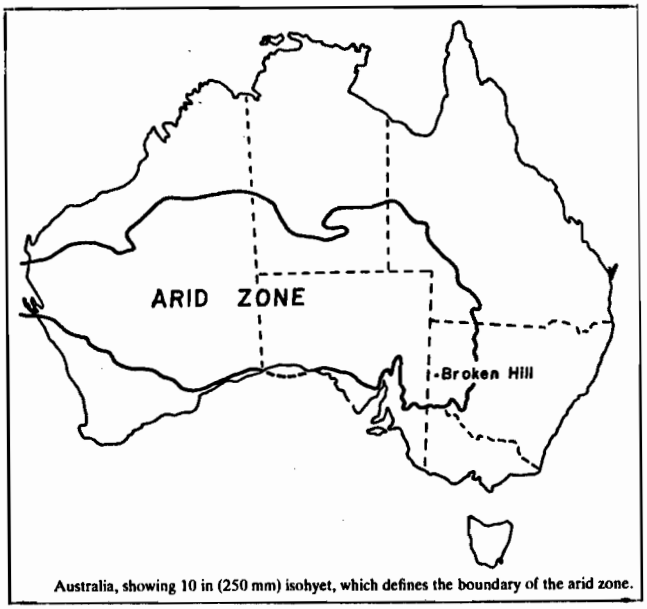

FOWLERS GAP
RESEARCH STATION
FENCES
PROPOSED FENCES
BORE
TANK
MAIN YARDS
OLD OR SECONDARY YARDS
PIPELINE
TROUGH
WH WATERHOLE
THE SELECTION STATION
MARRAPINA STATION
NUNDOOKA STATION
FLOODS CREEK STATION
STURTS MEADOWS STATION
ROWENA STATION
BROKEN HILL
NORTH MANDLEMAN
MANDLEMAN
SALT 1
2
3
4
5
SALT 6
Mandleman Bore
Mandleman Yards
Saloon Tank
NTH RAM
RAM
Planet Bore
LAMBING
MATING
Warrens Tank
Yards
WARRENS
NORTH WARRENS
CONSERVATION
Nelia Dam
The Lake
LAKE
LAKE HP
CONNERS
NORTH HP
EMU
HOMESTEAD
STRIP HP
GAP CREEK
SOUTH RIDGE
SOUTH SANDSTONE
Freislich Dam
Sandstone Bore
SANDSTONE
Sandstone Tank
Beadles Yards
BEADLE
BALD HILLS
GAP HILLS
Gas Hills PWD
NORTH JOHNSTONE
Johnstone Tank
SOUTH JOHNSTONE
Gorge Bore
GORGE
HOTEL
SALOON
Silver City Hwy
Cowlers Creek
WH
0
5
Kilometres

PART ONE: RESEARCH PROJECTS

Research projects are listed according to broad category of research, and are generally numbered within each category in roughly chronological order.

Categories are not intended to be mutually exclusive: some are, in fact, sub-headings of others. Nor do all projects listed within a particular category fit neatly or solely within that title. However, as far as practical, attempts have been made to cross-reference entries to provide an integrated record of research activity at the Station.

The category, Soil Conservation, encompasses all and only those projects conducted by the Soil Conservation Service. The report of this work was prepared by Mr David Eldridge, Rangeland Management Specialist with the Service, at Broken Hill. It has been included virtually intact, excepting cross-references and other editorial additions.



Australia, showing 10 in (250 mm) isohyet, which defines the boundary of the arid zone.

1. LAND SYSTEMS SURVEYS

A land system is a type of country with a characteristic pattern of topography, soils and vegetation reflected in diagnostic airphoto pattern. Maps and descriptions of land systems form a convenient synthesis of the natural environment and provide a basis for the study of land-use problems. Land systems are distinguished on the basis of airphoto patterns, and their characteristics are identified by ground observations at sample sites chosen from airphotos.

The following land systems surveys have been carried out at Fowlers Gap:

1.1 LAND SYSTEMS OF FOWLERS GAP

J.A. Mabbutt, J.P. Burrell, J.R. Corbett, M.E. Sullivan (School of Geography, U.N.S.W.).

Airphotos of the Fowlers Gap North One Mile Sheet at a scale of 1:63,360, flown in 1965, were initially used to distinguish land systems. Subsequently, special airphoto coverage of the Station at 1:25,000, flown in 1968 by the New South Wales Department of Lands was utilized. A contoured topographic map of the Station at 1:25,000, published by the New South Wales Department of Lands in 1971, was subsequently used in landform descriptions. A geologic map and account of the geology of the Station produced by C.R. Ward, C.N. Wright-Smith and N.F. Taylor in 1969 (See 2.1, 2.2, 2.3) was of assistance in the preliminary delineation of land types.

During the field survey, which was carried out early in 1968, 53 field sites were sampled. Observations were made of the geology, landforms, soils, and vegetation. Fourteen land systems were identified on the Station, their boundaries were mapped on airphotos, and their component units established. This original data was supplemented by subsequent survey work.

Tabulated descriptions of the land systems and of their component land units, which are more homogenous areas too small to be mapped, are presented in the Fowlers Gap Research Series publication listed below:

Publication

Lands of Fowlers Gap Station New South Wales (ed. J.A. Mabbutt) Fowlers Gap Arid Zone Research Station Research Series No 3, 1973. The University of New South Wales.

1.2 LANDS OF FOWLERS GAP-CALINDARY AREA

Survey Team

J.A. Mabbutt	School of Geography, University of N.S.W.
Janice R. Corbett	School of Geography, University of N.S.W.
P.L. Milthorpe	Soil Conservation Service of N.S.W.
J.C. Ngethe	School of Geography, University of N.S.W.
Marjorie Sullivan	School of Geography, University of N.S.W.

Other Contributors

P.F. Bailey	School of Biological Sciences, University of N.S.W.
F.C. Bell	School of Geography, University of N.S.W.
L.S. Hall	CSIRO Division of Wildlife Research
K. Myers	CSIRO Division of Wildlife Research
B.S. Parker	CSIRO Division of Wildlife Research

This land system survey of approx 12,000 sq km in northwestern New South Wales was carried out as a collaborative venture by staff of the U.N.S.W. School of Geography, the CSIRO Division of Wildlife Research, and the Soil Conservation Service in response to several related needs.

The CSIRO Division of Wildlife Research had been studying the rabbit problem in this area, partly on an environmental basis, and it was desired to extend this base. The Soil Conservation Service of New South Wales, through its recently established sub-district office in Broken Hill, was engaged in the assessment of lands and pastures in the northwest of the State, partly in relation to soil conservation practice and partly to determine advisable stocking rates and living areas under the existing policy of the Western Lands Commission. The School of Geography, University of New South Wales, had recently carried out a survey of land types on the Field Station at Fowlers Gap (see 1.1) and wished to extend this enquiry beyond the borders of the Station, to determine the regional extent of the land types previously defined and hence the relevance of research findings at the Station for the surrounding area. Finally, a study of lands in the area was called for under the programme of the CSIRO Rangelands Research Unit, in its concern with the delimitation and study of rangelands in the southern part of the Australian arid zone.

An area was therefore chosen to comprise the previous Fowlers Gap survey in the southwest and to enclose the main area of rabbit studies in the north.

It was agreed that the survey should be carried out by staff of the School of Geography, University of New South Wales, P.L. Milthorpe of The New South Wales Soil Conservation Service as plant ecologist, and J.C. Ngethe, a Range Officer of the Kenya Ministry of Agriculture and Animal Husbandry, at the time a United Nations (F.A.O.) Fellow in the School of Geography. Substantial support was given by the CSIRO units named above, including the supply of airphotos, plant identification, and photography, and through the provision of vehicles and support staff. This help continued with the drawing of the land system map and assistance with the preparation of the publication listed below.

Airphotos of the Fowlers Gap-Calindary area were available at a scale of 1:37,500. Guided by geologic and topographic maps of the area and using the experience of the earlier survey of Fowlers Gap Station, team members carried out preliminary

mapping of airphotos in the latter half of 1968, and type areas were then chosen for field sampling. Two periods of field survey, about six weeks in all, followed in the period October-December 1968 and a soil survey guided by previous work was carried out early in 1969.

During 1969 the boundaries of land types were revised on the airphotos and then transferred to photomaps. Eventually the mapping types were grouped into 31 land systems, depicted on a coloured map, scale 1:300,000, which also included brief descriptions of the land systems in its key.

The Report listed below includes tabulated descriptions of the land systems supported by a number of systematic accounts of the survey area, including its climate, geology, geomorphology, soils, vegetation, and fauna. The land systems have also been used to define pastures and pasturelands, so providing a basis for the study of pastoral land use.

Publication:
Lands of the Fowlers Gap-Calindary Area New South Wales (ed. J.A. Mabbutt) Fowlers Gap Arid Zone Research Station Research Series No. 4 1972. The University of New South Wales.

1.3 LAND SYSTEM SURVEY OF CORONA AREA, N.S.W
J. Field (BSc Hons Thesis, 1972, U.N.S.W; Supervised by Dr J.R. Corbett, School of Geography, U.N.S.W.)

In this project, the Fowlers Gap Calindary Land System Survey (see 1.2) was extended to the south-west to include a new and formerly unmapped area.

Although this survey did not cover much of the Research Station itself, Field's assessment of the use of the Northcote Key for classifying desert soils and for land system surveys is relevant to the arid zone generally.

Thesis:
Field J.B. (1972) A Land System Survey of the Corona Area New South Wales with Particular Reference to the Applicability of Northcote's Factual Key to Classifying the Soils. BSc. Hons. U.N.S.W.

2. GEOLOGICAL MAPPING

2.1 GEOLOGY OF THE FOWLERS GAP-NUNDOOKA DISTRICT
C.R. Ward (BSc. Thesis, 1967, U.N.S.W; Supervised by Professor L.J. Lawrence, School of Applied Geology, U.N.S.W)

The aim of this project was to map, on a scale of 20 chains to the inch, the northern half of the Fowlers Gap Arid Zone Research Station. Since the eastern half of the Station is made up of thick deposits of alluvium, mapping was restricted to the north-western quarter of the Station, and extended westward into Nundooka and Floods Creek properties. The area covered was in excess of 60 square miles. A similar map

prepared by C.N. Wright-Smith of the area adjoining to the south (see 2.2) completed the coverage of the Station.

Fieldwork for the project was conducted during six weeks at the end of 1966. Laboratory work was then carried out to study thin sections of the various rock types encountered. Further tests by X-ray and chemical methods were also performed on some specimens.

In the thesis listed below, the area is discussed in terms of seven recognizable physiographic blocks which are then related to the geological structures and stratigraphic units which make them up. Based on the composite geological picture built up by field and laboratory studies, correlations are suggested for beds of the area with other occurrences of rocks of similar age. A brief discussion of the applications of the geology of the area to water supply problems in connection with rural activities is also presented.

Thesis:
Ward, C.R. (1967) Geology of the Fowlers Gap-Nundooka District. BSc U.N.S.W.

Publications:
Ward, C.R., Wright-Smith, C.N. and Taylor, N.F. (1969) Stratigraphy and structure of the northeast part of the Barrier Ranges, New South Wales. J.Proc.Roy.Soc. N.S.W. 102: 57-71.

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Cooper, P.F. et al. (1978) Geology of the Torrowangee and Fowlers Gap 1:100,000 Geol. Surv. N.S.W.

2.2 GEOLOGY OF THE FOWLERS GAP HOMESTEAD DISTRICT

C.N. Wright-Smith (BSc Thesis, 1967, U.N.S.W; Supervised by Professor L.J. Lawrence, School of Applied Geology, U.N.S.W.).

In this project, Wright-Smith carried out geological mapping of an area approximately 66 square miles and centred on Fowlers Gap Homestead. The largest part of the area covered was on the Fowlers Gap property itself. However, the area also extended west into Floods Creek Station and south into Sturts Meadow Station.

Field mapping was carried out by first making a series of traverses east-west across the area. From this traversing,

the general stratigraphic sequence was revealed and "problem" areas delineated, concentrated effort then being put into resolving such problem areas.

The fieldwork was followed by laboratory studies of specimens collected.

In conjunction with two other students, Ward and Taylor (see 2.1, 2.3), tentative rock unit names were given to the Precambrian and Devonian rocks. The Precambrian was divided into Teamsters Creek Beds, composed of slates, metaquartzites and dolomites; the Faraways Hills Quartzite and the Fowlers Gap Beds, consisting of slates and metaquartzites. Two units were recognized in the Devonian, these being the Coko Range Beds, containing sandstones, slates, siltstones, grits and pebbly sandstones, and finally the Nundooka Sandstones. A number of silcrete deposits of probably Tertiary age were mapped in the area. The predominant structure in the Precambrian was found to be the Caloola Syncline, the syncline plunges to the south, a strong pattern of shears and cross joints being associated with the folding. The Coko Range Beds were found to have a definite uncomfortable relation with the Precambrian, the Nundooka Sandstones being down faulted by the Nundooka Fault, against the other Devonian Rocks.

Thesis:
Wright-Smith, C.N. (1967) The Geology of the Fowlers Gap Homestead District. BSc U.N.S.W.

Publication:
Ward, C.R., Wright-Smith, C.N. & Taylor, N.F. (1969) Stratigraphy and structure of the northeast part of the Barrier Ranges, New South Wales. J.Proc.Roy.Soc. N.S.W. 102: 57-71.

2.3 GEOLOGY OF THE CALOOLA SYNCLINE AND STURTS MEADOWS ANTICLINE
N.F. Taylor (BSc Thesis, 1968, U.N.S.W.; Supervised by Professor L.J. Lawrence, School of Applied Geology, U.N.S.W.)

Although the area covered by Taylor in this project lay to the south of the Fowlers Gap property, the field work was carried out from a base camp established at the Station and Taylor worked in conjunction with other students mapping the Station itself (Ward and Wright-Smith, see 2.1, 2.2) to propose a series of names for the rock units distinguished in the general area.

Thesis:
Taylor, N.F. (1967) Geology of the Caloola Syncline and Sturts Meadows Anticline. BSc U.N.S.W..

Publication:
Ward, C.R., Wright-Smith, C.N. and Taylor, N.F. (1969) Stratigraphy and structure of the northeast part of the Barrier Ranges, New South Wales. J.Proc.Roy.Soc. N.S.W. 102: 57-71.

2.4 GEOLOGY, ENGINEERING GEOLOGY AND HYDROGEOLOGY OF FOWLERS GAP

F.C. Beavis (School of Applied Geology, U.N.S.W.)

This study was undertaken to provide up-to-date information on the geology of the Station, and to collate all of the research carried out in pure and applied geology on the Station since 1963. In particular, a succession of extremely dry seasons prompted renewed investigation into the siting of water storages, and the exploration of groundwater resources (see also 5.1, 5.2, 6.1, 6.2, 6.3). Neither of these investigations could be undertaken, profitably and efficiently, until a reliable geological map of the Station area had been prepared, and the basic geology - lithology, structure, and weathering - properly assessed and understood.

Apart from these more immediate purposes of the study, it was used to test the idea that it might be possible to develop engineering geology and hydrogeology maps to assist in the location of water storage sites and of productive water bores. Since the existing geological map of the Station at the beginning of the study was small scale, based on a sketch topographic base map, and the geology itself determined almost exclusively on air photo interpretation with little ground control (see 2.1, 2.2, 2.3), complete geological re-mapping of the area was undertaken. The base map used was the Central Mapping Authority, Department of Lands, New South Wales 1:25,000 contour map of Fowlers Gap. Geological mapping for the basic studies was carried out at this scale.

Engineering geology and hydrogeology maps, at smaller scales, were also prepared.

Studies of weathering in the Precambrian rocks were made possible only by the drilling of five diamond drill holes to depths of about 70 to 100 m. All cores were logged in the field, and in the laboratory, and were used for mineralogical, fabric, petrographic and geomechanical study. Three percussion bores were drilled in the Devonian sediments for hydrogeological purposes, and to obtain data on the weathering of these rocks. Cuttings were logged in the field, and examined and tested in the laboratory. Pump tests for aquifer parameters were made in the field on these three bores. Additionally, water from the bores was chemically analysed. Analyses of waters from other bores, from tanks and from streams were carried out during the study. (See also 5.1).

For a proper examination of the engineering soils, over 30 test pits were excavated on the Station. These were logged, and both disturbed and undisturbed samples taken for laboratory testing. One test cut was made adjacent to Freislich Dam for the purpose of field testing compaction characteristics of the soil used in the dam. All laboratory tests used standard procedures laid down by the International Association of Rock Mechanics and the American Society for Testing Materials. (See also 5.2).

Publication:
Beavis, F.C. and Beavis, J.C. (1984). Geology, Engineering Geology and Hydrogeology of Fowlers Gap Station, Fowlers Gap Arid Zone Research Station Research Series No 6. University of New South Wales.

3. TOPOGRAPHICAL MAPPING

3.1 FOWLERS GAP SURVEY

G.J.F. Holden, A.J. Robinson, A.H.W. Kearsley, A.P.H. Werner (School of Surveying, U.N.S.W.)

The survey originated with a request by the Arid Zone Research Station Management Committee to the Minister for Lands for the provision of 1:25000 topographic mapping with 5m contours of the 39000 ha property leased by the University. Until 1968, the best available mapping of the area was in the form of unconnected air photograph mosaics with no elevation information, which proved quite inadequate for the locational purposes required by many research workers. The Minister agreed to undertake multicoloured mapping in two large sheets provided that all ground control work was supplied by the University. To this end, the School of Surveying carried out a control survey in 1968 in substitution for a final year student survey camp.

The existing control consisted of the major geodetic station (Gap) inside the property and the five others outside the property at an average distance of 50km from Gap. A line of SSM marks on provisional A.H.D. was also available at about 3 km intervals along the Silver City Highway which traversed the property from north to south.

The Control Survey was entirely by traditional triangulation, to break down the major network to a lower order greater density. Fourteen stations were established within the property and these were subsequently beaconed with tubular steel tripods, concreted in at the feet. The ground marks were concreted in before the survey commenced. All observations were to first order specifications. The network was adjusted by the parametric method and the precision of the adjusted co-ordinates is estimated at a standard error of 0.04m. The network was also connected at two stations by levelling to two SSM of the geodetic levelling line and all trigonometric heights of the network adjusted by condition method, the precision of heights being estimated at a standard error of 0.05m internally.

At the same time as the control survey was observed, eight premarked photogrammetric controls were established and ground marked by black and yellow polythene crosses prior to flying for the mapping phase, all of which were subsequently identified on the 1:60000 photography (115mm wide angle).

The mapping was carried out by the Lands Department and the two multicoloured sheets published in 1971 (See 3.2).

Subsequent to this survey, G.J.F. Holden decided to use the area for aerial triangulation and orthophotography testing as a data base for PhD research (see 3.3). Three more field surveys were carried out and a total of a further fifty photogrammetric control points established in 1969, 1970 and 1971. Twenty-eight of the additional points were established in 1969 and 1970, entirely by resection methods from the network points, these additional points being distributed symmetrically throughout a block of 3 x 10 photographs. In 1971 a final twenty-seven further points were established by edm traversing, these points being concentrated in two particular models for orthophotomap testing.

3.2 AERIAL PHOTOGRAPHY, CONTOURED MAPPING, AIR-PHOTO MAPPING
Department of Lands N.S.W.

As a result of an offer from the Minister for Lands, the assistance of his Department was obtained in air photography and mapping at the Station.

The Station was photographed from the air in October 1968 as follows:

1/60,000 : one run on the north of the Station (Panchromatic)
1/25,000 : entire Station (Panchromatic)
1/8,000 : selected paddocks for salinity and fertility trials (Colour negative)
1/4,000 : three investigational sites for detailed work on vegetation, soils etc (Colour negative).

A contoured map of the Station at a scale of 1/25,000 with 5m contour interval was published by the Department in two sheets in 1971. Copies are available from the Institute of Rural Technology, University of New South Wales. An airphoto map in two sheets, scale 1/25,000 was also produced.

3.3 AN EVALUATION OF ORTHOPHOTOGRAPHY IN AN INTEGRATED MAPPING SYSTEM
G.J.F. Holden (PhD Thesis, 1974; Supervised by Dr J.C. Trinder, School of Surveying, U.N.S.W.)

Since the modern revival of interest in Orthophotography, and in particular since early 1960 when production instruments for the technique became available, a number of practical tests have been carried out in order to determine the mapping accuracies which can be achieved in practice. Several mapping projects have incorporated orthophotographic processes, and a few have been conceived as orthophotomap projects. In this thesis, an analysis is made of current projects and previous tests, and the analysis shows that to a large extent both the projects and the tests have been rather biased by conventional mapping criteria, and that many of the

tests have been concerned solely with the problems of very large scale mapping. It is contended that this is rather paradoxical, because this technique is one which should be most advantageously used in quite a different context, namely that of medium scale mapping for underdeveloped terrain; a sphere of surveying in which world mapping capability is quite unable to cater with the demand.

From this viewpoint a series of tests was carried out, in which planning, fieldwork, and production phases were integrated from the initial stages of ground control intensification, through the aerial triangulation phase, culminating in the production of orthophotographs. Additionally the concept of producing contours from drop line profile charts was investigated under rather more realistic conditions than had been attempted previously, in order to obtain data on production times for the cartographic treatment. It proved necessary to devise a technique, namely that of drainage interpretation, in order to be able to deal with the problem of profile interpretation in broken terrain; and it is thought that this technique may have general application to other pictorial profile methods. During the progress of the work, other problems were identified, and in particular investigations were made into calibration methods for perspective centres in Independent Model Triangulation. Also a series of computer programs were developed for photogrammetric work with small programmable desk calculators, including a program for strip formation.

Fowlers Gap was chosen as the location for the study owing to the ready availability of photography at various scales of the Station and the opportunity it provided for carrying out extensive ground survey work without interference.

It was shown by the results of the tests that the planimetric accuracy of orthophotography is consistently rather high, and contributed only small errors to the final product of the integrated mapping project. It was shown that the intrinsic accuracy of profiling is high, but that a rather marked degradation occurs in the contouring phase, suggesting that somewhat reduced criteria should be adopted for elevation specification in orthophotmap medium scale mapping projects when based on the drop line technique.

Thesis:
Holden, G.J.F. (1974) An evaluation of orthophotography in an integrated mapping system. PhD U.N.S.W.

Publication:
Holden, G.J.F. (1974) An evaluation of orthophotography in an integrated mapping system, UNISURV S-12, University of N.S.W.

4. REMOTE SENSING

4.1 ASSESSMENT OF SHUTTLE IMAGING RADAR DATA OF THE FOWLERS GAP AREA

J. Richards, A.K. Milne, G.R. Taylor (Centre for Remote Sensing, and Schools of Electrical Engineering and Computer Science, Geography, and Applied Geology, U.N.S.W.)

This experiment is designed to investigate the usefulness of synthetic aperture radar data, acquired through the Space Shuttle Program, for the analysis of surface properties and the sub-surface morphology of the area around Fowlers Gap. It is part of a larger project conducted by the U.N.S.W. Centre for Remote Sensing in connection with N.A.S.A. and is headed by Dr J. Richards, Director of the Centre. Dr Milne is team leader for the Arid Zone area of the project.

The original submission for participation in the N.A.S.A program was lodged in March 1983 and approved in August of that year. Tour members of N.A.S.A.'s Jet Propulsion Laboratory visited the Station to arrange the groundwork for the radar imagery survey of the Fowlers Gap area to be undertaken by the Space Shuttle in October 1983. The project is due for completion in 1987 and a series of progress reports are to be submitted to N.A.S.A. throughout the duration of research.

The specific objectives are: to investigate the relationship between resolution and look angle in the identification and discrimination of lithological units from general surface types, including standing biomass; to determine the relationship between look angle, surface roughness, complex permittivity and depth of penetration; to determine the distribution between surface and sub-surface components in radar backscatter and to measure soil moisture and complex permittivity with depth in order to develop models for distinguising between solid rock, weathered layers, sediments and other surficial deposits.

Acknowledegments: Technical support and materials for this project are provided by the N.A.S.A. Space Shuttle Program.

4.2 LAND COVER ANALYSIS OF THE FOWLERS GAP AREA USING LANDSAT IMAGERY

A.K. Milne (Centre for Remote Sensing, U.N.S.W)

In this project, Landsat imagery of the area is being analysed, using the facilities of the Dipix Aires II image analysis system housed in the Centre for Remote Sensing, to map the major land cover types found on the property.

5. ENGINEERING GEOLOGY

5.1 WEATHERING OF ROCKS UNDER ARID CONDITIONS AND ITS ENGINEERING SIGNIFICANCE

F.C. Beavis (School of Applied Geology, U.N.S.W.)

In view of the economic importance of water in the Australian arid regions, a programme of research was commenced in 1978 into the geological factors which might contribute to the high failure rate of farm water storages in these regions. As weathering emerged as the fundamental problem, attention was focussed on an investigation of the processes and products of weathering in an arid zone.

The dolomites, low grade metapelites, limestones and quartzites at Fowlers Gap were studied using outcrop and diamond drill core. Six holes were drilled.

It has been concluded from this study, which is due for completion in 1984, that weathering at Fowlers Gap is the result of past humid and present arid climates. The applied results showed that secondary minerals, developed as a result of arid zone weathering, had a deleterious effect on the engineering properties of the rocks and salts.

Acknowledgments: This research was financed by grants from the Australian Research Grants Scheme and the Australian Rural Development Fund.

Publications:

Beavis, F.C., Beavis, J.C., and Reade, L.M. (1978) Engineering geology of small water storage structures in Australian arid regions. Q.J.Eng.Geol. II: 279-29

Beavis, F.C. (1979) Engineering Geology of Farm Water Storages. J.Proc.Roy.Soc. N.S.W. 112: 1-6.

Beavis, F.C. (1981) Engineering aspects of the weathering of dolomite in an arid climate. J.Geol.Soc.Aust. 28: 191-204.

Beavis, F.C., Roberts, F.I., Minskaya, L. (1982) Engineering aspects of weathering of low grade metapelites in an arid climatic zone. Q.J.Eng.Geol. Lond. 15: 29-45.

Beavis, F.C., Roberts, F.I., Minskaya, L. (1984) Engineering aspects of the weathering of calcareous and siliceous rocks in an arid climate. Aust.J.Earth Sci. 1: in press.

5.2 THE ENGINEERING GEOLOGY OF ARID ZONE SOILS AND THEIR STABILIZATION

E.G. Akpokodje

(PhD. Thesis, 1982, U.N.S.W.; Supervised by Professor F.C. Beavis, School of Applied Geology, U.N.S.W.)

The research described in this thesis was directed towards a study of arid zone engineering soils from the point of view of geological factors that might influence their properties.

The importance of water and effective transportation systems for the fast growing pastoral industries in the Australian arid region would imply successful design, construction and maintenance of relevant structures such as earth dams, excavated water storage tanks, and transporation routes. As a result of the inadequate understanding of the engineering properties and behaviour of these soils, many problems have been encountered in the course of construction of the above-mentioned structures. Lack of good conventional pavement construction materials is the major problem in the construction of roads in the area. In addition, the long distances between cities, towns and homesteads means that the provision of an adequate transportation system is only economically feasible by the construction of low cost but reliable roads. To achieve this, a detached study of the engineering properties of the soils, and the best ways of improving (stabilizing) their geotechnical behaviour are essential.

The thesis describes the results of field mapping and laboratory studies which considered the mineralogy, engineering properties and the stabilization of arid zone engineering soils at Fowlers Gap Arid Zone Reseach Station. Mineralogy and features of the soils were used as a basis for classification. The mechanical properties of the soils were determined. Experimental stabilization methods were investigated.

Nine engineering soil types associated with three major landform units have been recognized. The majority of the soils are saline and partial leaching has resulted in the redeposition of gypsum and $CaCO_3$ in the subsoil. Three main processes are responsible for the occurrence of gypsum, $CaCO_3$ and clay minerals in the soils, namely: (1) inheritance from underlying bedrock, (2) chemical weathering of primary minerals during the subtropical Tertiary climate and (3) aeolian activities.

The engineering behaviour of the soils is chiefly controlled by the mineralogy (clay and non-clay minerals) and the particle size distribution. The majority of the soils do not constitute good conventional pavement material and therefore require stabilization.

Cement is a better stabilizing agent than lime in improving the geotechnical properties of the soils. Between 3-8% cement content is required to achieve the recommended 7-day compressive strength of 1724 KN/m^2 (250 lb/sw in) in most soils. The highly plastic clayey soils need the addition of 2-4% lime to overcome mixing difficulties. The results of the different stabilization tests highlight the importance of using various criteria, especially those simulating field conditions in assessing the quality of stabilized soils. Adequate protection against increase in moisture content must be ensured before using cement stabilized clayey or gypsiferous soils for geotechnical construction.

Acknowledgements: This research was supported by funds provided by the University of Port Harcourt, Nigeria.

Thesis:
Akpokodge, E.G. (1982) The engineering geology of arid zone soils and their stabilization. PhD. U.N.S.W.

5.3 PICNIC CREEK STUDY
F.C. Beavis (School of Applied Geology, U.N.S.W.).

This project was commenced in November 1983. It comprises a detailed study of the geology of the valley of Picnic Creek where an infaulted block of highly deformed rock occurs. This block is obviously older than the other Precambrian rocks of the Station area, and much more highly deformed.

5.4 ENGINEERING GEOLOGY OF BULLDUST SOILS AT FOWLERS GAP
L. Smith (PhD Study Supervised by Prof F.C. Beavis, School of Applied Geology, U.N.S.W.)

This project, which is being carried out by Ms Larisa Smith as part of a PhD programme, is considering the origin of, and variation in, the engineering properties of bulldust soils in relation to their parent rocks at Fowlers Gap and in the general region of the arid zone of N.S.W. Mineralogical, textural, fabric, and mechanical aspects are being studied, and methods of stablization are being examined. Ms Smith commenced work on the project in 1984, but she is making use of material collected in 1983 by a student who subsequently resigned from the project.

6. HYDROGEOLOGY

6.1 A STUDY OF GROUNDWATER RESOURCES AT FOWLERS GAP ARID ZONE RESEARCH STATION
M. Hussein (M.App.Sc. Thesis, 1975, U.N.S.W.; Supervised by Professor F.C. Beavis, School of Applied Geology, U.N.S.W.)

The purpose of this work was to investigate the occurrence of groundwater in the pre-Cambrian rocks in part of the Fowlers Gap area in relation to rock structure and topography. Another purpose was to evaluate the relationship between climate, geology and water quality.

An aerial photo mosaic, scale 1:50,000 compiled from aerial photographs flown by the New South Wales Lands Department was used as a base map. Aerial photographs, scale 1:38,000 flown by the Department in 1965 were also used during the field work. Observations were made about the attitude and frequency of joints. Joint spacings were measured by taking a traverse across the rock outcrop and the distance between the joints was recorded. Thin rock sections were made from the main rock types and were described. Water samples were collected from creeks and excavated surface storages. Electric conductivities of the water samples were measured using conductivity meter, dionic Type-plant No. I.C.71 with callibration coefficient of 3.26. The conductivities measured were then corrected to values at 25°C using correction charts provided with the meter. Carbonate and bicarbonate concentrations in the water samples were measured during the sample collections using amicvoburette, 0.02M, H_2SO_4, phenolphthalein and methyl orange indicators. Analysis for other ions was carried out by the chemistry section at W.S. and L.B. Robinson University College in Broken Hill.

It was concluded that the Precambrian rocks were not a source of groundwater. The Tertiary sediments had the highest potential, but the Devonian rocks should be studied further.

Acknowledgements: The researcher received financial support from the Australian Development Assistance Bureau (ADAB).

Thesis:
Hussein, M. (1975) A study of ground water resources at Fowlers Gap arid zone research station. M.AppSc. U.N.S.W.

6.2 HYDROGEOLOGY OF DEVONIAN SANDSTONE, FOWLERS GAP ARID ZONE RESEARCH STATION - BROKEN HILL

E.W.A. Udofia (M.AppSc. Thesis, 1980, U.N.S.W.; Supervised by Prof. F.C. Beavis, School of Applied Geology, U.N.S.W.)

The Devonian Sandstone which forms a distinct physiographic and stratigraphic unit at Fowlers Gap Reseach Station, referred to as the Range, lies about 110 km north-east of Broken Hill along the Silver City Highway. It consists of four structurally and texturally controlled hydrogeological units which trend in a north-south direction. These units, from west to east, are: the Coco Range Sandstones and Conglomerate, the massive fine-grained sandstone, the weathered and practical sandstone and shale. The latter three constitute the Nundooka Sandstone. Out of the four units, the weathered and fractured unit is the most favourable water-bearing unit in the area. Generally, these units are regarded as fine to medium silty sandstone with low permeability.

Although Fowlers Gap Station depends primarily on groundwater for stock use, no detailed hydrogeological investigation had been carried out on the area.

Recharge of groundwater by direct penetration of rainfall at Fowlers Gap is infrequent and localised. It occurs in places where the formations' permeability has been modified by joints and weathering. However, much of the recharge is attributed to regional, rather than local flow systems. Groundwater flow in the study area is from north to south.

A single-rate pumping-test was performed to determine the aquifer characteristics, and the analyses of the time-drawdown data were carried out using Theis', Chew's and Cooper-Jacob's methods, as well as Theis' recovery method. The aquifer transmissivity was determined as $4.2m^2/day$, the storage coefficient as 1.75×10^{-4} to 3.97×10^{-4}. The Specific Capacity, as calculated from NSB/1 data, is $6m^3/day$ per metre of drawdown after 12 hours of continuous pumping. These low values of coefficient of transmissivity and Specific Capacity are attributed to the presence of silt and thin beds of clay and possibly to poor well-development.

Water quality analyses showed that the groundwater is of high salinity. Nevertheless, the present quality standard was found to be suitable for stock use.

Acknowledgements: Financial assistance for this research was provided by the Nigerian Steel Corporation.

Thesis:
Udofia, E.W.A. (1980) Hydrogeology of Devonian Sandstone, Fowlers Gap Arid Zone Research Station - Broken Hill. M.AppSc. U.N.S.W.

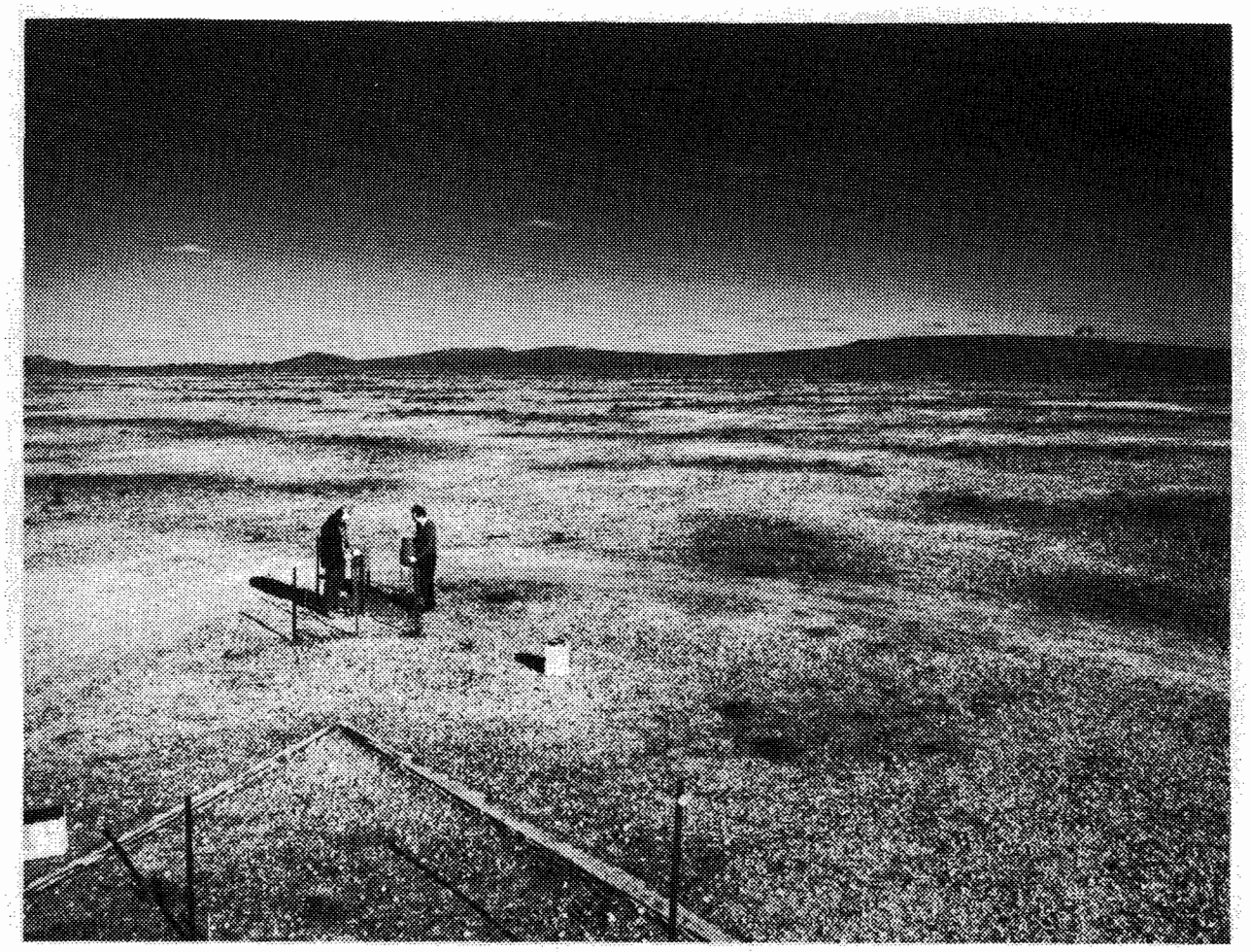
6.3 GROUNDWATER POTENTIAL OF NUNDOOKA SANDSTONE - FOWLERS GAP ARID ZONE RESEARCH STATION, BROKEN HILL (N.S.W.)

M.L. Sharma (M.AppSc. Thesis, 1981, U.N.S.W.; Supervised by Professor F.C. Beavis, School of Applied Geology, U.N.S.W.)

In general, groundwater in the Fowlers Gap area occurs under water table conditions in consolidated sedimentary rocks and moves through the interstitial openings of granular horizons and along joints, bedding planes and other fractures, which are present in the rock mass. The main purpose of this investigation was to determine the groundwater potential of the Devonian Nundooka Sandstone at Fowlers Gap. The Sandstone here is consolidated and is fractured and well-jointed.

The work followed that of Udofia (see 6.2) and sought to establish changes in the aquifer parameters and water quality in the period since the earlier work.

Apart from the general assessment, a pump test was carried out to determine the aquifer characteristics viz: the transmissivity and the storativity. A comparative study from previous data was made to assess the potential of the aquifer, and any variations since earlier tests. A



Professor Tom Chapman and Mr David Doran, of the School of Civil Engineering, U.N.S.W., inspecting instruments (See 7.1). Photo: K. Doig.

comparative study was also made in relation to groundwater quality. This involved a description of the occurrence of the various constituents in groundwater and of their relation to groundwater utilization, its movement and storage.

It was concluded that, in the area covered by the Nundooka Sandstone Formations, the potential of the aquifer is directly governed by the geomorphic features which in turn are controlled by the fabrics of the rocks and the drainage conditions. Moreover, development of groundwater potential in this area is mainly dependent on the rainfall, slope characteristics and the thickness of the surface formations as they control flow and the direction of subsurface water.

The lower piedmont zones succeeded by alluvial plains, where the channels merge, were considered to be the most suitable geomorphic units for groundwater exploration. It was recommended that these areas should be thoroughly investigated through geophysical methods, especially by the seismic (refraction) method followed by electrical resistivity method, because groundwater accommodation exists where the channels are discharged or merged.

Acknowledgements: This research was supported by funds from a United Nations University Fellowship.

Thesis:
Sharma, M.L. (1981) Groundwater potential of Nundooka Sandstone Fowlers Gap Arid Zone Research Station, Broken Hill (N.S.W.). M.AppSc. U.N.S.W.

7. HYDROLOGICAL RESEARCH

7.1 RAINFALL-RUNOFF RELATIONSHIPS IN ARID WESTERN N.S.W

T.G. Chapman, D.H. Pilgrim, I. Cordery, D.G. Doran (School of Civil Engineering, U.N.S.W.)

Although the volumes and frequency of runoff from the arid zone may be relatively low, this resource is a valuable one, being widely used for stock water and for diluting saline groundwater. In the absence of long-term stream flow records for the arid western half of N.S.W., dams in the area have traditionally been designed on the basis of local experience and judgement, with no quantitative basis on which to determine whether a catchment has sufficient runoff potential to fill a dam or tank. As the runoff characteristics of western catchments were known to be quite different from those in the coastal and tablelands regions of N.S.W., the design data from these areas could not be transferred to western N.S.W. In view of the considerable expenditure involved in the construction of these dams and tanks, and the importance of their satisfactory operation to the development of efficient management policies, it was considered desirable to obtain data on runoff from typical catchments in the arid zone.

In 1973, staff of the School, led by Associate Professor D.H. Pilgrim, visited the Station to carry out a preliminary survey of possible sites for the installation of equipment for collection of data on rainfall and runoff.

Commencing in 1974, with funding from the Water Research Foundation of Australia (WRFA), the project included two aspects: measurement of rainfall and runoff and of the relationship between them; and investigation of the conditions necessary for runoff to occur. (See 7.1.1 and 7.1.2 respectively.)

A network of recording instruments has been established on the Station, with siting based on three considerations: (1) to obtain data from a range of the different land systems (2) availability of suitable measuring sites (3) access in wet weather, necessitating locations near existing tracks.

In the hilly part of the Station, water level recorders have been installed by the University on one creek and three dams. Data has also been obtained from conventional stream gauging stations established on a further two natural basins by the Water Resources Commission of N.S.W. as part of the Australian Representative Basin Scheme (see 8.1).

Three small runoff plots have been installed on different land systems on each of two of the gauged natural basins. The plots are $25m^2$ and diamond-shaped, with galvanised steel cutoff walls delineating the boundaries. Runoff is collected in a cylindrical pit fitted with a recorder.

It was recognized that the small plots originally established on the flat alluvial areas of the Station could not satisfactorily sample the macroscopic features of most of this country. To sample these features, large 4 ha plots have been constructed on three different locations, with earth banks to delineate their boundaries. Tanks have been excavated at their downslope ends to act as collecting pits and have been fitted with water level recorders. A $120m^2$ plot has also been instrumented on the flat alluvial areas.

Rainfall intensities are being measured by a network of nine automatic rainfall recorders.

Acknowledgements: This project has been supported by a grant from the Water Research Foundation of Australia.

Publications:

Cordery, I, Pilgrim, D.H., Doran, D.G. (1983). Some hydrological characteristics of arid Western New South Wales. Hydrology and Water Resources Symposium 1983, Inst. Engrs. Aust., Natl. Conf. Publn. No. 83/13, pp 287-292.

Doran, D.G., Emmi, A.P. and Tilley, J.H. (1980) A hydrologic data network for arid zone research: An approach by the University of New South Wales at Fowlers Gap. Australian Hydrographic Workshop, 1980, Melbourne Oct.13-17.

Pilgrim, D.H., Cordery, I., and Doran. D.G. (1979). Assessment of runoff characteristics in arid Western New South Wales, Australia. The Hydrology of Areas of Low Precipitation, Proc. of the Canberra Symp., Dec. 1979, Internat. Assoc. Hydrol. Sciences, IAHS Pub. No. 128, pp 141-150.

Fowlers Gap data also utilized in:

Doran, D.G. (1979). A preliminary analysis of the applicability of generalized discrete distributions to sparse hydrological data. The Hydrology of Areas of Low Precipitation, Proc. of the Canberra Symp., Del. 1979, Internat. Asscn. Hydrol. Sciences, AIHS Pub. No. 128, pp 43-39.

Pilgrim, D.H. (1982). Assessment of Derived Rural and Urban Runoff Coefficients. Civil Eng. Trans. Inst. Engrs. Aust., Vol CE24, 1982, pp 235-241, Section 2-2.

7.1.1. RAINFALL RUN-OFF RELATIONSHIPS ON SMALL CATCHMENTS

This project utilizes information from the water level recorders installed on four natural basins to measure the flows of water into them, and from pluviographs which measure rainfall intensities at nine locations. Data from the two gauging stations installed by the Water Resources Commission is also utilised. Additional information is provided by flow and rainfall measurement instruments on the 4 ha plots on the flat alluvial country.

The records from these instruments provide information on the relationship between rainfall and runoff on small catchments in the arid West Darling region, which is needed for the design of stock dams and tanks and of their bywash capacities, and for design of road culverts and other types of creek crossings.

Analysis of the first 3 years of rainfall and runoff data provided some preliminary findings published by Pilgrim et al (1979). A background paper (Doran et al, 1980) describing the network in some detail was presented at the 1980 Hydrographic Workshop organized by the Australian Water Resources Council.

Results of a more comprehensive analysis of seven years of data have been reported by Cordery et al. (1983). High intensity convective storms were found to occur infrequently and most rainfall events result from widespread general storms, in contrast with widely reported results from other parts of the world. Streamflow is small but relatively frequent, over 40 runoff events having been observed in seven years. Appreciable depths of runoff are produced over a large proportion of the land surface but transmission losses keep the streamflows small. Data were obtained on losses to runoff from storm rainfall.

Data will continue to be collected as a long period of records is necessary for the derivation of firm relationships, especially with the extreme variability of rainfall and runoff in western New South Wales.

7.1.2 INVESTIGATION OF RUNOFF PROCESSES

In addition to utilizing the rainfall and runoff data from the 25 m^2 and 4 ha plots as described above, this project has involved regular surveys of vegetation condition and measurements of soil moisture contents on these plots. The state of the vegetation on each plot is being photographically recorded at intervals of about three months. Gravimetric soil water measurements are made regularly on surface and 150 mm deep soil samples taken from the proximity of each plot. A neutron moisture meter is also used. A time lapse camera has been recently installed to photograph the onset of runoff.

The aim of the project is to investigate the relative runoff-producing characteristics of different land types in arid areas such as Fowlers Gap, and the conditions (such as antecedent soil, wetness, rainfall duration and intensity, and vegetation cover) that are necessary before runoff commences. Knowledge of such factors will help in the development of sound methods for estimating runoff in western N.S.W.

Some preliminary results were published by Pilgrim et al. (1970), and further results are reported by Cordery et al. (1983). Over 40 runoff events were recorded over a seven year period. There is evidence of fairly low limiting values of rainfall above which runoff is always observed. There are occasions when runoff is produced from storms with as little as 5 mm of rain, conditions which are very different from those in the humid eastern part of the State. There is little evidence of any systematic differences of runoff from the different land types. Data collection and analysis are proceeding, and further results will be published at a later date.

7.2 DESIGN FLOOD ESTIMATION FOR SMALL CATCHMENTS IN WESTERN NEW SOUTH WALES

G.E. McDermott (M.E., 1982, U.N.S.W.; Supervised by Associate Professor D.H. Pilgrim, School of Civil Engineering, U.N.S.W.)

Although rainfalls and total runoff are small in the arid and semi-arid zones, flood flows to be passed by structures such as road culverts and bridges, and the spillways and bywashes of dams and excavated tanks are quite high. However, very little information has been available for estimation of the design flood flows for these structures.

Financed by an Australian Water Resources Council grant from the Department of National Development and Energy, this study used bankfull discharge estimates to provide the basis for an approximate method of flood estimation in hilly and undulating regions in New South Wales.

Bankfull flows were estimated at 35 sites at Fowlers Gap, 10 between Fowlers Gap and Tibooburra, and at 23 sites near Broken Hill and on the Barrier Highway between Broken Hill and Nyngan. A design equation was derived to relate these bankfull flows to catchment size and average stream slope. Frequency factors were also derived for determination of flows of various frequencies. The method is applicable to undulating and hilly regions in western New South Wales and catchment sizes up to 250km^2.

Acknowledgements: This research was supported by a grant from the Australian Water Resources Council of the Department of National Development and Energy.

Thesis:
McDermott, G.E. (1982). Design flood estimation for small catchments in New South Wales. M.E. U.N.S.W.

Publications:
McDermott, G.E. and Pilgrim, D.H. (1982) Design flood estimation for small catchments in New South Wales. Dept. of National Development and Energy, Aust. Water Resources Tech, paper No. 73, A.G.P.S. Canberra, 1982, 233p.

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McDermott, G.E. and Pilgrim, D.H. (1983) A design flood method for arid Western New South Wales based on bankfull estimates. Civ. Eng. Trans. Inst. Engrs Aust, Vol CE25, pp 114-120.

8. FLUVIAL GEOMORPHOLOGY

8.1 GEOMORPHIC PARAMETERS OF REPRESENTATIVE BASINS AND THEIR HYDROLOGIC SIGNIFICANCE

F.C. Bell, P.C. Vorst (School of Geography, U.N.S.W.)

Funded by the Australian Water Resources Council, the aim of this project was to develop procedures for mapping and measuring geomorphic parameters appropriate to the AWRC Representative Basins Program (1974).

The measurement and mapping of geomorphic parameters in Representative Basins has several purposes. Firstly, it provides descriptions of the physical characteristics of the basin which are useful for a variety of environmental studies, such as in the areas of land use planning and terrain evaluation, soil conservation, erosion and deposition, natural chemical cycling and wildlife ecology. Secondly, information on geomorphic parameters may be required for more specific purposes in hydrology, for example in the deterministic mathematical modelling of precipitation-streamflow processes. Such hydrologic applications have important roles in the design and operation of engineeering structures and in other aspects of developmental projects.

Commencing in January 1975 and concluding in May 1978, the study proceeded in two stages, each being of 19 months duration. The first stage consisted of a literature review, practical and theoretical investigations of established and suggested techniques, and preliminary field mapping of O'Hares Creek and Homestead Creek Representative Basins. In the second stage the techniques were evaluated and refined, and applied in complete surveys of O'Hares Creek, Homestead Creek and Deep Creek. Less detailed surveys were made of Brogers Creek and Yass River representative basins but these were valuable in testing the applicability of the techniques to a wider range of conditions. The second stage also included an investigation of the mathematical parameters of some deterministic models and their relationships to measured geomorphic parameters.

The arid zone of Australia provides a marked climatological and physiological contrast to the more humid areas where most gauged catchments are located. For this reason, the Homestead Creek Representative Basin on Fowlers Gap Arid Zone Research Station was chosen for detailed study.

With the aid of maps and aerial photographs, the basin was initially divided into relatively homogeneous geomorphic units. Geomorphic units are intended to account for mesoscale variability of the basin, and also provide a basis for the stratified sampling of channel and interfluve parameters to account for microscale variability.

Special attention was also given to the field surveying of relevant channel characteristics which are not normally obtainable from maps. Procedures were developed for assessing the systematic and random variability of channel parameters within units, making use of expected and observed correlations between parameters.

To measure and assess interfluve characteristics, data were obtained for surface roughness, soil and vegetation characteristics, in addition to commonly measured parameters of hillslope geometry.

Detailed data outputs for several Representative Basins, including Homestead Creek, were presented in a final project report to the Water Resources Council.

Acknowledgements: The project was supported by funds from the Australian Water Resources Council as part of the Representative Basins Program.

Publications:

Bell, F.C. & Vorst, P.C. (1981) Geomorphic parameters of representative basins and their hydrologic significance. Technical Paper No. 58. Department of National Development and Energy, Australian Water Resources Council. Australian Government Publishing Service, Canberra, 1981 (134 pages).

Vorst, P.C. & Bell, F.C. (1977) Catchment geomorphology and its hydrologic significance: A review. Australian Representative Basins Program Report No. 2. Australian Water Resources Council. Australian Government Publishing Service, Canberra, 1977 (22 pages).

8.2 ANALYSIS OF MINIATURE EXPANDING CHANNEL NETWORKS

A.D. Abrahams (School of Geography, U.N.S.W.)

Adjacent to Homestead Creek in South Sandstone Paddock, a large number of miniature drainage networks are incising and extending headwards into alluvial and colluvial deposits. These networks are identical in many respects to drainage networks developed in full-sized fluvially eroded landscapes. However, they are evolving extremely rapidly, and hence afford a unique opportunity to investigate the statistical properties of actively expanding networks.

During visits to the Station in 1974, 1975 and 1980, data were collected on the topological, link length and stream junction angle properties of 73 networks. In addition, these networks were mapped and photographed so that future changes in their form could be monitored.

These data have been used to date to investigate the topological and link length properties of channel networks. The main findings are as follows:

(1) There is no bias against the formation of cis links in expanding channel networks, though short cis links occur less frequently than short trans links.

(2) Tributary-source (TS) and source (S) links are similar in length in headwater areas, but the former links become longer than the latter ones downstream owing to the greater availability of space for TS links to develop.

(3) Both exterior and interior link length distributions are well fitted by the mixed gamma density. The development of the model density is based on the idea that link length distributions in natural landscapes represent a mixture of

link length populations from different parts of the landscape characterized by different ground slope and/or environmental conditions.

Investigation is continuing.

Acknowledgements:
This project was supported, in part, by a grant from the Australian Reseach Grants Scheme.

Publications:
Abrahams A.D. (1975). Initial bifurcation process in drainage networks. Geology 3: 307-308.

Abrahams, A.D. and Campbell, R.N. (1976) Source and tributary-source link lengths in natural channel networks. Geological Society of America. Bulletin 87: 1016-1020.

Abrahams, A.D. and Miller, A.J. (1982) An empirical approach to the frequency distribution of exterior link lengths in natural channel networks. Perspectives in Geomorphology, Vol 2, ed. H.S. Sharma, pp 59-83.

Abrahams, A.D. and Miller, A.J. (1982) The mixed gamma model for channel link lengths. Water Resources Research 18: 1126-1136.

8.3 DRAINAGE DISORGANIZATION IN ARID AUSTRALIA AND ITS MEASUREMENT
M. Sullivan (MSc Thesis, 1976, U.N.S.W.; Supervised by Prof. J.A. Mabbutt, School of Geography, U.N.S.W.)

Fowlers Creek was used as a case example in this study of arid zone drainage. As a small river channel which floods out over a short distance, Fowlers Creek offered an opportunity to study and elucidate the stages involved in channel breakdown.

The breakdown of Fowlers Creek involves changes in the form of the channel, a reduction of channel size, the splitting of the channel into distributaries, and the dying out of these distributary channels.

To study these changes, fourteen cross-sections were measured along the alluvial channel of Fowlers Creek. Nine of these sections were along the presently active channel, and five along a distributary course which is apparently abandoned, since river red gums (Eucalyptus camaldulensis) lining this channel were dead and reaches had become choked with silt. At each of these sections cross profiles were measured, and the slope of the channel reach levelled. Sediment samples were collected from the channel perimeter, the levee (where present) and the backplain, for analysis for their silt and clay content. The channel plan was also studied on airphotographs in each of these reaches to see if changes in channel form were associated with changes in the load carried.

Hydrologic models were tested against the Fowlers Creek system, and explanations sought for the deviation from predicted channel and sediment characteristics.

Models for the onset of channel flow were modified to derive a model which would predict the cessation of flow in a floodout situation. This was tested using data from Fowlers Creek and the Finke River. The model has since been used by other researchers e.g. in the Wollemi-Hunter River areas.

Thesis:
Sullivan, M.E. (1976) Drainage disorganization in arid Australia and its measurement. MSc. U.N.S.W.

Publications:
Sullivan, M.E. (1973) Downstream changes in profile characteristics of Fowlers Creek, N.S.W. Proc. I.A.G. Conference 1973.

Sullivan, M.E. (1977) Desert floodouts: a study of the processes of failure of arid zone channels. Proc. I.A.G. Conference 1977.

8.4 FLUVIAL LANDFORMS, RUNOFF AND SEDIMENT TRANSPORT ON FOWLERS GAP STATION

P. Fanning (MSc Study Supervised by Dr C.F. Pain, School of Geography, U.N.S.W.).

The principal sources of sediment along Homestead Creek, an upland tributary of Fowlers Creek, have been identified and monitored over a period of 3 years (1978-1981), and a model of sediment movement developed. This has then been compared with the historical pattern of sediment movement, as exemplified by the stratigraphic record preserved in the valley fill sediments to determine to what extent the types and amounts of sediment transported have changed in the historical and geological past.

Hypotheses concerning the causes of these differences have then been examined and include: (1) the effects of environmental change during the Pleistocene and Holocene periods (2) the effects of environmental change during European occupation (3) the effects of increased grazing pressure during the period of European occupation.

An MSc thesis based on this work is nearing completion.

9. CLIMATOLOGY

9.1 CLIMATE OF FOWLERS GAP STATION AND FOWLERS GAP-CALINDARY AREA

F.C. Bell (School of Geography, U.N.S.W.)

In this project, Dr Bell carried out a detailed study of climatological records and climatological references relating to the entire Western Division of N.S.W. to enable inferences to be drawn about the climatological characteristics of Fowlers Gap Station and the Fowlers Gap-Calindary area.

Detailed climatic records at Fowlers Gap Station commenced in November 1968 (although daily rainfalls had been recorded for some years earlier). Information obtained from November 1968 to approximately December 1971 was correlated with long-term data for other stations in the region and examined as part of the general dynamic climatology of north-western N.S.W.

Results were reported in the two publications listed below which deal with separate climatological aspects.

Acknowledgements: This work was supported, in part, by funds from the Water Research Foundation of Australia.

Publications:

Bell, F.C. (1972). Climate. Chapter III, Lands of the Fowlers Gap-Calindary Area New South Wales, Fowlers Gap Research Series No. 4 pp 41-67. University of New South Wales.

Bell, F.C. (1973) The climate of Fowlers Gap Station. Chapter IV, Lands of Fowlers Gap Station New South Wales, Fowlers Gap Research Series No. 3 pp 45-68. University of New South Wales.

9.2 ARID ZONE RAINFALL STUDIES

F.C. Bell (School of Geography, U.N.S.W.)

This is a long-term project involving the recording of rainfall at a number of sites at Fowlers Gap for at least fifteen years. When sufficient data are available, it should be possible to make a detailed study of the meteorological processes and space-time characteristics of Australian arid zone rainfall. Such a study has not been possible to date because of the general paucity of detailed rainfall data from the Australian arid zone.

The project commenced in 1970 when a network of rainfall gauges was established at the Station. From 1977, information has also been available from gauges established at runoff plots by the U.N.S.W. School of Civil Engineering (see 7.1). It is expected that by the end of 1984, sufficient data will have been collected for reliable conclusions to be drawn.

Acknowledgements: Early work on this project, providing

data on spatial variability of convective rainfall, was supported by funds from the Water Research Foundation of Australia 1971-1972.

Publications:

Bell, F.C. (1972) Rainfall intensities in inland Australia. Institute of Australian Geographers' Conference, Canberra, Feb 1972.

Bell, F.C. (1979) Precipitation. Chapter 13 in "Arid-Land Ecosystems: Structure, Functioning and Management." ed. R.A Perry, D.W. Goodall, Cambridge University Press 1979. pp 373-392. (International Biological Program Series).

9.3 EFFECT OF LOCAL TOPOGRAPHY ON RAINFALL AND RAINFALL MEASUREMENT

E.A. Fitzpatrick (formerly of School of Geography, U.N.S.W.)

Early in 1980, 19 non-recording rain gauges were installed on N-S and E-W slopes east of the Homestead at Fowlers Gap, with gauges set both vertically and normal to the ground surface, to determine the effect of local topography on rainfall and rainfall measurement. To date, it has not been possible to complete any worthwhile analyses of data because of the paucity of storm events during the drought conditions of recent times.

10. ARCHITECTURE

10.1 SOLARCH HOUSE

(Solarch - Solar Energy Research Unit, Graduate School of the Built Environment, Faculty of Architecture, U.N.S.W.)

The Solarch Group was established in November 1974 to investigate the use of solar energy and energy-efficient techniques in building. The first research programme undertaken was the design, construction and monitoring of a solar energy powered house suited to the arid zones of Australia. It was intended also to provide the undergraduate students of the Faculty of Architecture with an introduction to design for climate and the use of solar energy in building.

The Solarch Experimental House was designed in 1975. The aim of the design was to produce a house of conventional appearance, suited to the living style of the country, but largely prefabricated to overcome the problems of building in remote areas and to take advantage of the various characteristics of the arid zone climate.

The design is based on a system of well-insulated, prefabricated lightweight roof and wall panels erected on a concrete floor slab, which acts as a store for solar energy received through the windows. This is combined with a solar energy collector and hydronic storage system for boosting. The concrete floor slab has a series of helical coils of

plastic tubing cast-in to enable hot water from the storage tank to be circulated through the floor for additional heating as required. The water is heated by solar energy collectors which are an integral part of the north roof. A further area of collectors provide hot water for domestic use. Retractable canvas awnings on the north provide shade during the summer whilst allowing deep sun penetration during winter to heat the floor. The east and west walls are windowless.

The prefabricated components of the house were built in Sydney by staff and students, and were transported to the site in November 1976. On-site assembly was undertaken in December of that year. However, the house was not occupied until June 1978, due to staff changes and other related problems at Fowlers Gap.

The performance monitoring system was installed and commissioned in late 1977, but was beset with teething problems until mid-1979. In all, the monitoring period extended from May 1978 to December 1980, after which all recording equipment was removed for repair and subsequent use on other projects.

Analysis of the data collected indicates that the house performs satisfactorily in winter but is perhaps too warm in summer. Poor building management and the lack of circulatory fans have contributed to this situation, but a number of other influences have also become clear. It appears that the concrete slab floor does not provide sufficient thermal mass to hold internal temperatures down in summer. Additional internally located thermal mass could be added in the form of masonry walls. The results indicated that winter temperatures inside should have been one or two degrees higher. To increase the temperature elevation in winter however it would be necessary to increase the north glass area, thus increasing direct solar gains. Such action may improve the winter performance at the expense of further deterioration of the summer performance. One way of overcoming this may be to incorporate insulated shutters which can be used to vary the north glass area on a seasonal basis.

Acknowledgements:
This project received financial support from the Australian Housing Research Council. In addition, many companies donated materials and technical assistance to the project.

Reports etc:

Initial Report to Australian Housing Research Council. July 1976. by J.A. Ballinger.

Progress Report No. 1 1976.

Second Interim Report to Australian Housing Research Council. 1978. By J.A. Ballinger. Construction of Solarch Experimental House Mk 1 at Fowlers Gap.

Progress Report No 2 to Australian Housing Research Council. June 1979. Published as Fowlers Gap Research Series No. 5. 1980.

A report on Energy for Fowlers Gap Arid Zone Field Station. By J.A. Ballinger. Working Paper G.8021 April 1980.

Energy options for remote communities in Australia. Paper presented at the Fowlers Gap Arid Zone Field Station Open Day. July 1980. By J.A. Ballinger.

Final Report 1982. A report to the Australian Housing Research Council on the thermal performance of the Solarch Experimental House Mark 1, Fowlers Gap, New South Wales. By J.A. Ballinger.

Publications:

Bald, M., Ballinger, J.A., Hassall, D.N.H. (1980) Performance monitoring of passive solar demonstration houses. Proc. of the Australian and New Zealand Architectural Science Association Conference, 7-8 July 1980.

Ballinger, J.A. (1976). Solarch Experimental House Mark 1 - Design Proposal. Proc. International Solar Energy Society (Australian and New Zealand Section) Symposium, August 1976, Sydney.

Ballinger, J.A. (1977) Solarch Experimental House Mark 1 - the application of solar energy in Australian housing. N.S.W. Builder, Vol 6, No 8, pp 404-411.

Ballinger, J.A. (1977) Solarch Experimental House Mark 1 - Design and Construction. Therm.Insul.J2., No. 4, 6-9.

Ballinger, J.A. (1978) Solarch House. In Australian Access No 2, Ed K.V. Smith, Earth Garden, pp 257-259.

Ballinger, J.A. (1979) Aspects of the performance of a direct gain passive solar house for an arid zone climate. Proc. Thermal Insulation Institute of Australia Seminar: Energy and Thermal Insulation - The World Scene, Sept 1979.

Ballinger, J.A. (1980) The Solarch Experimental House Mark 1. Fowlers Gap Arid Zone Research Station Research Series No. 5. University of New South Wales.

Ballinger, J.A. (1980) A thermal performance report on the Solarch Experimental House at Fowlers Gap, N.S.W. Proc. of the Australian and New Zealand Architectural Science Association Conference, 7-8 July 1980.

Ballinger, J.A. (1981) Design for sun and climate. Bradford Insulation Information Booklet, May 1981.

Ballinger, J.A. (1982) A sunny future with passive solar design. Solarch, University of New South Wales.

11. PEDOLOGY

11.1 SOIL FORMATION AT FOWLERS GAP

C.J. Chartres (School of Geography, U.N.S.W.)

Since July 1979, Dr Chartres has carried out an investigation of soil formation at Fowlers Gap, aimed at identifying the soil parent materials of desert loam soils and at determining to what extent the soils have been affected by pedogenesis.

The results have indicated that the soils have at least three distinct layers of material (i.e. A horizon, B1/B2 horizons and Bcs/C horizons.) The BcsC horizons are truncated older soils; the B1/B2 horizons represent an aeolian deposit of silt and clay; and the A horizon is predominantly slope wash.

Techniques used have included routine soil physical and chemical analyses, X-ray diffraction, X-ray fluorescence, micromorphology and optical mineralogical analyses.

Studies of silica indurated hardpans and the distribution of aeolian silts and clays are continuing in north-western N.S.W.

Publications:

Chartres, C.J. (1982) Quarternary dust mantle soils in the Barrier Range, N.S.W. In: Quarternary Dust Mantles of China, New Zealand and Australia (ed Wasson, R.J.). A.N.U. Dept. of Biogeography and Geomorphology, Canberra pp 153-160.

Chartres, C.J. (1982) Pedogenesis of desert loam soils in The Barrier Range, north western N.S.W. I. Soil Parent Materials. Aust.J.Soil Res. 20: 269-281.

Chartres, C.J. (1983) Pedogenesis of desert loam soils in the Barrier Range, north western N.S.W. II. Weathering and Soil Formation. Aust. J. Soil Res. 21: 1-13.

Chartres, C.J. (1983) The micromorphology of desert loam soil and implications for Quarternary Research in western N.S.W., Australia. In: Soil Micromorphology (ed. Bullock, P. & Murphy, C.) Proc. of Int. Working Meeting on Soil Micromorphology, London (1981). pp 273-279. A.B. Academic Publishers, Berkhamsted, U.K.

11.2 THE MORPHOLOGY AND GENESIS OF SCALD SOIL SURFACES IN AN ARID ENVIRONMENT

P.A. Hazelton (PhD Thesis, 1980. U.N.S.W.; Supervised by Dr M.D. Melville, School of Geography, U.N.S.W.)

This study was undertaken to more precisely establish the morphology of scalds and to investigate their likely genesis. Literature in this field had made limited

distinction between various types of bare areas, and little work had been completed concerning the physical and chemical nature of scald soils. Hazelton set out by chemical and physical means to distinguish between those bare areas that are scalds and bare areas that are relatively transient features of the surface and thus not scalds; to determine whether the chemical properties of the soil profile below the surface related to a distinctive surface type, and whether scalds were a residual water erosion feature.

The study area was located at Fowlers Gap.

Following an initial reconnaissance in July 1973, the main study was commenced in June 1974 when a 1300 m transect was established, with permanently marked sampling points at 10m intervals traversing various types of bare areas. The surface micro-relief was surveyed by Dumpey level and soil samples were taken at four constant depths 0-5 (A), 15-20 (B), 45-50 (C), 85 (D) cm. These samples were analysed in the laboratory in order to characterise some of their important physical and chemical properties.

In November, 1974, two further transects were surveyed at right angles to the existing transect, and were sampled in a similar manner to the main transect. Numerical analyses of the laboratory results from the main transect were undertaken to characterise and separate the sampling points into scald and non-scald soils.

Further field sampling was undertaken in March 1978 to determine whether the criteria established for identifying scalds was unique to Conservation Paddock. From the results obtained, it was shown that the properties which characterised scalds were not unique to Conservation Land System.

It was concluded that in scald identification, chemical properties rather than physical appearance should be used, as it had been demonstrated that all bare surfaces could not be assumed to be scalds. Furthermore, from the pipette analysis results, scalds in the Fowlers Gap Region appeared to be ancient fluvially-deposited leached surfaces exposed by water erosion rather than, as literature suggested, being formed by it.

Thesis:
Hazelton, P.A. (1980) The morphology and genesis of scald soil surfaces in an arid environment. PhD U.N.S.W.

Publications:
Hazelton, P.A. Morphology and genesis of scald soil surfaces in a semi-arid environment - Fowlers Gap N.S.W. In press, Catena, Special Number on Acidic Soils following International Conference on Aridic Soils, Jerusalem 1981.

Hazelton, P.A. & Melville, M.D. Identification of Scald Soil Surfaces in a Semi Arid Environment - Fowlers Gap. NSW. In press, Geoderma.

11.3 MORPHOLOGY AND GENESIS OF CRABHOLE MICRO-RELIEF AT FOWLERS GAP

G. Upton (BSc Hons Thesis, 1981, U.N.S.W.; Supervised by Dr M. Melville & Prof. J.A. Mabbutt, School of Geography U.N.S.W.)

Crabholes are small micro-relief depressions averaging 50cm in diameter and 30 cm in depth, and occur on a range of land surfaces in the generally flat alluvial plains that extend either side of the Barrier Range in western New South Wales. In this fourth year Honours project in Applied Geography, Upton defined these land surfaces for crabhole occurrence at Fowlers Gap in the eastern side of the Range.

Four basic land surface types were defined for the plains of Fowlers Gap, and were discussed in terms of their soils, vegetation pattern of water infiltration, and the degree of crabhole occurrence. Crabholes most commonly occur on non-crusted surfaces, while on crusted surfaces, crabhole developmnent is minimal. The upper 60 cm of the soil profile of the non-crusted surface consists of three distinct layers. From field experimentation and observation, the role of these layers was discussed in terms of their controls on water infiltration and crabhole genesis. The main processes were found to include drafting in the topsoil and tunnelling in the subsoil, which only occur where a direct path to the subsoil is provided by combinations of vertical crates.

The impact that certain types of land use have on crabhole development (and vice versa) was also discussed, and it was suggested that compaction of the topsoil may retard crabhole development.

Thesis:

Upton, G. (1981) Morphology and genesis of crabhole micro-relief at Fowlers Gap. BSc Hons. U.N.S.W.

Publications:

Upton, G.M. (1983) Genesis of crabhole micro-relief at Fowlers Gap, western New South Wales. Catena 10: 382-392.

11.4 SOIL SALINITY/LANDFORM RELATIONSHIPS AT FOWLERS GAP

K. Hucker (BSc Hons Thesis, 1983, UNSW; Supervised by Dr C.J. Chartres, School of Geography, U.N.S.W.)

This project, conducted during 1983, investigated the possible factors associated with the distribution of soil salts at Homestead Creek, Fowlers Gap.

The distribution of salts was examined both vertically in the profile and laterally across the Homestead Creek Valley along two transects crossing 4 soil types: lithosols, desert loams, brown solonized soils and alluvium. A third transect

across the aeolian material blanketing dolomite (desert loam soils) was also examined.

In addition, random grid sampling on each of the four soil types was carried out to determine the variability of salt concentrations within each soil type.

Results show that variations within soil groups, in particular the desert loams, is high and may be accounted for by differences in infiltration and evaporation from the gilgai micro-relief.

The brown solonized soils are highly calcareous but generally low in soluble salts, particularly sodium, although in places calcium concentrations are high. Sodium concentrations of the brown solonized soils when found adjacent to but lower in the landscape than desert loam soils (which are high in sodium) indicate migration of ions downslope from the desert loams into the brown solonized soils.

Thesis:
Hucker, K. (1983) Soil salinity/landform relationships at Fowlers Gap. BSc. Hons. U.N.S.W.

12. SOIL/VEGETATION ASSOCIATION

12.1 SOIL/VEGETATION ASSOCIATIONS IN AREAS OF PATTERNED GROUND AT FOWLERS GAP, WESTERN N.S.W.

M.D. Melville, J.R. Dodson (School of Geography, U.N.S.W.)

This ongoing project commenced in 1977 when marsupial-proof fencing was erected around four sites on patterned ground areas at Fowlers Gap. The sites were photographed in colour from the air and maps prepared of their microtopography and vegetation/soil surface types. Chemical analyses of soil and plant samples were conducted for each site.

Very significant differences in soil profile properties have been established between various soils surface/vegetation association units as mapped in the four areas of patterned ground. Therefore, the detailed association maps of the enclosure areas in Airstrip and Hotel Paddocks represent detailed soil type maps. The degree of difference between the soil profile properties are as great as might be expected between different Great Soil Groups even though the mosaic pattern includes areas of only a few metres square. Therefore, no single representative profile can be described for these soil landscapes. From other soil profile measurements, it is hypothesised that the maintenance of the soil/vegetation pattern relates to the microtopographical/microhydrological characteristics of the landscape. The analysis of these data is continuing.

The chemical characteristics of these soil types is being related to those of some plant species that they support in these patterned ground areas. These studies are continuing, along with detailed sampling of plant species distribution and abundance over a range of seasonal conditions.

Note: See also 33.17.

12.2 SOIL VEGETATION SURVEY OF SALT I AND SALT II PADDOCKS

L. Walsh (BSc Hons Thesis, 1976, U.N.S.W.; Supervised by Dr M. Melville, School of Geography, U.N.S.W.)

This investigation was designed to test the suitability of the multivariate analytical technique, non-centered varimax principal components analysis, for use in vegetation surveys of homogeneous landscapes such as the Conservation Land System of Fowlers Gap Arid Zone Research Station. Such a survey would provide a benchmark of the vegetation with which changes in the pastures due to grazing or natural climatic variation could be compared. To verify these results replicate analyses were done.

This vegetation structure was then related to environmental factors such as drainage, soil salinity, soil texture and distance from the nearest stock watering place by the use of a canonical correlation analysis. This method examined simultaneously the soil and vegetation variation.

Nodes of vegetation did result and some of these could be positively identified. However, in most cases it was difficult to relate these to environmental factors as there was a lack of background information about the species and communities. Drainage was the most significant factor controlling the vegetation structure. The pastures were found to be severely degenerated as the unpalatable perennial copperburrs, B. divaricata and B. ventricosa were dominant.

Thesis:

Walsh, L. (1976) A survey of the vegetation of Salt I and Salt II paddocks of Fowlers Gap Research Station, relating the vegetation to selected soil properties. BSc Hons. U.N.S.W.

12.3 A STUDY OF THE DISTRIBUTION AND REGENERATION OF EUCALYPTUS GILLII, MAIDEN (CURLY MALLEE)

R.M. Read (BSc Hons Thesis, 1983, U.N.S.W; Supervised by Dr J.R. Dodson, School of Geography, U.N.S.W.)

Eucalyptus gillii is a mallee found in the Flinders Ranges of S.A. and the Barrier Ranges of western New South Wales. It has a restricted distribution being found on shallow calcareous soils on undulating topography. At present there is little evidence of regeneration.

The purpose of this study, conducted during 1983, was to investigate the importance of soil in controlling its distribution and assess its population characteristics.

This involved the testing of the seed's viability, the analysis of the effects of soil on its germination and growth under controlled moisture conditions, the comparison of soil chemical properties relative to the presence and absence of E. gillii and the comparison of population structure across the geographic range of the species.

It was found that seed viability or dormancy was not responsible for the lack of regeneration of E. gillii and that environmental parameters such as climate, soils and competition were inhibiting regeneration.

Texture appeared to be an important control on the germination of seeds where optimal soil moisture conditions existed. Chemical properties of the soil only affected the growth of E. gillii during latter stages of its development.

Population structure varied with geographic location and two significantly different populations were identified.

The implications of these results were then discussed in relation to its distribution and population status.

Thesis:
Read, R.M. (1983) A study of the distribution and regeneration of Eucalyptus gillii, Maiden, (Curley Mallee). BSc Hons U.N.S.W.

13. PLANT ECOLOGY

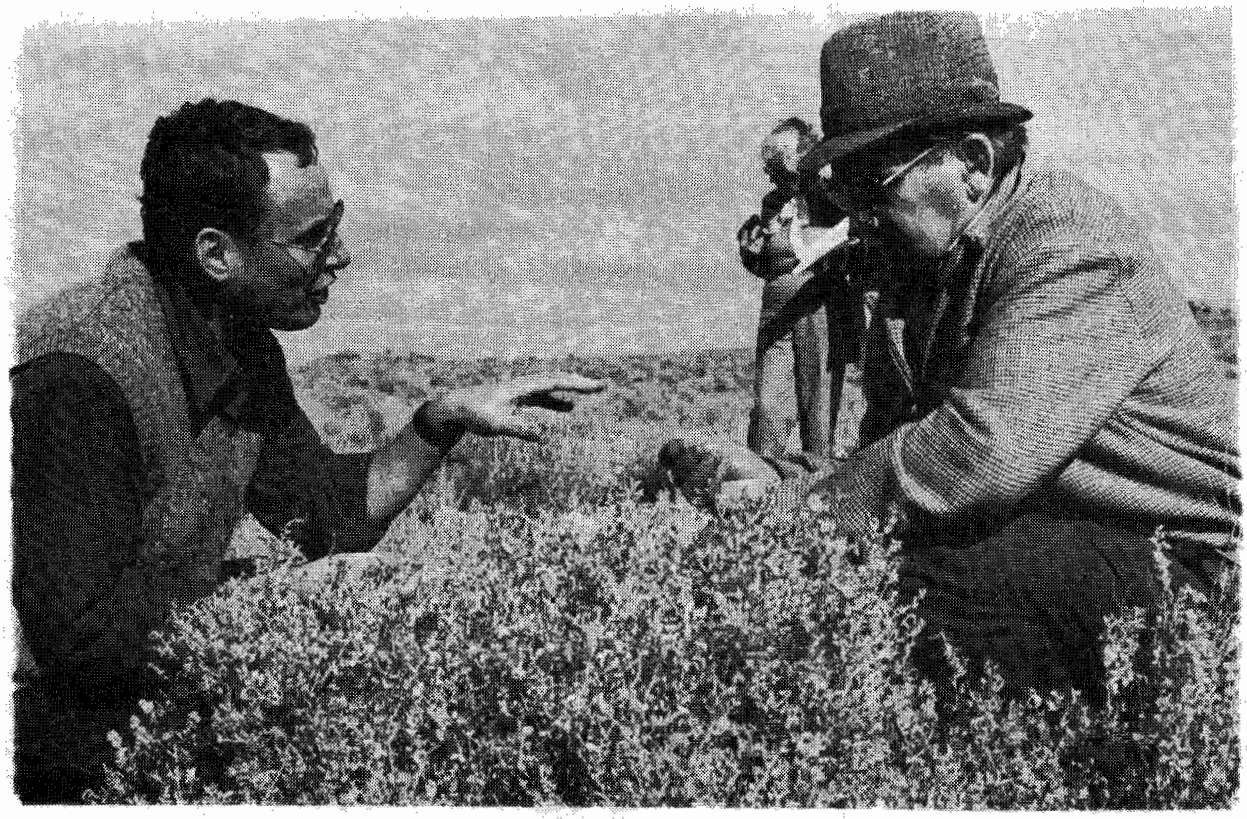
13.1 GERMINATION IN RELATION TO SEASON OF RAINFALL

J.P. Burrell (School of Geography, U.N.S.W.)

From 1969 to 1973, Dr Burrell conducted an investigation of germination in relation to season of rainfall in the South Sandstone enclosure of Fowlers Gap.

Instruments installed included soil thermometers and a pluviograph. After rainfall, germination data as species/abundance were collected along 10cm wide permanent transects running the length of the enclosure. Temperature requirements for germination of ephemeral species were tested at the gradient control germinator. Soil was also collected for checking the amount of seed storage in a glasshouse experiment at Kensington.

Though most of the data obtained have since been destroyed in cyclone Tracey, vertical stereo colour slides taken at the time of the November 1969 sampling have survived.



Dr Mark Westoby of the School of Biological Sciences, Macquarie University See 13.2, 13.3, 13.4, 14.1) examining vegetation cover with Mr Dick Condon, Western Lands Commissioner. Photo: R. Hannah.

Dr Jenny Anderson of the School of Zoology, U.N.S.W., explains to Professor Ray Golding, Pro-Vice-Chancellor, U.N.S.W., the operation of the blowfly trap used in blowfly ecology research at the Station (See 24.1, 24.2). Photo: R. Hannah.

13.2 SPECIES RICHNESS OF VEGETATION

B. Rice (Independent researcher), M. Westoby (School of Biological Sciences, Macquarie University)

Tenth ha plots were sampled at Fowlers Gap for variation in plant species richness after summer rain in February 1976, and again after winter rain in August 1978, as part of a larger project dealing with richness of Australian vegetation-types.

Data were collected from seven study areas within Australia, including Fowlers Gap.. At each sample site, an area 50 x 20m was searched and the species for all vascular plants found within it were recorded. The plots were placed subjectively in each study region in such a way as to sample a cross section of the major types of vegetation present, and so are not a random sample of all the vegetation in the given region.

At Fowlers Gap, the total richness of most sites was in the range 50-80 species, counting both winter and summer ephemerals. These values are comparable with those found in semi-arid vegetation on other continents. Relatively few of the Fowlers Gap species are fully perennial, surviving droughts such as the 26 month one which intervened between the two sampling periods of this study, and few grow as ephemerals during both seasons.

Publication:

Rice, B. and Westoby, M. (1983) Plant species richness at the 0.1 hectare scale in Australian vegetation compared to other continents. Vegetatio 32: 129-140.

13.3 DEMOGRAPHY OF ATRIPLEX VESICARIA

M. Westoby (School of Biological Sciences, Macquarie University), B. Rice (Independent researcher)

From 1975, Drs Westoby and Rice have monitored the recruitment and survival of individuals of Atriplex vesicaria in permanent transects in Johnstone and Sandstone paddocks.

The transects are arranged along radii leading away from water. It is expected that grazing pressure from stock will be greater closer to water. The main purpose of the project is to explore the exact effects of this on the survival and vigour of individual plants of various species and size-classes.

The location and size of individual plants in these transects are measured and recorded from time to time.

Following extensive mortality of adults during the 1976-78 drought, 5 cohorts of seedlings have established. The fourth and fifth of these were about 4% the pre-drought density of adults, suggesting that the soil seed bank is largely exhausted. In Johnstones a 50 year drought in 1981-82 killed

most seedlings, while in Sandstone where the summer drought was less intense, only the youngest seedlings suffered increased mortality.

Publications:
Westoby, M. (1980) Elements of a theory of vegetation dynamics in arid rangelands. Israel J. Botany. 28: 169-194.

Westoby, M. (1981) How diversified seed germination behaviour is selected. Amer. Nat. 118: 882-885.

13.4 SOIL SEED RESERVES

M. Westoby, J.M. Ewen, A.C. Grice (School of Biological Sciences, Macquarie University)

Data on soil seed reserves were collected at Fowlers Gap over a period of drought which followed heavy rains and consequent heavy seed-set.

Seeds were extracted from 482 fifty-gram samples of soil collected from a large range of locations in January 1976, August 1976, January 1977, August 1977, November 1977 and December 1977. One to three replicate samples were taken from each location. Most locations were sampled repeatedly, but the set sampled at each date was not completely the same. Seeds were extracted from soil samples by flotation and counted under a binocular microscope. Replicate soil samples were spread thinly on sterilized soil and kept moist under various conditions of temperature and day length and the germinating seedlings counted until emergence stopped. Correction coefficients were obtained for both procedures to allow absolute density to be estimated.

The study was preceded by moderate winter rains and heavy summer rains which led to substantial inputs of seed to the soil reserves. As there were no further rains producing growth and seed-set for the duration of the study, it was possible to examine the decline in the soil seed reserves of individual species in the absence of further input.

It was found that soil seed populations of three common grass species, Dactyloctenium radulans, Sporobolus actinocladus, and Enneapogon avenaceus, did not decline detectably over sixteen months of drought despite harvester ant activity. These data contrasted with evidence from North America showing that desert soil seed reserves are substantially depleted both by ants and by rodents.

Acknowledgements: This work was funded by the Australian Department of the Environment.

Publication:
Westoby, M., Cousins, J.M., and Grice, A.C. (1982) Rate of decline of some soil seed populations during drought in western New South Wales. Chapter 2 of Ant-plant interaction in Australia ed. Buckley, R.C. Dr W. Funk Publishers, The Hague.

13.5 THE DEMOGRAPHY OF THE LEGUMINOUS SHRUBS ACACIA VICTORIAE, CASSIA NEMOPHILA AND C. PHYLLODINEA IN SEMI-ARID SOUTH-EASTERN AUSTRALIA

A.C. Grice (PhD Study, Supervised by Dr M. Westoby, School of Biological Sciences, Macquarie University)

In this doctoral study, Grice investigated the population structure of three shrub species of semi-arid Australia. Work commenced in May 1978. The thesis has been submitted in 1984, and a paper is in preparation.

The study is aimed at answering the following questions: (1) What population structures occur (2) Is there a source of intermittency of recruitment to adult populations; four possible sources being unavailability of seeds, inviability of seeds, lack of conditions suitable for germination, or failure of seedlings to survive, (3) How, in terms of recruitment, growth and mortality, is the structure of adult populations determined.

Results indicate that population structure varies greatly over short distances so that some populations are dominated by small individuals while others have very few. If recruitment is intermittent, it is due to intermittent seedling survival. Germination is frequent and often on a large scale. Size-frequency histograms reflect growth rates of "established" plants rather than simply the timing and scale of recruitment from a seed-bank.

Acknowledgements: Mr Grice was in receipt of a Commonwealth Postgraduate Research Award.

13.6 GERMINATION BIOLOGY OF ARID-ZONE EPHEMERALS

E. Singer (PhD Student, Institut Fur Spezielle Botanik, Mainz, West Germany)

From 1978 to 1980, Mr Singer, a visiting research student from West Germany, made use of laboratory facilities at Macquarie University in a study of the germination biology of arid-zone ephemerals. Field studies and specimen collections were carried out at Fowlers Gap.

The major conclusion reached was that the classic laboratory germination experiment whereby seeds are arranged on filter paper and cultivated under controlled temperature and environmental conditions may be misleading, as the actual field germination behaviour of a seed is influenced significantly by the "fruiting structure" of each species. The physical shape and properties of the fruiting structure modifies the immediate environment of the seed itself and hence its germination behaviour.

Further information on this project is unavailable at the time of printing.

13.7 EVALUATION OF PLANT BIOMASS-DENSITY RELATIONSHIPS AS A POTENTIAL TOOL IN THE ASSESSMENT OF DRYLAND RANGE CONDITIONS AND TRENDS

D.J. Anderson (School of Botany, U.N.S.W.)

Supported by the Rural Credits Development Fund, the principal objectives of this study were to determine whether the "self-thinning rule" could be applied satisfactorily to monospecific stands of chenopod shrublands characteristic of semi-arid rangelands in western N.S.W. and whether the application of this rule could provide an index for simply evaluating range condition and/or trend.

Preliminary data sets were gathered originally during the period April 1977 through to December 1978. Six sites located at increasing radial distances from a principal watering point in Sandstone Paddock were selected initially for detailed analysis. Density and corresponding biomass data were collected for Atriplex vesicaria populations in (5 x 5) m quadrats located in a stratified, random fashion within each site, so as to sample representatively small-scale variability in abundance, and performance known from earlier studies by Anderson to be influenced by local microtopographical variation.

Collection of corresponding data sets was extended subsequently to Maireana-dominated shrubland in Holding Paddock to provide information on biomass/density relationships in multispecific stands for comparison with the essentially mono-specific saltbush stands.

As preliminary data analysis proceeded, it became obvious that a two-year period of data collection was inadequate to provide an effective insight into likely variations in effective rainfall. Accordingly, data have been gathered on a comparative basis for the period April 1977 - December 1982.

It has been concluded from information gained to date that the "self-thinning rule" may apply in monospecific stands of chenopod rangeland in semi-arid Australia, but only when a particular cohort is sufficiently abundant and aged to promote competition and therefore a biological basis for mortality by thinning. Thus the application of the self-thinning rule in studies of population dynamics in Australian perennial shrublands may not necessarily provide a simple basis for evaluating rangeland condition per se, but certainly focuses important attention on the dynamics of growth and regeneration in these shrublands.

Two papers are in preparation.

Acknowledgements: The research was supported by a grant from the Rural Credits Development Fund.

13.8 PLANT PATTERN ANALYSIS AND RADIAL DISTRIBUTION FUNCTIONS

J. Emmerick (PhD Thesis, 1979 U.N.S.W.; Supervised by Professor D.J. Anderson, School of Botany, U.N.S.W., & Dr M.B. Dale, Cunningham Laboratories, CSIRO)

This project was a methodological one, concerned with developing techniques for the analysis of spatial patterns in plant populations.

Spatial pattern analysis can provide useful ecological information, throwing light upon structure and process in the plant community. When community structure is understood, information which can be a basis for designing sampling regimes for a wide variety of studies becomes available. Pattern analysis may have future applications in fields such as the remote sensing of vegetation, the implications of which have not yet been fully developed.

In this study, conducted from 1975 to 1979, Emmerick developed a method of plant spatial pattern analysis using Radial Distribution Functions (RDF). The RDF is defined as the average relative density of individuals at a specified distance from an arbitrary individual. It was intended that the method should be readily understood and flexible so that it could be used in investigative studies. For this reason, the RDF method was developed in an experimental, empirical way rather than from formal mathematical theory. The lack of mathematical formalisation necessitated the use of an extensive series of trials with artificial populations in which the behaviour of RDFs in response to various data structures could be observed. While RDF behaviour could be characterised with artificial data sets, the utility of RDF analysis in practical situations could only be assessed through applications to field data.
Fowlers Gap yielded two data sets (for atriplex vesicaria) which were used for testing and developing pattern analytic techniques.

Findings in regard to atriplex vesicaria were substantially in agreement with those of Professor D.J. Anderson (see 13.6) whose work was not primarily methodological but who was concerned with understanding the pattern and regeneration in populations of perennial saltbush (Atriplex vesicaria).

Acknowledgements: Dr Emmerick was in receipt of a CSIRO Postgraduate Scholarship for the duration of this study.

Thesis:
Emmerick J. (1979) Plant pattern analysis and radial distribution functions. PhD U.N.S.W.

13.9 MINERAL CYCLING IN GILGAI-PATTERNED SALTBUSH COMMUNITIES

J.L. Charley (Department of Botany, University of New England)

From 1970 to 1976, Dr Charley conducted field and laboratory studies to investigate the process of mineral cycling in a saltbush community at Fowlers Gap.

Mineral cycling is the overall process whereby chemical elements circulate between compartments of the ecosystem in response to biotic activities. For convenience, the general pathway can be said to begin where active and passive processes move inorganic ions from the substrate into plant roots. Subsequently these elements are incorporated to varying degrees in organic form, utilized and redistributed within the plant, and eventually returned to the soil in litter. Decomposition of organic residues ultimately restores the contained minerals to inorganic form and they can once again repeat the circuit.

Numerous interconnected sub-compartments or pools comprise this overall pathway and there are in addition certain points at which transfers across the boundaries of the ecosystem occur.

In the arid zone, where the environment is unstable and short-term variability is the predominant characteristic of the climatic setting, significant biological activity is seldom sustained for long periods and mineral transfers between separate ecosystem pools occur in short bursts. The principal distinguishing feature of mineral turnover in the arid zone must be that it is pulsed in time.

In the publication listed below, Charley sets out the findings of his research, discussing the contributions of the major aspects of the complex of functions that comprises the mineral cycle of semi-arid and arid ecosystems.

Publication:

Charley, J.L. (1977) Mineral cycling in rangeland ecosystems Chapter VIII in "Rangeland Plant Physiology" ed. R.E. Sosebee. Society for Range Management, Range Science Series No 4, Denver.

13.10 A STUDY OF THE CHANGES IN POPULATIONS OF ATRIPLEX VESICARIA (BLADDER SALT BUSH) AND MAIREANA ASTROTRICHA (LOW BLUEBUSH) IN GAP CREEK PADDOCK

P. Semple (Undergraduate Project, Supervised by Mr J.D. McFarlane, School of Wool and Pastoral Sciences, U.N.S.W.)

The first part of this project is to collate data collected by student groups from four 50 x 1m belt transects in 1979, 1980, 1982, 1982 and 1984. This will be followed by an attempt to relate seedling establishment and shrub senescence and death to certain micro-environmental features e.g. proximity to shrubs, soil attributes, and microtopography. The latter will be concerned mainly with *Atriplex vesicaria*, the dominant shrub.

14. VEGETATION MONITORING

14.1 LONG-TERM PHOTO SITES

M. Westoby (School of Biological Science, Macquarie University) B. Rice (Independent researcher)

In 1954 and 1955, Professor N.C.W. Beadle established 14 permanent quadrats about 14 x 3 m, inside and outside 5 enclosures. He photographed and took notes on these from 1954 to 1957.

In 1976, Westoby and Rice relocated, restaked and rephotographed most of them and have continued to rephotograph them annually. Where a quadrat could not be exactly relocated, a new one was established in the same area. Two quadrats were also established inside and outside the exclosure in the N.E. corner of North Mandleman paddock, showing mulga regeneration.

In 1984, the photographs were passed on to the Soil Conservation Service, who will continue to rephotograph the sites.

15. VEGETATION SURVEYS

15.1 VEGETATION SURVEY OF FOWLERS GAP

J.P. Burrell.

See 1.1.

15.2 ASSESSMENT OF ARID-ZONE VEGETATION USING AIRPHOTO PATTERN

S.E. Hall (MSc Thesis, 1973, U.N.S.W.; Supervised by Dr J.P. Burrell, School of Geography, U.N.S.W.)

Native vegetation is an important natural resource in western New South Wales, providing unimproved pastures for a rangeland sheep industry. An adequate inventory of this vegetation constitutes an important prerequesite in the search for rational forms of range management and an assessment of future range trends.

In this thesis, a quantitative study of the vegetation in a selected area was carried out. Given the need to obtain information on large areas at a minimum cost, it was accepted that an *a priori* subdivision of the area studied on the basis of airphoto pattern provided the most useful and natural way of selecting sampling sites and an adequate basis for extrapolation of data collected in these sites to the remainder of the area. Data on species cover were collected in the various units of airphoto pattern mapped and used to describe the vegetation associated with each of them. An index of difference was tested as a means of comparing these units and defining their differences, and the areas covered by the several units estimated.

The area mapped as Conservation Land System on Fowlers Gap Station was selected as the study area. This land system was subdivided into units according to tone-texture elements appearing in 1:25,000 black and white air photographs, and their corresponding areas estimated.

With the exception of one unit, each unit of airphoto pattern is characterized by a distinctive and recognizable type of perennial and semiperennial vegetation. Field observations indicated that this was the case, and evidence provided by the species cover data and the index of difference analysis were consistent with these observations. In addition, the ephemeral vegetation showed different response to rains in the various units. These facts strongly suggest that there is a correlation between the elements of airphoto pattern and the vegetation units, and that the use of airphotographs provided an ecologically meaningful basis for subdividing the area.

The survey indicated that the perennial and semiperennial vegetation of the study area is dominated by chenopod shrubs, particularly of the genus Bassia, although in some units grasses are dominant or important components of the vegetation, while in other restricted areas there is a tree upper storey. The main differences between the perennial and semiperennial vegetation of the units which cover the greatest areas are due to variations in the proportion of the various species present, rather than to changes in floristic composition. This applies to a lesser degree to other units, and one unit was found to have a very distinctive floristic composition.

Three units of airphoto pattern cover around 85 per cent of the area and elements of these units are fairly generally distributed across the land system. The remaining units cover a very small proportion of the total area, although because of their sometimes restricted distribution, some of them can be of local importance. Over 30 per cent of the total area corresponds to unvegetated scalds.

Acknowledgements:
Ms Hall was in receipt of a two year scholarship and a travel grant from the National Council for Scientific and Technical Research, Argentina.

Thesis:
Hall, S.E.B. (1973) Assessment of arid-zone vegetation using airphoto pattern. MSc U.N.S.W.

16. PLANT PHYSIOLOGY

16.1 ENERGY EXCHANGES AT NATURAL SURFACES

D.J. Hasick (PhD Thesis, 1982, Macquarie University)

Micrometeorological methods were used to estimate the sensible heat and water vapour fluxes from natural vegetation in which two relatively discrete sinks for momentum appear to be present, and to determine the partition of radiant energy into sensible and latent heat.

Comparisons were made of the energy fluxes from an arid zone chenopod shrubland at Fowlers Gap under relatively low plant water stress in spring 1974 and high water stress in autumn 1975. The energy available to the chenopod community (net radiation-heat flux) was shared about equally between sensible and latent heat fluxes during spring. In autumn, when conditions were much drier, the available energy was partitioned about 3:1 between sensible and latent heat fluxes. The extent of stomatal control in limiting water loss and thereby maintaining plant species through dry periods was examined for Atriplex and some relatively less xerophytic species.

The partition of net radiation and the general microclimate of coastal heath under low stress were also examined and the results compared with the chenopod shrubland. The partition of available energy at the heath site was very similar to that at the chenopod shrubland under relatively low stress, the ratio of sensible heat to latent heat being close to unity.

Linear relationships were established between the friction velocity and the horizontal windspeed at a reference height. From these relationships the aerodynamic resistance could be estimated using a single anemometer. Thus, the boundary layer studies demonstrated that sensible and latent heat fluxes from the natural surfaces examined can be measured using standard micrometoerological techniques.

The partitioning of the energy fluxes between the lower and upper levels of the vegetation was attempted by analysis of the physiognomy of the vegetation as well as of the aerodynamic regime. A relationship was proposed which involves surface temperatures and windspeeds close to the surface, giving an acceptable approximation of energy exchange characteristics. A 'two-layer' model was developed in which surface temperatures and wind speed close the surface are used to determine energy exchange characteristics. The model was tested using field data from both the chenopod shrubland and the coastal heath.

Investigation of leaf resistances showed that the leaf resistance of Atriplex spp. was about ten times higher in the dry season of 1975 than in the wet spring of 1974.

Measurements of the surface temperatures of leaves in the

chenopod shrubland community showed that the maximum values of the leaf temperature occurred after local noon. This effect,presumably by causing a greater outgoing flux of infra-red radiation in the afternoon, produced for a given incoming short-wave radiation flux a smaller net radiation flux in the afternoon than in the morning. At the heath site, where maximum leaf temperatures occurred at about local noon, there was no marked asymmetry in the relationship between net radiation and incoming short-wave radiation.

Acknowledgements: This research was supported by a Commonwealth Postgraduate Scholarship.

Thesis:
Hasick, D.J. (1982) Energy Exchanges at Natural Surfaces. Macquarie University.

Publications:
Hasick, D.J. (1977) A two-layer model for momentum fluxes at vegetated surfaces. Second Australasian Conference on Heat and Mass Transfer, University of Sydney, Feb. 1977, pp 517-521.

Hasick, D.J. Heat and water vapour fluxes in an arid zone Community. In Studies of the Australian Arid Zone IV. Chenopod Shrublands. Ed. R.D. Graetz & K.M.W. Howes pp 54-60.

16.2 PHOTOSYNTHETIC RESPONSES IN SEMI-ARID ENVIRONMENTS

E.A. Chapman (Plant Physiology Unit, Division of Food Research, CSIRO), S.W.L. Jacobs (Royal Botanic Gardens)

This project was a comparative study of C_3 and C_4 plant species of the family Chenopodiaceae and other C_3 species growing in the chenopod at Fowlers Gap and at other sites in western N.S.W. Field measurements of photosynthesis, leaf resistance, leaf temperature and leaf water-potential were made. The effects of light, wind, temperature and humidity on CO_2 uptake were compared between sites and species.

The project was commenced in October 1974 and completed in October 1975.

A major finding was the greater independence between CO_2 fixation and leaf resistance in the C_4 species. The independence was more marked under drier conditions. The perennial C_3 species, however, were equally well-adapted to the local environment and the behaviour of one C_3 chenopod species was similar to that of a C_4 species from the same family. Unlike the C_3 annuals, neither the C_3 nor the C_4 chenopods had simple diurnal patterns of photosynthesis.

Publication:
Chapman, E.A. and Jacobs, S.W.L. (1979). Photosynthetic responses in semi-arid environments. In "Studies of the Australian Arid Zone IV Chenopod Shrublands". Ed. R.D Graetz and K.M.V. Howes pp 41-53.

16.3 MEMBRANE LIPID TRANSITIONS: THEIR CORRELATION WITH THE CLIMATIC DISTRIBUTION OF PLANTS

E.A. Chapman (Plant Physiology Unit, Division of Food Research, CSIRO)

This project was conducted from October 1975 to February 1979.

Samples of chenopod and other species were collected from Fowlers Gap and a wide range of other sites in Australia for a study of their membrane lipids.

A correlation between the temperature response of membrane lipids and the ability of the plants to withstand chilling temperature has been shown for crop plants. It is possible that selective breeding of these crops might have favoured development of a membrane with specific physical properties favourable to a particular environment. To determine whether the same correlation exists in native plant species where natural selection dominates, the polar lipids of plant leaves were examined.

The results showed that, in general, the critical temperature for the primary change in membrane lipid structure is relatively high (9° to 17°C) for plants from tropical regions and low for winter-growing plants from temperate regions. This correlation between the critical temperature of the membrane lipids and the plant's habitat indicates that the temperature response of the membrane lipids is a major factor in limiting the distribution of plant species. It also indicates that this property would be important in determining the lower temperature limit for the storage and transport of tropical fruits and vegetables.

Publication:

Raison, J.K., Chapman, E.A, Wright, L.C., and Jacobs, S.W.L. (1979) Membrane lipid transitions: their correlation with the climatic distribution of plants. In "Low Temperature Stress in Crop Plants - the Role of the Membrane". Eds Lyons, J.M.; Graham, D. and Raison, J.K. Academic press, New York, pp 177-186.

17. ECOLOGY

17.1 VEGETATION AND SOIL RESPONSE TO GRAZING HERBIVORES IN A SEMI-ARID RANGELAND

L. Stewart (BSc Thesis, 1980. U.N.S.W. Supervised by Dr M. Melville, School of Geography, U.N.S.W.)

The impact of grazing sheep and kangaroos upon the vegetation and soils of a semi-arid rangeland was studied, using the concept of the "piosphere". This concept shows changes in environmental conditions near a watering point.

Two paddocks with different grazing histories were compared to determine the impact of sheep. One paddock was supporting

sheep and the other had sheep excluded. The paddock supporting sheep had a higher nutrient status and greater vulnerability to soil erosion near the watering point than the paddock without sheep. There was no vegetation within 50m of the watering point and some perennial plant species showed a distribution that appeared to be function of the presence and behaviour of sheep. In the other paddock, the pattern of vegetation was more related to the presence of kangaroos. This suggests that the effect of sheep tends to overrule the effect of other factors.

It was concluded that the impact of sheep is to degrade the rangeland, and that this impact is often compounded by poor management, especially overstocking.

Thesis: Stewart, L. (1980) Vegetation and soil response to grazing herbivores in a semi-arid rangeland. U.N.S.W.

17.2 GRANIVORY IN THE AUSTRALIAN ARID ZONE

S.R. Morton (Postdoctoral Fellow, Biological Sciences, University of Sydney); D.W. Davidson (Department of Biology, University of Utah, U.S.A.)

The project aimed to examine the patterns of seed-eating in Australian arid habitats and compare these with patterns seen in North American deserts. There was reason to believe that in North America rodents were the dominant consumers of seeds, whereas in Australia rodents are virtually non-existent as granivores. The study therefore attempted to examine the pattern of granivory and to interpret this pattern in the light of the theory of evolutionary convergence at the community level.

The major components of the investigation included: the study of seed populations in soils; the study of harvester ant communities; the study of granivorous birds, particularly the zebra finch; an experimental study of removal of seeds by different groups of granivores; the study of the dispersal of seeds by animals as distinct from consumption of seeds.

Fowlers Gap was one of three sites used in the investigation.

Acknowledgements: The study was conducted with the support of the Australian Research Grants Committee. Dr Morton was in receipt of a University of Sydney Postdoctoral Research Fellowship and Dr D.W. Davidson in receipt of a travel grant from the Ian Potter Foundation of Melbourne.

Publications:

Davidson, D.W. & Morton, S.R. (1981) Competition for dispersal in ant-dispersed plants. Science, Vol 213, pp 1259-1261.

Davidson, D.W. & Morton, S.R. (1981) Myrmecochory in some plants (F. chenopodiaceae) of the Australian arid zone. Oecologia (Berl) 50: 357-366.

Davidson, D.W. & Morton, S.R. (1984) Dispersal adaptations of some Acacia species in the Australian arid zone. Ecology 65: in press.

Morton, S.R. (1982). Granivory in the Australian arid zone: diversity of harvester ants and structure of their communities. In "Evolution of the Flora and Fauna of Arid Australia" ed. W.R. Barker and P.J.M. Greenslade pp 257-262. Peacock Publications, Frewville, South Australia.

Morton, S.R. (1985) Granivory in the Australian arid zone: an experimental comparison with North and South American deserts. Ecology 66: in press.

Morton, S.R. & Davies P.H. (1983) Food of the zebra finch (Poephila guttata) and an examination of granivory in birds of the Australian arid zone. Australian Journal of Ecology 8: 235-243.

18. PASTORAL PRODUCTION

18.1 LOWER-COST FENCING TRIALS

J. Brain (Institute of Rural Technology, University of N.S.W.)

At the time of the take-over of Fowlers Gap lease by the University in January 1966, the property was badly run-down. A major priority, therefore, for the University during the early years of occupancy was the restoration and regeneration of the property.

Since fencing represents a very high proportion of total capital costs on a Western Division property, the University decided to initiate an investigation of cheaper, effective fence construction. Mr John Brain of the Institute of Rural Technology was assigned the task of investigating the feasibility of lower-cost fencing on the property.

A literature search was conducted of available information in this area. Extensive inspections of fencing trials in N.S.W and Victoria were carried out and attendance made at demonstrations and field days of various fencing techniques. An automated fencing device was also investigated. In co-operation with the University of N.S.W. School of Civil Engineering, a number of tests were made of materials and their performance.

Following these investigations, a "rational" low-cost fence design was developed, applying engineering principles of fencing components. Since the Station was a research facility, it was important for the fence design to be more stock-proof than was considered necessary for normal Station operations.

Mr John Brain, of the Institute of Rural Technology, U.N.S.W. and the Fowlers Gap Fence (see 18.1). Photo: K. Doig

During 1968 and 1969, approximately 150km of this low-cost fence was erected at Fowlers Gap and checked regularly for failure and for maintenance of tension. It was found that if adequate end assemblies and long strains were used, fence tension remained constant indefinitely.

The basic characteristics of the fence are: (a) greater attention to design and construction of end assemblies (b) long strains with few or no intermediate strainer posts (c) widely spaced posts (d) high tensile wire (e) wires attached to posts and droppers rather than threaded through bored holes (f) measured tension on wires.

The essential difference between this "suspension" fence and the conventional fence is that loads imposed on the suspension fence are absorbed mainly by the wires and end assemblies, whilst those of the conventional fence are borne mainly by the posts. Whilst suspension fences may not be appropriate for high density stocking situations, their cheapness and efficiency can be employed to advantage in many parts of Australia.

The publication by the University of the booklet "Fowlers Gap Fences" represented the first attempt to provide the grazier with information to enable him to understand the engineering principles that operated in a fence structure. Demonstrations and field days were also arranged, as a University extension exercise (See 34.2).

Following these trials at Fowlers Gap, the entire Western Division has rapidly adopted the cost-saving techniques which effectively reduced the cost of fencing work by up to 50%.

Publications:

Brain, J. (1976) Fowlers Gap Fences, University of New South Wales.

Brain, J. (1976) Cutting costs of fencing. Wool Technology & Sheep Breeding, Vol XXIII No 111.

Brain, J. (1976) Suspension Fencing Power Farming Vol 85, July 1976, No. 7, pp 20-22.

Brain, J. (1976) Suspension Fencing. The Agricultural Technologist Journal Vol 7, No. 3, pp 37-38, 46.

18.2 INCREASING GROSS INCOME THROUGH IMPROVED REPRODUCTIVE PERFORMANCE AND WOOL PRODUCTION IN AN ARID ENVIRONMENT

THE DEVELOPMENT OF LEAST-COST MANAGEMENT FOR SHEEP FLOCK AT FOWLERS GAP ARID ZONE RESEARCH STATION

Project Supervisor: J.P. Kennedy. (School of Wool and Pastoral Sciences, U.N.S.W.)

The above project titles include a number of individual studies conducted by the School of Wool and Pastoral Sciences of the University of New South Wales, with financial assistance provided by the Wool Research Trust Fund, on the recommendation of the Australian Wool Corporation.

The former project was funded from July 1971 to June 1976 and aimed to study methods of increasing sheep productivity without incurring additional costs or with low cost procedures. Research interest was concentrated on seeking ways to increase lambing percentage and wool cut per head.

From July 1976 to December 1980, the stated aims of funded research were to "develop management plans and procedures for the arid zone which will minimise the labour costs of mustering and handling sheep but will maintain or increase wool producion and reproduction rate, decrease mortality and control flystrike".

Specifically, experiments were conducted to investigate the effects on productivity of the timing of shearing and joining, mulesing-at-marking, drenching weaners, and breeding rams in the arid environment.

Funding from the Wool Research Trust Fund ceased at the end of 1980, but a number of experiments are continuing.

The results of the Wool Research Trust Fund programme, which in many instances contravene established pastoral practice, are summarised in the publications listed below.

For project descriptions of individual aspects of this research, see 18.2.1 - 18.2.9.

Publications:

Kennedy, J.P., Auldist, I.H., Hawker, H., Popovic, P., Reynolds, J.A. (1974) Management Strategies for Increasing Reproduction Rate of Sheep in Far Western New South Wales. Wool Technology and Sheep Breeding, Vol XXI, No II; 49-51.

Kennedy, J.P. (1979) Merino Sheep Production in Arid Zones. Proc. 1979 Annual Conference, Consultants Section, Australian Institute of Agricultural Science, Sydney, Feb 1979, pp 51-57.

Kennedy, J.P. (1981) Practical application of knowledge of factors influencing wool growth. 1981 Sheep and Wool Refresher Course (Queensland Department of Primary Industries Conference and Workshop Series 81011) pp 44-46.

See also:
Articles distributed by Australian Wool Corporation and published as follows:

"Lifting lamb survival in the arid zone." Farm, March 1983, pp 10-13.

"Cutting costs by changing routines". Weekly Times, 6/4/83, p12.

"New practices can cut arid zone flock costs". Grazier, May 1983, p7.

"Flock management to cut arid zone costs." Stock Journal, April 28, 1983, p17.

18.2.1 COMPARISON OF THE PRODUCTIVITY OF THREE TYPES OF SOUTH AUSTRALIAN MERINO

J.P. Kennedy, I. Auldist, P. Popovic, J. Reynolds, S. Gray (School of Wool & Pastoral Sciences, U.N.S.W.).

One of the initial research objectives of the School of Wool and Pastoral Sciences for Fowlers Gap was to study variations within the strains of Merino utilised within the environment.

Observations conducted by Professor I.L. Johnstone from 1966 to 1970 showed that wool production and returns, and optimal joining times, could be substantially different with different strains. In order to examine these differences, an experiment was initiated in 1970 with financial support from the Wool Research Trust Fund.

In 1970, nucleus breeding flocks of 200 ewes from each of three studs were established on the property. From 1970 to 1979, observations were made and recorded of the reproductive performance, incidence of flystrike, and wool production of each of the flocks. Samples of wool were also collected for measurement of washing yield and mean fibre diameter.

From analysis of the data collected, it was concluded that the finer wool produced by the Ashrose sheep made them more profitable than Bluff or North Bungaree. However, the differences between Bluff and Ashrose, both representative of the Collinsville type, indicate the variation that exists between studs within types.

Acknowledgements: This research was supported by funds from the Wool Research Trust Fund.

18.2.2 STUDIES OF SEASONAL VARIATIONS IN REPRODUCTION AND VITAL STATISTICS OF SHEEP

J.P. Kennedy, I. Auldist, P. Popovic, J. Reynolds (School of Wool & Pastoral Sciences, U.N.S.W.)

An early priority for research at Fowlers Gap by the U.N.S.W. School of Wool & Pastoral Sciences was a study of some of the aspects of the reasons for low fertility in sheep flocks. An experiment commenced early in 1970 with the objective of studying seasonal variations in fertility of ewes for the purpose of defining the optimum time for mating in the West Darling. Funded by the Wool Research Trust Fund, the experiment was designed to produce information on the influence of the time of joining, and lambing, on lambing percentage, wool production, ewe mortality, lamb growth and mortality, and the incidence of post-partum oestrus.

Merino ewes of the South Australian strain were joined in groups of 80 to 100 ewes at four different times each year from 1971 to 1976. Joinings continued for 51 to 56 days with three Merino rams in a 415 ha paddock. Sire-Sine crayon marks on ewes were recorded at 17 day intervals during joining. Shortly before lambing commenced, pregnancy diagnosis was made with the aid of an ultrasonic pregnancy tester. Ewes, branded with identifying numerals, lambed in a 605 ha paddock and were inspected daily with binoculars. Lambing date and litter size were recorded. At lamb marking, ewes were classified as lactating, lambed but not lactating, and not lambed. Lambs were weaned 10 weeks later and the survival of ewe lambs until they reached 16 months old was measured.

Anlaysis of the data collected indicated that the most common and serious causes of reproductive wastage were failure of mated ewes to lamb, lamb mortality between birth and marking, and mortality of young ewes between weaning and 16 months of age. In some years, mortality of ewes before and during lambing was substantial.

Results revealed that a much better reproduction rate followed joining in April rather than at the traditional time of October to March. Contrary to the belief held by many pastoralists, the autumn joining did not appear to increase the likelihood of flystrike in lambing ewes and in marked and mulesed lambs.

Acknowledgements: This research was supported by funds from the Wool Research Trust Fund.

Publications:

Kennedy, J.P., Auldist, I.H., Popovic, P.G., Reynolds, J.A. (1976) Reproduction rate of Merino sheep in arid N.S.W. Proc.Aust.Soc.Anim.Prod.II, pp 149-151.

Kennedy J.P. (1978) Net reproductive rates of Merino sheep flocks in an arid area. Proc.Aust.Soc.Anim.Prod. 12: 253.

18.2.3 INVESTIGATION OF PRODUCTIVITY DIFFERENCES BETWEEN PADDOCKS

J.P. Kennedy, J. Reynolds (School of Wool & Pastoral Sciences, U.N.S.W.)

During the collection of experimental data at Fowlers Gap, it became evident that there were large differences in the productivity of similar sheep which were grazing in different paddocks at similar stocking rates. To determine the extent and causes of paddock differences on productivity, an experiment supported by the Wool Research Trust Fund was commenced in October 1974.

Groups of approximately 40 wethers were allocated randomly to six paddocks. Additional young wethers were added to each paddock after shearing in 1976. Sheep were weighed at intervals throughout each year, and at shearing fleeces were weighed and samples taken for estimation of yield and fibre diameter. Photographs were also taken at regular intervals of the vegetation at fixed points.

The initial stage of the experiment was completed in 1980 and the results are presently being prepared for publication.

A follow-up study was commenced in 1981 by Ms L. Stewart, an MSc student in the School of Geography (see 18.9).

Acknowledgements: This research was supported by funds from the Wool Research Trust Fund.

18.2.4 A STUDY OF THE BENEFITS OF BREEDING RAMS

J.P. Kennedy, J. Reynolds, S. Gray (School of Wool & Pastoral Sciences, U.N.S.W.)

Most graziers purchase rams from studs which are located in non-arid regions. However, it has been demonstrated in a 1967 study that locally-bred rams had superior reproductive performance to rams imported into the Pilbarra region of Western Australia. In 1974, a nucleus breeding flock was established at Fowlers Gap Research Station to study the possible adaptational advantages of rams bred in the arid zone compared to rams imported from higher rainfall country.

Rams from the Fowlers Gap Bungaree breeding group and purchased stud rams of a comparable age were joined with ewes in 1977/78, 1978/79 and 1980. The ewes were randomly divided into four groups of which two were joined in December/February and the other two in March/May in the first two years, but in 1980 the ewes were combined into two groups which were joined in January/March.

Raddle marks on the ewes were recorded regularly. In addition, tests were conducted to assess the libido, rectal temperature and respiration rate of the rams. The lambing percentage of the ewes was also recorded.

Respiration rates of rams were measured several times during the day on four occasions during summer between January, 1978 and January, 1980. On every occasion Fowlers Gap rams had lower respiration rates than purchased rams. Rectal temperatures were also measured on four occasions during summer. At one of these, Fowlers Gap rams had a lower temperature than purchased rams but at all other times there were no differences.

In summer of 1977/78, during a severe drought accompanied by very hot weather, the Fowlers Gap rams were active earlier in the joining period, raddled more ewes and sired more offspring than the imported rams, but during the cooler autumn of 1978 and in subsequent years no differences were observed.

These preliminary results suggest that locally-bred rams may be physiologically better adapted to the hot, dry conditions of the environment.

Ram breeding is continuing in a flock which is known as the Open Nucleus group. This was established in 1976 when maiden ewes from 14 different properties were obtained by choosing a small number of the ewes which had the highest fleece weight on each property. In the first two years these ewes were joined to rams which were loaned by Mr Pocock, "Pantlatinga", Lameroo, South Australia. After this, rams bred in the flock have been used as sires. Those selected have been the rams with the highest clean fleece weight, provided that their wool was not more than 2 m coarser than the average and that they were not excessively wrinkly. Twin-born rams have been preferred.

Acknowledgements: This research was supported by funds from The Wool Research Trust Fund.

Report:

Gray, S.J. and Kennedy, J.P. (1978) A comparison of rams bred in the arid zone with rams imported from studs. Australian Rangelands Society Conf, Adelaide.

18.2.5 INFLUENCE OF TIME OF SHEARING AND JOINING ON PRODUCTIVITY

J.P. Kennedy, I. Auldist, S. Gray, J. Reynolds (School of Wool & Pastoral Sciences, U.N.S.W.)

Two experiments with strong wool Merino sheep were conducted at Fowlers Gap, commencing in 1973 and concluding in 1981. In one experiment, ewes were shorn in either autumn or spring for six years. In the other, ewes were joined in either December or March and were shorn in February/March, April/May, August or October/November for three years. The aim of these experiments was to assess the influence of the timing of shearing and joining on the productivity of sheep in an arid zone.

In both studies, there was a significant correlation between the rate of wool growth and rainfall in the woolgrowing

period. When wool growth was corrected for rainfall, shearing time did not have a significant effect on wool growth. Losses of ewes and the percentages of dry ewes did not differ between shearing times but there were more dry ewes in the December-joined flock than in the March-joined flock.

Acknowledgements: Financial support was provided by The Wool Research Trust Fund.

Publication:
Kennedy, J.P., Auldist, I.H., Gray, S.J., Reynolds, J.A. (1982) Influence of the timing of shearing and joining on productivity of sheep in the arid zone of Western New South Wales. Proceedings of Australian Society of Animal Production, 14, 507-510.

18.2.6 INFLUENCE OF THE TIME OF MULESING ON THE SURVIVAL AND THE INCIDENCE OF FLYSTRIKE OF LAMBS AND WEANERS

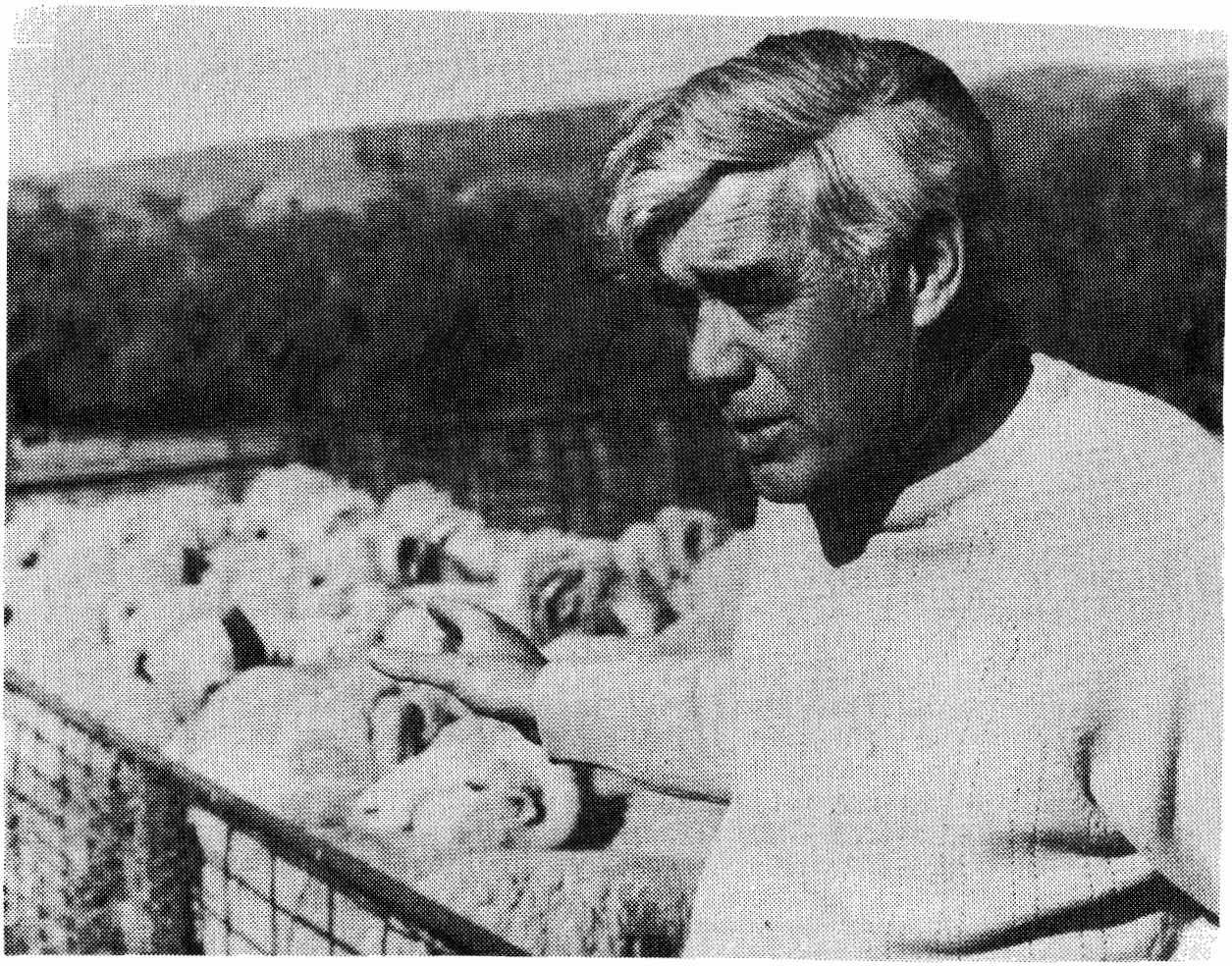
J.P. Kennedy, S. Gray, J. Reynolds (School of Wool & Pastoral Sciences, U.N.S.W.)

Although the Mules operation is a proven method of reducing the susceptibility of sheep to blowfly strike, surveys indicated that only 55 per cent to 60 per cent of pastoralists in the West Darling applied the operation. In 1974, a study was commenced to assess the effect of age at Mulesing on lamb survival and production. In collaboration with the CSIRO Division of Animal Health, and as part of a state-wide survey, data were also collected on the incidence of blowfly strike in different types of sheep and under various weather conditions, and analysed in relation to the control group of lambs in their Mulesing study.

Seven groups of ewe lambs were Mulesed at marking in July of 1974, 1975 and 1977 and September 1976. Similar lambs from the same mobs were marked but not Mulesed until 3 to 11 months later. In 1976 tails were docked short or longer. The occurrence of flystrike was recorded, at irregular intervals, in lambs during the first spring-summer-autumn after marking.

Analyses of the results showed that over the four years of the study there was no difference in the percentages of ewe lambs which survived from marking to approximately 19 months of age between lambs which were Mulesed at marking or were Mulesed at older ages. However, in those years in which conditions during spring and summer were favourable for flystrike, very few Mulesed lambs were struck. It was concluded that Mulesing at marking does not lead to more mismothering than marking only, that lambs which are Mulesed at marking are protected from breech strike during the spring and summer following marking and that Mulesing at marking avoids the extra work involved in Mulesing weaners.

Acknowledgements: This research was supported by a grant from the Wool Research Trust Fund.



Professor J. Kennedy, of the School of Wool and Pastoral Sciences, U.N.S.W. - Leader of a research team investigating aspects of arid zone sheep management (See 18.2) Photo: K. Doig.

Publications:
Kennedy, J.P., Gray, S.J., Reynolds, J.A. (1983) Influence of age of Mulesing on survival of lambs in Far Western N.S.W. Second National Symposium, Blowflies & Flystrike in Sheep, Sydney 1983. Dept of Agriculture, N.S.W. pp 26-29.

Reynolds, J.A. (1975) The effect of time of Mulesing on lamb survival and production at Fowlers Gap in 1974. West Darling Pastoralist, News Report No. 83, 31/7/75 pp 2-4.

Watts, J.E., Muller, M.J., Dyne, A.L., Norris, K.R. (1976) The species of flies reared from struck sheep in South-Eastern Australia. Australian Veterinary Journal, 52: 488-489.

Watts, J.E., Murray, M.D., Graham, N.P.H. (1979) The blowfly strike problem of sheep in New South Wales. Australian Veterinary Journal Vol 55, pp 325-334.

18.2.7 STUDY OF THE INCIDENCE & CONTROL OF INTERNAL PARASITES IN SHEEP

J.P. Kennedy, S. Gray. (School of Wool & Pastoral Sciences, U.N.S.W.)

Internal parasitism has rarely been regarded as a disease problem in the arid zone, but the high mortality, of the order of 20%, from marking to first joining, of young sheep as recorded by Kennedy et al (1976), Kennedy (1978) and Hawker (1976) (see 18.2.2, 18.5), and the evidence that parasites were present, prompted Kennedy and Gray to conduct a replicated drench/no drench experiment between 1977 and 1979. The aims of the experiment were to study the effect of parasites on survival, wool growth and liveweight gain of weaner sheep; to monitor the change in parasite burden throughout the year; and to determine which parasite species were present.

During the period the experiment was conducted, the annual rainfall was 33, 152 and 141%, respectively of the annual mean of 195 mm. Worm burdens and production of sheep given anthelmintic treatment at approximately monthly intervals were compared with those in untreated sheep. Total worm counts in untreated sheep were low, ranging from 15 to 3,750. Nematodirus spp. were the most common nematode parasites recovered. Infections with T. richostrongylus spp. were recorded in 2 of the 3 years; T. rugatus was the only species represented when species identification was made in 1979. Infections of Haemonchus contortus were only detected in the last year. Tapeworms (Moniezia spp.) were occasionally recovered. Anthelmintic treatment reduced worm burdens to a very low level but had no significant effect on survival rate, liveweight gain, or wool production. It was concluded that in the arid areas of western New South Wales, worm infection would not limit production or cause mortality in young sheep, except in unusually wet years.

Acknowledgements: Financial support was provided from the Wool Research Trust Fund.

Publication:
Gray, S.J. and Kennedy, J.P. (1981) Gastro-intestinal parasites in sheep in an arid environment. Australian Journal Experimental Agriculture and Animal Husbandry 21: 179-182.

18.2.8 BENEFITS OF VACCINATING LAMBS AND EWES

J.P.Kennedy (School of Wool & Pastoral Sciences, U.N.S.W.)
C.R. Carter (Fowlers Gap Arid Zone Research Station)

Research on Fowlers Gap over several years revealed that mortality of young sheep was a serious source of wastage in the flock. Since infection with clostridial organisims is one of the possible contributions to mortality, a study was made to compare survival rates of lambs which had, or had not, been vaccinated.

In 1981, the ewe lambs of four mobs of sheep were divided into three groups: one vaccination (at marking); two vaccinations (at marking, and again about 6 weeks later); and control (no vaccinations).

Survival percentages from marking to shearing were recorded in 1982. It was found that survival rates, to about 12 months of age, of vaccinated lambs were significantly higher than unvaccinated lambs viz. 92.3% in lambs treated once, 90.9% in lambs treated twice and 83% in untreated lambs.

In 1983, consequences of vaccinating ewes late in pregnancy were evaluated. Survival of lambs, to about 5 months of age, from vaccinated ewes was 89.7% compared with survival of 90.6% from unvaccinated ewes. When ewes were vaccinated and the lambs also were vaccinated at marking, survival was 96.2% but this was not significantly greater than the other survival rates.

The study is continuing.

Acknowledgements: Financial support was provided from the Wool Research Trust Fund.

18.2.9 MAINTENANCE OF SHEEP BLOWFLY POPULATIONS

J.P. Kennedy; W. Dobbie (School of Wool and Pastoral Sciences, U.N.S.W.)

The objective of the experiment was to test the hypothesis that there is a continual low level of flystrikes, most of which are unobserved (termed covert strikes), and that these covert strikes are important in maintaining populations of L.cuprina.

From March 1 to June 30 1981, 190 wethers were individually examined twice a week. Only three strikes were detected, and all were covert, with one continuing for five weeks. It was concluded, therefore, that covert strikes do occur in arid areas and that they may explain the survival of sheep blowfly species during long periods of harsh conditions.

The research has since been extended to a detailed study of the size of the fly population on Fowlers Gap. This work is being carried out by Associate Professor Erik Shipp and Dr Jenny Anderson of the School of Zoology. The project is funded by the Australian Wool Corporation (see 24.1).

Acknowledgments: Financial support was provided from the Wool Research Trust Fund.

Publications

Dobbie, W.R. & Kennedy, J.P. (1983) Observations on covert flystrike in wethers in Far Western New South Wales. Second National Symposium, Blowflies & Flystrike in Sheep, Sydney, 1983. Dept of Agric, N.S.W. pp 130-132.

18.3 A STUDY OF DUST CONTAMINATION IN MERINO WOOL IN LOW RAINFALL AREAS

D.H. Charlesworth (MSc Thesis, 1970, U.N.S.W.; Supervised by Prof P.R. McMahon & Mr J.R. Paynter, School of Wool and Pastoral Sciences, U.N.S.W.)

Dust is a major contaminant in fleece originating from low rainfall areas. The price of dusty wool is invariably lower than uncontaminated wool, partly because of increased handling costs, but chiefly because the penetration of dust damages the wool fibre, thus reducing the quality of yield.

David Charlesworth, a postgraduate student in the School, commenced a series of studies in 1968 to examine the problem of dust penetration.

His research revealed a strong association between depth of dust penetration and photochemical damage as evidenced by increased alkali solubility. Dust particles were also found to weaken fibres through mechanical abrasion of the cuticular layer.

A comprehensive evaluation of the fleece properties and constituents of a large flock of different strains of merino was also carried out, revealing that wax content was the only fleece parameter that strongly influenced dust penetration. Wax fluidity and suint content both had small positive correlations with depth of dust penetration and dust content. Contrary to the opinion often held in the wool trade, fibre density had very little effect on dust penetration.

Charlesworth conducted a trial of sheep rugs on a flock of sheep at Fowlers Gap. Rugs were applied to the sheep after shearing from 1968 to 1970. Three varieties were tested: PVC, nylon reinforced PVC and 10 oz cotton canvas. It was found that the canvas rugs were far more durable than the synthetic varieties. They effectively restricted dust entry into the fleece, and thereby improved the style of the wool. Rugging was also associated with an appreciable increase in clean fleece weight.

Finally, a mob of sheep at Fowlers Gap were treated with a number of synthetic and natural polymeric and manomeric compounds with a view to the alleviation of dust contamination. However, the trials indicated that this method was unlikely to reduce dust contamination sufficiently to be of practical interest.

Acknowledgements: This work was supported by a grant from the Australian Wool Board.

Thesis: Charlesworth, D.H. (1970) A study of dust contamination in Merino wool in low rainfall areas MSc. U.N.S.W.

18.4 THE ECONOMICS OF RUGGING SHEEP FOR WOOL IMPROVEMENT IN A HOSTILE WOOL GROWING ENVIRONMENT

R. Sallaway (School of Wool and Pastoral Sciences, U.N.S.W.)

From 1972 to 1974, a sheep rugging study was conducted at Fowlers Gap by Mr R. Sallaway. The study was part of a larger project organized by the N.S.W. Department of Agriculture and was partly funded by the rug manufacturing company, Gollin & Co. Throughout New South Wales approximately 17,000 sheep were tested with a new and improved rug design.

It was found that successfully retained rugs protected and dramatically upgraded the wool, with increased yield and greatly improved processing potential. Rugged fleece wool gained a premium of 25 cents per kilo over control fleece wool in a 1973 shearing comparison.

However, under extensive grazing conditions as at Fowlers Gap, rug losses are high and re-rugging during the period between shearing is not economically viable.

"Strategic" rugging is practised in the tablelands areas as an insurance against off shears losses from cold stress.

Acknowledgements: This study was part of a N.S.W. Department of Agriculture project, and was partly funded by the rug manufacturing company, Gollin & Co.

Report: Evaluation of Sheep Coats, Final Report. Department of Agriculture, N.S.W.

18.5 THE EFFECT OF AGE ON SHEEP PRODUCTION IN AN ARID ENVIRONMENT

H. Hawker (PhD Thesis, 1976, U.N.S.W. Supervised by Professor J.P. Kennedy, School of Wool & Pastoral Sciences, U.N.S.W.)

Several aspects of the performance in relation to age of Merino sheep in far western N.S.W. were studied at Fowlers Gap Research Station. Experiments were conducted under extensive conditions in large paddocks (580-3500 ha).

The exhibition of oestrus was studied in young ewes born at five times of the year in three years, and growing at

different rates due to variable seasonal conditions. Mean ages and liveweights at puberty ranged from 283 days to more than 480 days, and from 31 kg to 49 kg, respectively. Age at puberty was largely controlled by a time of birth x growth rate interaction. While February- and April-born ewes were strongly influenced by seasonal factors, with growth rate relatively unimportant, the latter was important for ewes born in July, September and November, and strongly influenced the timing of puberty. The age at puberty was less variable, and subsequent oestrous activity in all ewes was more regular, between late December and May. Within groups, early growth influenced liveweight at puberty, but not its timing. There was little difference in the exhibition of oestrus between continuous and intermittent exposure to rams.

Sexual development was studied in ram lambs born at five times of the year in two years. Parameters of testicular development were closely related to one another, and were more closely related to liveweight than to age. Spermatozoa appeared in the testis in the ranges 30-37 kg liveweight, 50-80 g testis weight and 117-154 mm seminiferous tubule diameter. Approximate means for other parameters were 136 days and 37 kg (penis development complete), 184 days and 38 kg (first mount), and 221 days and 43 kg (first service). Libido was variable and not consistently related to any factor. Although the rate of body growth was the main factor controlling the rate of sexual development, season and/or an age x growth rate interaction was at times significant, as development was relatively rapid in November-born, and slow in July-born rams.

The influence of age between 2 and 8 years on the productivity of breeding ewes was examined over several years. Age did not influence the proportion of ewes lambing or the number of lambs born, although the data were limited. Age also did not influence breeding ewe mortality (9.6%), although losses were higher (at least 35%) before 19 months of age. Age had a generally curvilinear influence on liveweight (peak at 5 years) and on wool production and per cent yield (peaks at 3-4 years). Staple length declined linearly with age. Fibre diameter initially increased sharply while crimps per inch did not change consistently with age. All parameters differed considerably between years. Reproduction depressed liveweight and wool production, although not markedly.

Acknowledgements: The research was carried out while Dr Hawker held an Australian Wool Corporation postgraduate scholarship.

Publications:

Hawker, H. & Kennedy, J.P. (1974) Factors affecting puberty in Merino ewes Proc. Aust. Soc. Anim. Prod. 10: 285.

Hawker, H. & Kennedy, J.P. (1978) Puberty and subsequent oestrus activity in young Merino ewes. Australian Journal of Experimental Agriculture and Animal Husbandry. 18: 347-354.

Hawker, H. & Kennedy, J.P. (1978) Influence of season and of reproductive status on the wool growth of Merino ewes in an arid environment. Australian Journal of Experimental Agriculture and Animal Husbandry 18: 648-652.

18.6 CONTROL OF RABBITS

N.S.W. Department of Agriculture (In association with Fowlers Gap Station staff and staff of the School of Wool & Pastoral Sciences, U.N.S.W.)

A rabbit control trial was conducted by officers of the N.S.W. Department of Agriculture in association with staff of the Station and of the U.N.S.W. School of Wool and Pastoral Sciences. The study was conducted from January to February 1978 and was part of a series of trials aimed at investigating control and management of rabbit populations in the Western Division of N.S.W.

Two areas in different land systems were chosen as study sites, because they support different warren types. The Strip paddock is on the Nuntherungie land system which has warrens similar to those found throughout much of western N.S.W. Mandleman paddock is on the Conservation land system which has exceptionally large, raised warrens in small discrete groups of 3-4.

The study was conducted from mid January to early February to take advantage of the hot dry conditions. The parameters monitored were changes in rabbit population and the rate of warren reopening. Rabbits were shot on adjacent areas and autopsied to obtain information on ages, abdominal fat, length, weight and breeding status.

The treatments applied were ripping of warrens or poisoning with 1080-impregnated oats or poisoning plus ripping or no treatment. The ripping was done using a 62-horsepower tractor with a single-type ripper, ripping to an average depth of about 50cm. The warrens were first ripped one way and then cross ripped, i.e. at right angles to the first rip. Ripping was extended to about two metres outside the burrow extremities and the ripped warren was then levelled out by pushing the front-end loader bucket on the tractor across the rip furrows. Poisoned oats were laid by a Rolling Drum bait layer in concentric circles around all warrens in the block assigned to the poison treatment. Ten to fourteen days later the trails were filled in using a length of heavy steel towed at an angle along the trail. All posioned blocks were checked daily for dead animals until no more were found. Those animals found were picked up, counted and then buried.

The indications are that rabbit control is a practicable proposition in this type of country, and under the conditions encountered.

In both trials, the effectiveness of ripping during a hot, dry summer was confirmed by the low re-opening rates of warrens. Even though the rabbit density was high in trial B, only one

entrance appeared in the ripped areas and all sign of rabbits disappeared. The single re-opened entrance may have been formed by an animal other than a rabbit. In trial A, the results were confused by the larger very small experimental areas. If the areas had been much larger, there would not have been the edge effect whereby rabbits from warrens outside the area came in to feed at night.

1080 poisoning had a substantial effect in trial B in the short term but little effect in trial A. More than 100 dead rabbits were picked up and buried from trial B, but less than 10 were found in trial A. No non-target poisoning was found in the extensive daily search. Although 1080 on its own was shown to produce a substantial decline in one of the trials, it was not of any advantage when used in conjunction with ripping, since almost all ripped warrens in both trials remained closed.

Acknowledgements: This work was supported by a grant from the Wool Research Trust Fund.

Publication:
Martin, J.T. & Atkinson, W. 1978 The technology of rabbit control in a semi-arid environment; Chapter 4.5 "Poisoning and Ripping Trials, Fowlers Gap (Area B)". N.S.W. Department of Agriculture.

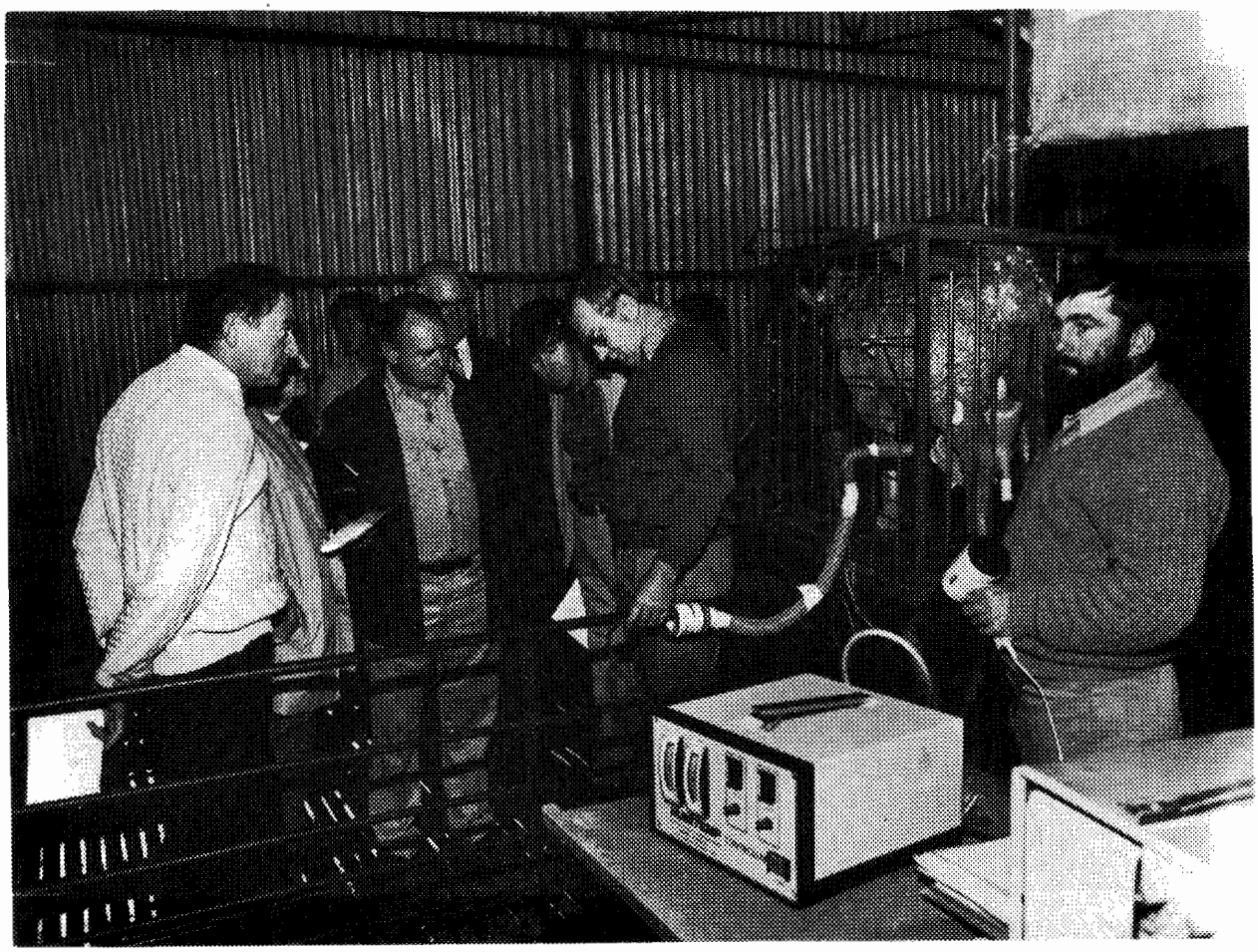
18.7 COMPARISON OF THE PRODUCTIVITY OF PROGENY OF BOOROOLA-CROSS AND FOWLERS GAP RAMS

R. Ponzoni (South Australian Department of Agriculture) in association with J.P. Kennedy (School of Wool & Pastoral Sciences, U.N.S.W.) and C.R. Carter (Fowlers Gap Arid Zone Research Station)

The Booroola Merino is a medium wool type which expresses high fecundity. This collaborative study between the South Australian Department of Agriculture and the U.N.S.W. School of Wool and Pastoral Sciences aims to evaluate the productivity of Booroola-cross progeny.

At shearing in 1983, respective clean wool weights and mean fibre diameters of wool from ewes born in 1981 were 2.78 ± 0.04 kg and 21.6 ± 0.2 µm Booroola x Bungaree progeny. The mean fibre diameters differed significantly, which was surprising since Booroola cross wool was expected to be finer. Mean live weights before shearing were very similar at 38.0 kg and 38.7 kg for Booroola crosses and Fowlers Gap, respectively.

Another two groups of progeny will be compared in 1984.



Professor Max Webster, of the Department of Physiology, University of New England, presenting a project demonstration of his research (see 18.8) at the 1982 Fowlers Gap Open Day. Photo: K. Doig.

18.8 GENOTYPE AND PHENOTYPE INTERACTIONS: TEMPERATURE REGULATION AND RENAL COMPETENCE

M.E.D. Webster (Department of Physiology, University of New England)

Associate Professor M.E.D. Webster commenced a study in July 1980 to identify the influence of genetic factors, acclimatisation and environmental factors during development on the productivity, adaptability and survival of adult Merino sheep in an arid environment. The School of Wool and Pastoral Sciences U.N.S.W. is involved in this project in a consultative capacity.

One of the objectives is to identify sheep which are best suited to the ecological circumstances at Fowlers Gap.

Sheep selected according to their renal and thermoregulatory loads are being mated to exaggerate possible genetic factors. The offspring of these matings are being studied during their development in semi-arid conditions of Fowlers Gap. Particular attention is being paid to factors that relate to heat exchange, scope of thermoregulatory control and control of electrolyte metabolism in relation to growth, wool production and reproduction in sheep drinking either Bore water or Tank water and to the factors that influence scrotal heat exchange in rams.

Field studies are being complemented by intensive laboratory studies of thermoregulatory control, body electrolyte regulation and water turnover - especially in animals in the extremes of the field populations.

The study is expected to continue until 1985.

Note: See also 33.16.3, Survey of "Salt" Paddocks.

Acknowledgements: This project is assisted by financial support from the Wool Research Trust Fund.

Publications:

Burton, D.L., Morris, R.J.H., Thomas, F.A., Webster, M.E.D. (1981) Effects of increased extra-cellular (NA^+) and osmolarity on body temperature and regulation. Proc. of Australian Physiological and Pharmacological Society, 12: 135.

Thomas, F.A. and Webster, M.E.D. (1980) Changes in cerebrospinal fluid NA^+ and Ca^{++} during mild heat stress with and without water deprivation. Proc. Aust. Physiological and Pharmacological Society, 11: 158.

Thomas, F.A. and Webster, M.E.D (1980) Temperature regulation plasma and cerebrospinal fluid Na^+ balances during dehydration and subsequent rehydration in sheep. ibid, 11; 3.

Thomas, F.A. and Webster, M.E.D. (?) Temperature regulation, plasma and cerebrospinal fluid ionic patterns and dehydration in sheep. Pfugers Archiv.

18.9 FACTORS CONTRIBUTING TO DIFFERENCES IN WOOL PRODUCTION ON FOWLERS GAP

L. Stewart (MSc Study Supervised by Dr J.R. Dodson, School of Geography, U.N.S.W.)

In late 1981, Ms Stewart commenced a study to identify possible physical and biological causes of the significant and consistent variations in wool production between paddocks on Fowlers Gap Station. Comparisons are being made of the vegetation biomass and wool production of five paddocks.

This work is a follow-up to an earlier study by Kennedy and Reynolds (See 18.2.3).

An MSc thesis is to be submitted in 1984.

19. PASTORAL MANAGEMENT

19.1 REDUCTION OF EVAPORATION FROM STOCK WATER TANKS IN THE ARID ZONE

T.R. Fietz (Water Research Laboratory, U.N.S.W.)

In 1967, funds were awarded by the Water Research Foundation for evaporation reduction trials from small excavated tanks at Fowlers Gap. Following discussions with overseas experts in the field, it was concluded that a project on the scale originally planned would not result in significant findings, since evaporation from large water storages is different from that from small water storages. As funding was unavailable for a more ambitious project, it was decided to disband the study.

However, a report was written using a minor amount of data from Fowlers Gap (see below).

Report
(Using a minor amount of data from Fowlers Gap)
Fietz, T.R. Reduction of Evaporation from Small Surface Water Storages.

19.2 PASTORAL MANAGEMENT IN THE WEST DARLING REGION OF NEW SOUTH WALES

P.D. Chudleigh (PhD Thesis, 1971, U.N.S.W. Supervised by S.J. Filan, School of Wool and Pastoral Sciences, U.N.S.W.)

Two surveys of management practices and problems on pastoral properties in the West Darling region of New South Wales were conducted in 1968 and in early 1969. The results of these surveys suggested that differences among management policies adopted by graziers were associated with a lack of consensus of opinion about the biological and financial consequences of alternative policies, as well as with interpersonal differences. It was concluded that research into the

biological and financial consequences of alternative management policies was desirable as a prerequisite for improvement in decision-making processes in the region.

Chudleigh constructed a mathematical model of the management system of a particular West Darling station. The model took into account such factors as rainfall incidence, pasture responses, pasture use and depletion, sheep numbers, flock composition by sex and age. sheep production measurements such as death rates, wool cuts per head, and lamb marking percentages, animal husbandry practices, costs and product prices. End points included annual net cash income, taxable income, and a monthly cash flow.

Experiments were conducted on the model with the aim of assessing the sensitivity of financial results to changes in levels of such factors as wool cuts and lamb marking percentages.

Assessment of the validity of the model was partly subjective. The manager of the case study property accepted as valid the implications of various aspects of the model when these were discussed with him. An attempt was also made to construct a more objective test of the validity of the model: thirty replications of a simulation of the fifteen year period used in the study were used to provide estimates of the distribution of outcomes of the simulation model to test the hypothesis that the "real" results recorded over 1953 to 1968 could have come from the population of results produced by the simulation for each financial year. It appeared from application of this validation test that the simulation model provided a valid representation of the physical operations of the property. However, owing to the combination of restrictive price assumptions with some simplified accounting procedures, the model was unsuccessful in reproducing financial results actually recorded. It was concluded that the model may be useful in evaluation of the relative economic value of alternative management practices in view of the close agreement in regard to the basic physical measures of performance, although further development of the model was considered to be desirable.

Acknowledgements: The researcher was in receipt of a postgraduate fellowship (Dean's Award, Faculty of Applied Science, U.N.S.W.) for the duration of the study.

Thesis:

Chudleigh, P.D. (1971) Pastoral management in the West Darling Region of New South Wales. PhD Thesis. U.N.S.W.

Publications:

Chudleigh, P.D. (1971) Some observations on pastoral management in the Western Division of New South Wales. Fowlers Gap Arid Zone Research Station, Research Series No. 1. The University of New South Wales, Kensington.

Chudleigh, P.D. and Filan, S.J. (1972) A feed index system for simulating stocking rate adjustments in arid areas. Fowlers Gap Arid Zone Research Station, Series No. 2. The University of New South Wales, Kensington.

Chudleigh, P.D. and Filan, S.J. (1972) A simulation model of an arid zone sheep property. Aust. J. Agric. Econ., 16: 183-194.

19.3 RAINFALL STUDIES IN SIMULATION OF WOOL PRODUCTION IN AN ARID REGION

S.J. Filan (MSc Thesis, 1975, U.N.S.W. Supervised by Professor P.R. McMahon and Mr J.P. Kennedy, School of Wool and Pastoral Sciences, U.N.S.W.)

The main part of this study involved testing and improvement of the initial statistical model of monthly West Darling rainfall data originally used by Chudleigh (1971) and Chudleigh and Filan (1972) (See 19.2). It was found that Chudleigh's model failed to reflect the degree of "persistence" in rainfall that is observable in historical data. An improved statistical model was developed. The computer programmes used in this analysis have since been made available to the CSIRO Rangelands Research Group.An appendix to the study covered an analysis of sheep prices at Yelta Saleyards during 1960-1968. This examines effects of age and sex of sheep, and fleece cover, on sheep prices, jointly with the effects of wool and meat prices and district seasonal conditions.

Thesis: S.J. Filan (1975) Rainfall Studies in Simulation of Wool Production in an Arid Region. MSc U.N.S.W.

Filan, S.J. (1979) Management and the Shrublands. From: Studies in the Arid Zone - Part 4. Chenopod Shrublands. Ed R.D. Graetz and K.M.W. Howes. Division of Land Resources Management, CSIRO, Melbourne.

19.4 RESOURCE OPTIMIZATION IN ARID GRAZING SYSTEMS

I Fisher (PhD, 1974, U.N.S.W. Supervised by Associate Professor D.T. Howell, School of Civil Engineering, U.N.S.W.)

This project was a theoretical/numerical analysis of stocking policies, conducted during 1970-1973.

The project aimed to determine optimal management policies for arid grazing through simultaneous consideration of feed and water resources. Although extension of the methods developed will eventually permit this aim to be fulfilled, the research of this thesis concentrated on the determination of optimal stocking-destocking policies for a single paddock, assuming a non-limiting supply of drinking water.

A simulation of the paddock ecosystem was developed and used to estimate the joint probability density function of the state variables of the ecosystem at adjacent points in a decision process.

From the density function, the probabilities associated with all possible transitions of the state variables during each stage were estimated for use in a stochastic state - increment dynamic programming model of the paddock ecosystem. This yielded stocking/destocking policies which were optimal with respect to the characteristics ascribed to the paddock ecosystem, the assumed objective of maximisation of net benefits and the prevailing price structure.

It is argued that the approach taken allows a more realistic determination of optimal stocking/destocking policies than does simulation alone. Furthermore, it is feasible to specify a level below which the amount of perennial vegetation is not permitted to decrease with more than a specified probability for each stage. Such a constraint should be an integral part of any method of determining optimal stocking policies, if long-term productivity of the paddock ecosystem is to be maintained. This is not possible when using simulation alone.

The methods developed can be extended to determine optimal stocking/destocking policies for a group of paddocks having dissimilar characteristics, after which the effect of a limited water supply could be examined. Ultimately, the optimal development of water resources could be determined for a group of paddocks.

Thesis:
Fisher, I.H. (1974) Resource optimization in arid grazing systems. PhD U.N.S.W.

Publications:
Fisher, I.H. Derivation of optimal stocking policies for grazing in arid regions. I. Methodology. II. Combined Simulation and Dynamic Programming. Applied Mathematics and Computations. In press.

19.5 EVALUATION OF SHEEP HANDLING DEVICES FOR CRUTCHING

I.H. Auldist, R. Taylor (Fowlers Gap, J.P. Kennedy (School of Wool and Pastoral Sciences, U.N.S.W.)

During two weeks in September 1975, six sheep handling devices were evaluated on their suitability for restraining sheep for crutching.

Crutching was done in 3 different sets of sheep yards on the Station. The sheep used were large-framed South Australian strain Merinos which were in good condition and carried 6 months wool. Approximately 3250 sheep and 1300 lambs were crutched with the aid of the devices.

The devices evaluated were the "Lubker Race and Cradle", the "Payne Race and Cradle", "Husky Jetstream Harrington Patent, the Woolcock Cradle", the "Cyclone Woodruff Sheep Handler", and the "Moffat-Virtue Sheephandler". Units for evaluation were supplied by the Australian Wool Corporation.

The objectives of the evaluation procedure were to determine (a) the suitability of the devices for one-man operation; (b) the time taken to secure crutch and release the sheep; (c) the fatigue caused by crutching with the device; (d) the ease of collecting wool from crutching, and the extent to which wool was contaminated with dirt etc; and (e) the requirements for forcing pens, races etc. to provide proper feed up to the device.

All devices had one characteristic in common: they needed a dog or another man to operate efficiently. Operator fatigue was not a factor with any but the Woolcock, and all but the Woodruff allowed crutching of a standard acceptable to Fowlers Gap management.

Rates of output for the machines were not substantially different when crutching ewes under optimal feeding conditions; for one-man operation however the Lubcke and Harrington showed superiority due to better feeding. In general, outputs were similar to conventional crutching rates; they would be expected to rise with more familiarisation.

The crutching devices were less suited to handling lambs. The Woodruff, Harrington, Moffat-Virtue and Woolcock belt system could not be used for lambs and the Payne cradle needed modification. Lamb restraint was difficult in the Lubcke, Woolcock and Payne machines, which was reflected in the output rate.

Acknowledgements: Crutching devices and assistance with the evaluation were provided by the Australian Wool Corporation.

Publication:
Auldist, I.H., Taylor, R., Kennedy, J.P. (1975) Evaluation of sheep handling devices for crutching. Wool Tech. Sheep Breed. Vol.XXII, No. 111:5-11.

20. FIBRE METROLOGY

20.1 CHARACTERIZATION OF FLEECE PROPERTIES OF A FERAL GOAT FLOCK

D. Teasdale, M. Hogan (School of Wool and Pastoral Sciences, U.N.S.W.)

Fleeces have been taken from a feral goat flock at Fowlers Gap in 1983. The animals were selected so that they covered a range of ages and colours for both sexes. The fleeces will be analysed to determine their value to processors. An attempt will be made to correlate visual characteristics with fleece value to assist farmers when selecting feral animals for shearing prior to despatch to abbatoirs.

Report: M. Hogan will produce a report of findings of this research as an undergraduate project to be submitted to the U.N.S.W. School of Wool and Pastoral Sciences in December 1984.

21. BIOLOGY OF ARID ZONE HERBIVORES

21.1 BIOLOGY OF ARID ZONE HERBIVORES

T.J. Dawson, D.B. Croft (School of Zoology, U.N.S.W.) Ex members of project: E.M. Russell, C.J.F. Harrop, M.J.S. Denny.

This major research project, funded by the Australian Research Grants Scheme from 1967 to 1982 aimed to achieve an understanding of the ways large herbivores, both native and introduced, adapt to successfully survive in an arid environment. There have been two aspects to this aim:

(i) A description of "natural history" or general ecology of native species such as red kangaroos, euros, rock wallabies and emus, and an examination of their interaction and competition with introduced species, both domestic and wild (sheep, goats, rabbits, etc.).

(ii) An understanding of the fundamental mechanisms used by animals in adapting to harsh arid environments. These studies include detailed work in physiology and behaviour.

Studies in certain key areas were proposed: In behaviour these were field studies on: (1) movements of individuals within and between local populations (home ranges), (2) short and long-term relationships between individuals, (3) structure and function of the mating systems of arid zone kangaroos, (4) the structure and function of male fighting and male-male relationships, (5) competition within and between species for resources. In the laboratory, a study was to be undertaken on the development of fighting behaviour in males and the mechanisms by which dominance is established, its function and its stability.

Key areas in ecological physiology have been (1) an examination of the mechanisms by which the large arid zone

herbivores cope with the severe problems of water restriction, high ambient temperature and low nutrient availability. Much of the work at Fowlers Gap over the past decade has centered on the kangaroos. In the past couple of years however attention has been concentrated on the emus because these large birds seem to use ecological strategies diametrically opposed to those of kangaroos. (2) Selectivity of diet and its physiological basis and implications in large arid zone herbivores.

Acknowledgements: The project was supported by a grant from the Australian Research Grants Scheme (1967-1982).

Publications

General:

Dawson, T.J. & Russell, E.M. (1973) Mammalian fauna of Fowlers Gap Station. Chapter X, "Lands of Fowlers Gap Station New South Wales", Fowlers Gap Arid Zone Research Series No. 3. University of New South Wales.

Dawson, T.J. (1974) Recent advances in marsupial physiology (non-reproductive). Aust. Mammal 1: 181-187.

Dawson, T.J. (1977) Kangaroos. Scientific American. 237, 2: 78-79.

Russell, E.M. (1974) Recent ecological studies on Australian marsupials. Aust.Mammal 1: 189-209.

Russell, E.M. (1974) The biology of kangaroos. Mammal Review. 4: 1-59.

For detailed descriptions of individual projects within this general research project, see 21.1.1- 21.1.21.

(A) ENVIRONMENTAL PHYSIOLOGY OF THE RED KANGAROO AND EURO

21.1.1 STANDARD (BASAL) METABOLISM AND RESTING BODY TEMPERATURES IN THE RED KANGAROO

T.J. Dawson, A.J. Hulbert (School of Zoology, U.N.S.W.)

Red kangaroos from Fowlers Gap were studied by Dawson and Hulbert in an investigation of the relationship between standard energy metabolism and body size in marsupials as well as the level of metabolism in relation to the eutherian level. Also included in the investigation were measurements of body temperature and surface area.

The standard metabolism of marsupials was found to be proportional to almost the same fractional power of body weight as that of eutherian mammals and the whole animal kingdom in general. The level of metabolism in the marsupials, however, was approximately 30% lower than that of eutherian mammals. The marsupials were also found to have mean body temperatures 2-3^{o} C lower than is usual for eutherians.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme.

Publication:
Dawson, T.J., Hulbert, A.J. (1970). Standard metabolism, body temperature, and surface areas of Australian marsupials. American Journal of Physiology, Vol 218, No 4, pp 1233-1238.

21.1.2 BIOCLIMATOLOGICAL STUDIES ON THE MICROENVIRONMENTS OF THE DESERT KANGAROOS

T.J. Dawson, M.J.S. Denny (School of Zoology, U.N.S.W.)

During a field investigation at Fowlers Gap, it was noted that red kangaroos and euros spend hot summer days resting in two different microenvironments. Red kangaroos were observed in relatively open country under the shade of small trees, while euros tended to be found around rocky outcrops in small caves and under rock ledges.

To give an accurate assessment of the nature and magnitude of the difference in heat loads experienced by the two species in their respective habitats, a complete bioclimatological study was undertaken.

Sites were chosen after detailed observations of the daily resting or lying-up habits of the kangaroos. Aspects of the microenvironment measured were air temperature, solar radiation influx, total radiation influx, relative humidity and wind speed. Measurements were also made during a cold period in late autumn to permit an estimate of the environmental extremes to which the animals are subject.

It was evident from the study that, while the euro lives in desert regions, it avoids much of the high heat load by its choice of microhabitat, and as a result must effect a considerable saving in the water required for temperature regulation. The red kangaroo microhabitat on the other hand, does not give full protection from solar radiation. Under a small desert tree, the red kangaroo has a reduced heat load compared to that in the open desert, but it is still considerable. Under these circumstances, the animal can only dissipate its metabolic heat and any heat that flows into its body by evaporation of water.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme.

Publication:
Dawson, T.J., Denny, M.J.S. (1969) A bioclimatological comparison of the summer day microenvironments of two species of arid zone kangaroos. Ecology, Vol 50, No 2, pp 328-332.

Since kangaroos may spend some of the time during hot summer days standing in the shade, a study was undertaken to compare

the difference in the effective radiation temperatures that would be applicable to kangaroos (or any larger mammal) lying or standing in shade, and also to compare these results with the effective radiation temperature to which an animal standing in the sun is exposed.

Measurements were made to assess the temperature and environmental characteristics of these three situations at three times during a typical summer day (20 January, 1970). Aspects of the microenvironment examined were air temperature, solar radiation influx, and total radiation influx.

It was found that the effective radiation temperature differed considerably between positions 70cm and 10cm above the ground in the shade, the latter being approximately 6°C lower at midday. Thus by lying down, kangaroos should be able to effect a reasonable water saving as compared with standing in the shade. The difference in the effective radiation temperatures should be greatest on very hot days when the surface temperature outside the shade is highest.

Acknowledgement: This study was supported by a grant from the Australian Research Grants Scheme.

Publication:
Dawson, T.J. (1972) Likely effects of standing and lying on the radiation heat load experienced by a resting kangaroo on a summer day. Aust. J. Zool., 20: 17-22.

21.1.3 INSULATIVE AND REFLECTIVE PROPERTIES OF THE FUR OF RED KANGAROOS AND EUROS

T.J. Dawson (School of Zoology, U.N.S.W.) G.D. Brown (Div. of Animal Physiology, CSIRO)

In a collaborative study between the School of Zoology, U.N.S.W., and the CSIRO Division of Animal Physiology, which was supported in part by a grant from the Australian Research Grants Scheme, the insulative and reflective properties of the fur of red kangaroos and euros were investigated.

The usually accepted function of fur is the reduction of the rate of heat loss from the animal when the environment is cold. In desert environments, the fur has the additional functions of reflecting solar insulation and insulating the body against radiation that is absorbed and converted to heat at or near the surface of the fur. To examine these functional aspects of the thermal properties of kangaroo coats, Dawson and Brown conducted laboratory experiments on fur samples collected from red kangaroos and euros at Fowlers Gap.

The reflectivity of the furs of the two species to solar radiation was measured in laboratory experiments and the effects of season, site on body and wind speed were determined.

It was found that the differences in fur insulation and reflectance between the red kangaroo and the euro are quite marked and conform well with the difference in habitat selection by these species. The fur insulation of both the kangaroos was found to be similar to that of tropical and temperature zone eutherian mammals, even though they have a much lower basal heat production than eutherians.

Acknowledgements: This research was supported in part by a grant from the Australian Research Grants Scheme.

Publications:

Dawson, T.J., Brown, G.D. (1970) A comparison of the insulative and reflective properties of the fur of desert kangaroos. Comp.Biochem.Physiol. Vol 37, pp 23-38.

See also: Dawson, T.J. (1972) Thermoregulation in Australian desert kangaroos. Symp.zool.Soc.Lond. No 31, pp 133-146.

21.1.4 THERMOREGULATORY RESPONSES IN RED KANGAROOS AND EUROS

T.J. Dawson (School of Zoology, U.N.S.W.)

In this aspect of the ARGS-supported project, Biology of Arid Zone Herbivores, the thermoregulatory abilities of the red kangaroos and euro were investigated to determine the manner in which these animals, as marsupials, deal with the problems of hot deserts. Since the two species differ in their selection of habitat, the red kangaroo being an animal of the open plains while the euro lives around rocky hill country where it makes use of small caves as heat refuges, the two species were also examined from a comparative point of view.

Heat balance measurements were conducted on the two species in summer fur in a large climate room, the temperature of which could be controlled to $\pm 0.5^{o}C$.

The study showed that both species had basal metabolic rates considerably below that predicted for eutherians of similar size. The low metabolism, which is characteristic for marsupials, results in a low water requirement for temperature regulation.

In addition to the differences in the insulative and reflective properties of the fur of red kangaroos and euros identified by Dawson and Brown (see 21.1.3), a second major difference in thermoregulatory response between the two species was found to exist in their respiratory responses to high temperature. Red kangaroos, at all temperatures between $35^{o}C$ and $45^{o}C$, had panting rates much below those of the euro.

Licking appeared to be not insignificant in the evaporative water loss of the two kangaroos.

Acknowledgements: This project was supported by a grant from the Australian Research Grants Scheme.

Publications:
Dawson, T.J. (1972) Thermoregulation in Australian desert kangaroos. Symp.zool.Soc.Lond. No 31, pp 133-146.

Dawson, T.J. (1973) Thermoregulatory Responses of the Arid Zone Kangaroos, Megaleia rufa and Macropus robustus. Comp.Biochem. Physiol. Vol 46A, pp 153-169.

21.1.5 HEAT DISSIPATION DURING EXERCISE IN THE RED KANGAROO

T.J. Dawson (School of Zoology, U.N.S.W.), D. Robertshaw, C. Richard Taylor (Harvard University, Cambridge, Massachusetts)

In this study of the red kangaroo, Dawson, Robertshaw and Taylor investigated the role of sweating in thermoregulation during exercise, and its control.

The heat balance of kangaroos resting at 24°C was compared with that of animals hopping on a treadmill at a speed of 4 km/h.

Results of these experiments indicated that the red kangaroo has adopted separate evaporative cooling mechanisms for use during rest and during exercise. The resting kangaroo pants and selectively spreads saliva to increase evaporative cooling but does not sweat. The exercising kangaroo, on the other hand, is unable to spread saliva and uses an alternative system of evaporative cooling, sweating.

Acknowledgements: This study was supported jointly by grants from the Australian Research Grants Committee and the United States National Science Foundation.

Publications:
Dawson, T.J., Robertshaw, D., Taylor C. R. (1974) Sweating in the kangaroo: a cooling mechanism during exercise, but not in the heat. Am.J.Physiol, Vol 227, No 2, pp 494-498.

See also: Dawson, T.J. (1977) Kangaroos. Scientific American, Vol 237, No. 2, 78-79.

21.1.6 ENERGETICS OF LOCOMOTION OF KANGAROOS

T.J. Dawson (School of Zoology, U.N.S.W.), C. Richard Taylor (Harvard University)

In this collaborative project funded by the Australian Research Grants Scheme and the United States National Science Foundation, Dawson and Taylor set out to investigate whether it is energetically less costly for an animal to hop or to run.

Two red kangaroos collected from Fowlers Gap were trained to hop on a treadmill while wearing a lightweight ventilated mask. Oxygen consumption was measured by pulling room air through the mask at metered rates and measuring the difference

in oxygen concentration between air entering and leaving the mask. Measurements were made while the animals travelled at speeds from 1-22 kph. In separate experiments, stride frequencies were counted at speeds from 1-25 kph. Stride length was calculated from stride frequency and treadmill speed.

The experiments indicated that at speeds of less than 19 kph., the hopping kangaroo expends more energy than a running four-legged animal of the same weight, but at speeds exceeding 19 kph, it appears to be cheaper to hop.

At high speeds the hopping gait has marked advantages over running. Once kangaroos start hopping, the energetic costs do not change over a wide range of speeds. The pattern of hopping energy expenditure appears to be explained by the combination of a fixed hopping rate and the elastic storage of energy in tendons. Energy can be stored in such elastic fibrous tissues much as it is stored in the spring of a pogo stick.

This raises the question why hopping is so rare in large animals. The answer probably lies in the locomotor pattern of kangaroos at low speeds which can be best described as a "pentapedal type" of locomotion, since the animal uses its heavy tail as a fifth leg. The pentapedal gait is clumsy and energetically costly.

It is clear, however, that the kangaroo mode of locomotion has advantages in spite of its shortcomings at low speed. It is considered that the energetics of hopping may give some insight into the survival of the large hopping herbivores of Australia while their quadrupedal counterparts became extinct.

Acknowledgements: This project was funded jointly by the Australian Research Grants Scheme and the United States National Science Foundation.

Publications:

Dawson, T.J., Taylor, C.R. (1973) Energetic cost of locomotion in kangaroos. Nature, Vol 246, No. 5431, pp 313-314.

See also: Dawson, T.J. (1977) Kangaroos. Scientific American, Vol 237. No 2, 78-79.

21.1.7 WATER REQUIREMENTS AND WATER BALANCE OF DESERT KANGAROOS

T.J. Dawson, M.J.S. Denny (School of Zoology, U.N.S.W.)

One aspect of the general ARGS-supported project, Biology of Arid Zone herbivores, involved field and laboratory studies of the water requirements and water balance of the red kangaroo and the euro.

To obtain and compare information about the water and electrolyte balances of these animals under extreme conditions, samples of urine were taken simultaneously from both species under various seasonal conditions. Samples of blood and urine were collected for analysis from red kangaroos and euros at Fowlers Gap on six occasions during 1967 and 1968.

It was concluded from this early study that the urine osmolality of both the red kangaroos and the euros in the study area was apparently influenced by both environmental temperature and the condition of the feed. Temperature, while being important, was not found to be a completely overriding factor. The highest mean values for urine osmolality were obtained in October 1967 when temperatures were moderate but feed was dry due to lack of adequate rain. It was concluded that the pattern of differences in the urine osmolality between the two species may be associated with differences in microenvironment and in the types of feed utilized.

In view of the indications that food preferences are an important factor in the differences in water balance between the red kangaroo and the euro in the saltbush terrain of western NSW, further studies were carried out to assess the importance of this factor in influencing an animal's survival prospects under extreme conditions.

During two successive summers in 1970 and 1971, red kangaroos and euros were trapped at Fowlers Gap at an artificial earth dam at which considerable numbers of these animals had been observed drinking during summer evenings. The animals were weighed and samples of blood taken from them. In 1971, the kangaroos were also injected with tritiated water and the total body water content and mean daily water turnover were estimated using the technique described by Denny and Dawson (1973). Samples of blood and urine were treated and analysed by the techniques used by Dawson and Denny in their earlier study in order to determine the concentration of sodium, potassium and protein in plasma and urine, and plasma and urine osmolality.

Laboratory studies were also carried out in small outdoor pens or in pens in a temperature-controlled room where animals were subjected to dehydration regimes.

It was concluded from these studies that the arid zone kangaroos tend to be much more parsimonious in their water use than their introduced placental counterparts in the region, sheep and feral goats. On the other hand, the range of mechanisms used by arid zone kangaroos to maintain functional efficiency in the face of severe volume reduction due to environmentally-induced dehydration also can be largely found among the desert adapted placentals elsewhere in the world.

Comparison of the findings for the red kangaroo and the euro indicated differences between the two species in their patterns of water loss from interstitial spaces, cells and gut, which may reflect the flexibility of evolutionary response to specific physiological problems. While the overall problems of both species are similar, there are specific problems which are emphasized; those of the euro were thought to be nutritional, while those of the red kangaroo were considered to be thermoregulatory.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme.

Publications:

Dawson, T.J., Denny, M.J.S. (1969). Seasonal variation in the plasma and urine electrolyte concentration of the arid zone kangaroos Megaleia rufa and Macropus robustus. Aust.J.Zool., Vol 17, pp 777-84.

Denny, M.J.S., Dawson T.J. (1973). A field technique for studying water metabolism of large marsupials. Journal of Wildlife Management, Vol 37, No 4, pp 574-578.

Dawson, T.J. (1978) Osmotic and volume regulation during dehydration in desert kangaroos. From "Osmotic and Volume Regulation", Alfred Benzon Symp. X1, Munksgaard 1978.

(B) BEHAVIOUR AND ECOLOGY OF THE RED KANGAROO AND EURO

21.1.8 BREEDING PATTERNS AND AGE STRUCTURE OF POPULATIONS OF WALLAROOS/EUROS

E.M. Russell, B.J. Richardson (School of Zoology, U.N.S.W.)

The collection of field samples for Richardson's taxonomic study of kangaroos (see 30.1) provided an opportunity to compare four members of the wallaroo group (Macropus robustus robustus, M.r. erubescens, M.r. alligatoris, and M. antilopinus).

Samples of M.r. erubescens (euros) were shot at Fowlers Gap between 1966 and 1968. Field observations made of these animals at Fowlers Gap were also utilized on this project.

The paper listed below reports data obtained on the breeding patterns and age structure of populations of all four of these species, together with observations on dispersion and the types of habitat used by sympatric populations of M.r. alligatoris and M. antilopinus in the Northern Territory.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme, and by a travel grant from the Nuffield Foundation.

Publication:

Russell, E.M. and Richardson, B.J. (1971) Some observations on the breeding, age structure, dispersion and habitat of populations of Macropus robustus and Macropus antilopinus (Marsupilia) J.Zool.Lond. 165: 131-142.

21.1.9 DRINKING BEHAVIOUR IN THE RED KANGAROO AND EURO

E.M. Russell, D.G. Nicholls (School of Zoology, U.N.S.W.)

The aim of this study was to obtain information about the pattern of drinking behaviour of red kangaroos and euros, considered to be of interest in the comparison of the adaptation of both species to the same environment. Observations of the drinking behaviour of these animals drinking at the same source of water were made in December 1968 at Fowlers Gap. Detailed observations were made during the pre-dusk period and the following data were recorded: time spent within 5 metres of the water as times of arrival and departure; sex and age; presence of pouch-young in females; duration of all periods when the animals were actually drinking.

Measurements of the volume of water drunk in a known time were made on animals in captivity at the School of Zoology and the Cowan Field Station of the University of N.S.W. in Sydney.

These studies indicated that euros spent more time than red kangaroos close to the water, and drank for a longer time, although slightly less of their time at water was spent drinking. Females with large pouch young did not drink for significantly longer times than other females. Estimates of rates of drinking suggest that the volume drunk was of the order of two litres.

Acknowledgements: This work was suported by a grant from the Australian Research Grants Scheme.

Publication:

Russell, E.M. & Nicholls, D.G. (1972) Drinking behaviour in the red kangaroo (Megaleia rufa) and the Euro (Macropus robustus). Z. Saugetierkunde 37: 311-315.

21.1.10 BEHAVIOURAL/POSTURAL ADAPTATIONS TO DESERT EXISTENCE IN THE RED KANGAROO

E.M Russell, C.J.F. Harrop (School of Zoology, U.N.S.W.)

In this project, Russell and Harrop recorded field observations of the behaviour of red kangaroos during very hot summer conditions and related these observations to prevailing environmental conditions, to determine how the behaviour of large mammals in such conditions may have functional significance for their survival in hot, arid conditions.

Field observations were carried out at Fowlers Gap from January to February 1973. Animals were observed at different times of the day, generally while in the shade of a tree, and changes in their behaviour and the time at which they occurred were recorded on check sheets. Observations were also made to obtain information about the time at which animals moved out of their daytime shelters.

Aspects of the microenvironment of the red kangaroos, including air temperature, net total radiation, relative humidity and wind speed, were measured at the same time as behaviour observations were recorded.

Results indicated that the kangaroos avoided high levels of solar radiation by grazing at night and remaining in shade during the day. On very hot days, the period of inactivity was longer than on cooler days because animals stopped grazing and returned to shelter earlier in the morning and began to graze later in the afternoon.

Animals in shelter during the day were not completely inactive. Frequent changes of posture and position, grooming and licking of forelimbs occurred. The main postures adopted were Lying, Standing Crouched with the tail projecting behind the body and Standing Tail Forward, when the tail projected forwards between the legs. During late afternoon, red kangaroos spent long periods of time lying, with only short periods of Standing Crouched, and very little Standing Tail Forward. At midday, very little time was spent lying, and there were long periods of Standing Crouched and Tail Forward. The main change in Standing from midday to late afternoon was in Standing Tail Forward.

Kangaroos spent more time lying and less time standing at midday on cooler days. On very hot days, air temperature remained above body temperatures until long after animals had begun to graze, and comparisons of posture at different times of day at the same air temperature showed that Standing Crouched and Tail Forward decreased considerably during the afternoon.

Thus, marked postural changes occurred which could not be related to air temperature, wind speed or relative humidity. The level of solar radiation was closely correlated with time of day; and the change from standing to lying occurred after the reflux of solar radiation had begun to decline. In the publication listed below, Russell and Harrop discussed observed postural changes in relation to the animals' radiation environment. They suggested that the Standing Crouched and Tail Forward positions, which occur at the time of greatest radiant heat load, have some function related to temperature regulation.

Acknowledgements: This project was supported by a grant from the Australian Research Grants Scheme.

Publication:

Russell, E.M. & Harrop, C.J.F. (1976) The behaviour of red kangaroos (Megaleia rufa) on hot summer days. Z. Tierpsychol. 40: 396-426.

21.1.11 SOCIAL ORGANIZATION OF RED KANGAROOS

E.M. Russell (School of Zoology, U.N.S.W.)

Between January 1973 and January 1976, Dr Russell conducted observations of red kangaroos at Fowlers Gap to obtain information about the size and composition of groups and their stability in space and time, together with the pattern of social interactions within groups.

On three occasions, November 1974, January 1975 and March 1975, all areas of red kangaroo habitat were traversed during daylight, in a vehicle travelling at 20 k.p.h. (or less, depending on terrain). All areas of trees and shrubs which might shelter red kangaroos were visited, and all groups seen were described as accurately as possible. The operational criterion for groups was that any animal closer than 50 metres from another formed a group with that animal. In practice this was applicable without difficulty. Data for the three samples were pooled. A total of 760 groups (1935 animals) were surveyed in this way. On each of these occasions and in January 1976, certain grazing groups were watched at dawn and dusk, for longer periods ranging from a few minutes to 2 hours. These animals were watched as they came out to graze from day-time shelter and as they returned to shelter early in the morning.

The size and, as far as possible, the composition of each group, was recorded. Animals seen were classified as large male, male, female, female with obvious pouch young, juvenile, small juvenile (clearly young-at-foot) and unknown.

The groups observed ranged in size from one to 25 animals. Only 11% of the animals were alone, and groups of two, three or four accounted for nearly two-thirds of all animals seen. Groups of two were most common; more than half of them containing one female with young-at-foot. Although there are solitary males, there is clearly considerable association of males and females in groups of three or more; 30% of groups of three animals were male-female-juvenile groups. However, the composition of groups was very variable. Neither one-male nor multi-male groups occurred exclusively. All-female and all-male groups occurred.

It was concluded that individual animals or small groups do not maintain territories. Most, if not all, males and females do not form permanent associations. Although there is a brief association during oestrus, it is not known how long this lasts. Males associate also with non-oestrus females in groups which may contain one or more than one large adult male. There is clearly nothing which suggests harem formation. The most significant association is that of female and her young.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme.

Publication:
Russell, E.M. (1979) The Size and Composition of Groups in the Red Kangaroo, Macropus rufus. Aust.Wildl.Res. 6: 237-44.

21.1.12 SUMMER AND WINTER OBSERVATIONS OF THE BEHAVIOUR OF THE EURO

E.M. Russell (School of Zoology, U.N.S.W.)

Detailed observations of the behaviour of euros were carried out for summer from 26 January to 4 February 1968, and for winter from 20-23 June 1968. The study area was located in South Sandstone Paddock.

Animals were observed through binoculars and behaviour recorded in terms of ten classified activities, together with the time of commencement and completion of any activity. The types of habitat (rocky outcrops, creek beds and gullies, or open country) in which the animals were seen and the sex of animals sighted were also recorded.

At air temperatures between 32.5 and 42.5°C, more animals were seen in shelters among a rocky outcrop providing almost complete protection from solar radiation than among dense tree-shrub shelters which did not afford the same degree of protection. At lower air temperatures, more animals were seen in tree-shrub shelters. The most noticeable features of the behaviour of the animals in these shelters were the relatively high proportion of time spent standing crouched and the time spent licking forelimbs and abdomen in relation to any other grooming activity. Time spent licking tends to increase at higher temperatures, and there is also a slight positive correlation between time spent standing and temperature.

Acknowledgements: This work was supported by a grant from the Australian Research Grants Scheme.

Publication:
Russell, E.M. (1969) Summer and winter observations of the behaviour of the euro, Macropus robustus (Gould). Aust.J.Zool. 17: 655-664.

21.1.13 FLEHMEN IN KANGAROOS

D.B. Croft (School of Zoology, U.N.S.W.); G.M. Coulson (Department of Zoology, Uni. of Melb.)

From observations by Croft of red kangaroos and euros at Fowlers Gap, and of these species plus red-necked wallabies and eastern grey kangaroos in captivity at the U.N.S.W. Cowan Field Station, and from observations by Coulson at Melbourne Zoo of a further three species in the genus Macropus, a general review of the incidence of Flehmen behaviour was made. Previously this behaviour was said not to occur in kangaroos; however, this assertion was shown to be false. The behaviour is shown in the courtship of these species of Macropus kangaroos and is well-developed in the Antilopine Wallaroo.

Professor Terry Dawson, Dr David Croft and students of the School of Zoology, U.N.S.W. with captured kangaroo. (See 21.1). Photo: L. Stewart.

Acknowledgements: This work was funded by an A.R.G.S. Grants Scheme grant.

Publication:
Coulson, G.M., Croft, D.B. (1981) Flehmen in kangaroos. Aust.Mammal, 4, 139-40.

21.1.14 SOCIAL ORGANIZATION OF THE RED KANGAROO AND THE EURO
D.B. Croft (School of Zoology, U.N.S.W.)

The aim of this study was to determine and compare the social organization of two main arid zone kangaroo species, the red kangaroo and the euro.

Each species was observed on alternate 2-day blocks from March 1976 to April 1977, with additional observations in the summer of 1977-78. For each species the population was divided into five age/sex classes: large and medium adult males, adult females, and sub-adult males and females. Size classes of pouch young and the presence of young-at-foot were also noted for adult females.

The diurnal activity budget for major individual behaviour (eg. locomotion, feeding, grooming, thermoregulation) and social behaviour was determined. The distribution of group sizes and associations between age/sex classes were also determined. The matrix of social interactions between age/sex classes in each of three types of social interaction - non-agonistic, agonistic, sexual - was compiled. The mother-young relationship was analysed in further detail.

The red kangaroo proved to be the more gregarious of the two species, but the pattern of social interactions between age/sex classes was similar for the two kangaroos. The results of the study were discussed in the publications listed below in terms of various ecological and physiological factors influencing social organization.

Acknowledgements: Funded by an A.R.G.S. grant.

Publications:
Croft, D.B. (1981) Behaviour of red kangaroos, Macropus rufus, (Desmarest, 1822) in Northwestern New South Wales, Australia. Australian Mammalogy, 4, 5-58.

Croft, D.B. (1981) Social behaviour of the euro, Macropus robustus (Gould), in the Australian arid zone. Aust.Wildl.Res., 8, 13-49.

21.1.15 INTER- AND INTRASPECIFIC CONFLICT BETWEEN ARID ZONE KANGAROOS AT WATERING POINTS
D.B. Croft (School of Zoology, U.N.S.W.)

Observations at a watering trough used by red kangaroos and euros were made between 1800 and 2400 h for three week periods in January 1978 and 1979. For each species, the population was divided into five age/sex classes: large and

medium males, adult females, sub-adult males and females. The frequencies of agonistic interactions between age/sex classes during conflict over a drinking position were determined. A win/loss matrix for access to a drinking position was constructed.

It was observed that, in each species, adult males dominate adult females. Between species, the large red kangaroo does not dominate an equivalent age/sex class in the euros. Individuals do not space themselves randomly along the trough, rather the pattern is a clumped one. No set individual distance is maintained but neighbouring kangaroos closer than 60 cm tend to elicit aggressive behaviour. The probability that an individual will defend its drinking position tends to decline with time spent drinking.

Acknowledgements: Funded by an A.R.G.S. grant.

Publication:
Croft, D.B. (1983) Inter- and intraspecific conflict between arid zone kangaroos at watering points. Aust.Wildl.Res. (Submitted).

21.1.16 CAVE SHELTER USAGE BY THE EURO
D.B. Croft (School of Zoology, U.N.S.W.)

Following earlier studies by Dawson & Denny (See 21.1.2) and Russell (See 21.1.12), Dr Croft commenced, in January 1979, an investigation of the patterns of cave shelter usage by euros during the summer months. The aspects investigated were: (i) timing of entrance and exit from cave shelters (ii) cave shelter occupancy rate and its relationship to temperature (iii) competition for cave shelter and (iv) microclimactic characteristics of cave and other shelter sites.

A combination of time-lapse photography and direct observation were used to study (i) and (iii) above. For (ii), a regular census of cave usage was made at 1200h through the summer. The microclimatic study is yet to be successfully completed.

Results indicate that cave occupancy is only high on days exceeding 37^{o}C. Competition for cave shelter is intense between males but some male/female sharing occurs. No long-term defence of a cave site seems to occur except for a few large males. Cave shelters are occupied for most of the inactive period but euros lie outside the caves during early morning and late afternoon.

Acknowledgements: Funded by an A.R.G.S. grant.

Publication:
See: Croft, D.B. (1981) Social behaviour of the euro, Macropus robustus (Gould), in the Australian arid zone. Aust.Wildl.Res., 8, 13-49.

21.1.17 HOME RANGES AND MOVEMENT PATTERNS OF KANGAROOS IN NORTHWESTERN NEW SOUTH WALES

D.B. Croft (School of Zoology, U.N.S.W.)

The aim of this study was to determine home range characteristics, seasonal changes in home ranges and larger scale movements for kangaroo species on Fowlers Gap.

Samples of 8-10 red kangaroos (Macropus rufus) and euros (Macropus robustus) and 3 eastern and western grey kangaroos (Macropus giganteus and Macropus fuliginosus, respectively) were fitted with radio transmitters. Radio tracking of these individuals was then undertaken at 15 minute intervals for 2 week periods in the summer and winter of each year 1980-1983. Further locations of individuals were made at 2-daily intervals in summer. For each data set, either daily or seasonal, a 95% probability ellipse around location points was calculated to look at overlap between home ranges. Activity centres were determined from the harmonic mean centre of locations and home range boundaries and shape from a 95% isopleth at a harmonic distance enclosing this percentage of points.

It has been concluded that all four species are relatively sedentary but red kangaroos occupy significantly larger home ranges than the other species. Some large scale shifts (>10km) in home ranges of red kangaroos were found during drought.

Approximately 30 student and staff volunteers from the School of Zoology, U.N.S.W. and 20 volunteers from Earthwatch (Mass. USA) assisted in this project.

Analysis of results will be completed and published in 1984.

Acknowledgements: Funded by an A.R.G.S. grant and Earthwatch (Mass. USA).

(C) DIETARY PREFERENCES OF ARID ZONE HERBIVORES

21.1.18 (1) WATER USAGE AND DIET PREFERENCES OF RED KANGAROOS, EUROS, SHEEP AND FERAL GOATS

T.J. Dawson, M.J.S. Denny, E.M. Russell, B.A. Ellis (School of Zoology, U.N.S.W.)

During the summer months of January and February 1970, a drinking and distribution study was made of euros, red kangaroos, sheep and feral goats. Kangaroos were trapped and tagged at the site of an artificial earth dam, and then released. Dispersal of marked kangaroos away from the trap was followed by traversing the study area during daylight in a four wheel drive truck. Information of the drinking frequency and distribution of sheep and feral goats was obtained by observation.

Water budget and diet studies of the four large mammalian

herbivores were carried out in January and February 1971. Water usage was estimated using tritiated water. To help assess the influence of various factors on the water turnover, measurements were also made of plasma and urine characteristics, total body water and diet composition.

It was concluded from these studies that the marsupials had a much lower water usage than either of the eutherians. The tritiated water turnover of the goats was three times, and that of the sheep four times, the value obtained for kangaroos. While much of the difference between the marsupials and eutherians appeared to be due to fundamental physiological differences, the high water usage of sheep was in part related to the high intake of halophytic plants in their diet.

The water turnovers of the two species of kangaroo were not found to differ. Drinking studies and urine osmolalities suggested, however, that the open plains dwelling red kangaroos had a higher water requirement than the hill-inhabiting euros.

The principal components of the diets of the red kangaroo were grasses; of the euro, grasses and shrubs; of goats, trees and shrubs; of sheep, halophytic shrubs.

Acknowledgements: This study was supported by the Australian Research Grants Scheme.

Publication:

Dawson, T.J., Denny, M.J.S., Russell, E.M., Ellis, B.A. (1975) Water usage and diet preferences of free ranging kangaroos, sheep and feral goats in the Australian arid zone during summer. J.Zool.Lond. 177: 1-23.

21.1.19 COMPARISON OF THE DIETS OF YELLOW-FOOTED ROCK WALLABIES, EUROS, FERAL GOATS AND RABBITS

T.J. Dawson, B.A. Ellis (School of Zoology, U.N.S.W.)

In this study conducted from 1974-1976, the food plants eaten by the rare yellow-footed rock wallaby and its possible mammalian herbivore competitors in western New South Wales were investigated over a range of seasonal conditions. The other species examined were the euro, and the introduced feral species, the goat and the European rabbit.

In view of the rarity of the yellow-footed rock-wallaby, shooting of individuals to obtain gut samples was out of the question. Faecal analysis was therefore utilized.

The study indicated that, in good vegetational conditions, the largest component (42-52%) of the wallaby's diet was forbs, mostly small herbaceous ephemeral species. During drought, browse became the most important dietary component (44% of intake). Under these conditions, there was marked

overlap between the wallabies and goats (75% in all plant categories). Even during good seasonal conditions, there was considerable overlap in the species eaten by the rock-walabies and the other mammalian herbivores, and this increased when vegetation conditions deteriorated. This pattern was most noticeable with the introduced species, goats and rabbits, but competition appeared least from the other macropodid, the euro.

Acknowledgement: A grant from the Australian Research Grants Scheme supported the study.

Publication:
Dawson, T.J, Ellis, B.A. (1970) Comparison of the diets of yellow-footed rock-wallabies and sympatic herbivores in Western New South Wales. Aust.Wildl.Res. 6: 245-54.

21.1.20 DIET COMPETITION AMONGST ARID ZONE HERBIVORES UNDER DROUGHT CONDITIONS

T.J. Dawson, B.A. Ellis (School of Zoology, U.N.S.W.)

With the onset of drought in 1978, data were collected to estimate the diet selectivity of and diet overlap amongst red kangaroos, euros, sheep, feral goats and rabbits during bad seasonal conditions.

Acknowledgement: Research was supported by a grant from the Australian Research Grants Scheme.

Publication:
Dawson, T.J.; Ellis, B.A. Competition between native and introduced herbivores in the Australian arid zone. From "Arid Australia". Proceedings of a Symposium on the origins, biota and ecology of Australia's arid regions. Ed. H.G. Cogger. The Australian Museum, Sydney (In press).

21.1.21 ENVIRONMNENTAL PHYSIOLOGY AND ECOLOGY OF THE EMU

T.J. Dawson, R.M. Herd (School of Zoology, U.N.S.W.); E. Skadhauge (ex Visiting Professor, School of Zoology, U.N.S.W.; Dept of Veterinary Physiology, University of Copenhagen)

Research into the environmental physiology and ecology of emus, conducted from 1977 to 1982 as part of the ARGS-funded project, the Biology of Arid Zone Herbivores, included the following aspects:

(i) a study of the pattern of daily activity of emus, and in particular, the pattern of feeding activity, location of feeding, and the plants available to be eaten, in conjunction with estimates of diet from faecal samples.

(ii) a study of the diurnal pattern of activity of the emu. Emus appear to show seasonal differences in activity pattern between summer and winter. For example, they may drink twice daily in summer and only once daily in winter, and may rest during the middle of the day in summer.

(iii) studies of the water balance and energy metabolism of the emu. The water and electrolyte status of emus was investigated both in the field and the laboratory.

Acknowledgements: This research was supported by the Australian Research Grants Scheme.

Publications:

Dawson, T.J., Herd, R.M. (1983) Digestion in the emu: Low energy and nitrogen requirements of the large ratite bird. Comp.Biochem.Physiol. 75A: 41-45.

Dawson, T.J., Herd, R.M., Skadhauge, E. (1983) Water turnover and body water distribution during dehydration in a large arid-zone bird, the Emu, Dromaius novaehollandiae. Journal of Comp.Physiol. 153: 235-240.

Dawson, T.J., Read, D.G., Russell, E.M., Herd, R.M. (1984) Seasonal variation in the daily activity patterns, water relations and diet of emus. Emu 84: 93-102.

Herd, R.M. Dawson, T.J. (1984) Fibre digestion in the emu (Dromaius novaehollandiae) a large bird with a simple gut and high rates of passage. Physiol.Zool. 57: 70-84.

Herd, R.M. Histology of the gut of the emu (Dromaius novaehollandiae) Emu: manuscript submitted 1983.

21.2 WATER RELATIONS IN ARID ZONE MACROPODIDS

M.J.S. Denny (PhD Thesis, 1973, U.N.S.W.; Supervised by Professor T.J. Dawson, School of Zoology, U.N.S.W.)

Although living in close proximity to each other, the red kangaroo and the euro have quite separate ways of surviving the heat and aridity of the desert. Both are known to be able to survive periods of drought but the red kangaroo apparently survives by leaving the drought area and seeking food and water elsewhere, whilst the euro tends to remain in the drought area and tries to last out the drought period.

Supported by a CSIRO postgraduate scholarship, Denny set out to compare the ability of the two species to withstand heat stress and water deprivation, and also compare the performance of these marsupials with that of other large mammals that inhabit desert areas.

Various aspects of water metabolism were measured in the two species during cool conditions when water supply was ample. Similar measurements were also performed on animals subjected to heat stress and dehydration. The water turnover of the kangaroos was estimated with the use of the radioactive tracer, tritiated water. Tritiated water and other radioactive tracers were also used to measure body water and its distribution into the various compartments of the body. To estimate the kangaroos' performance during dehydration, measurements were made of the changes occurring in water

turnover and body water distribution during heat stress and dehydration and of the changes in the amounts of water loss from the body via urine, faeces and evaporation that may occur when the kangaroos are deprived of water. Finally, a detailed examination of the form and function of the kangaroos' kidneys was undertaken, with comparisons made for hydrating and dehydrating conditions.

The study concluded that both the red kangaroo and the euro have ruminant-like characteristics e.g. long TOH equilibrium time and high body water content. They also show many reactions to heat and dehydration typical of desert adapted mammals, e.g. a low water turnover, particularly during dehydration, and a capacity to survive a 20% weight loss.

The study also indicated that slight differences occur between the two species of kangaroo. The euro is more economical in water usage during dehydration and appears to be able to reduce the water lost via the urine, faeces and evaporation to a greater extent than the red kangaroo.

Acknowledgements: Dr Denny was supported by a CSIRO postgraduate scholarship.

Thesis:
Denny, Martin Jon Shaw. (1973) Water relations in arid zone macropodids. PhD U.N.S.W.

Publications:
Denny, M.J.S., Dawson, T.J. (1975) Comparative metabolism of tritiated water by macropodid marsupials. Amer. J. Physiol., Vol 228, No 6, June 1975, pp 1794-1799.

Denny, M.J.S., Dawson, T.J. (1975) Effects of dehydration on body-water distribution in desert kangaroos. Amer. J. Physiol., Vol 229, No. 1, July 1975. pp 251-254.

Denny, M.J.S., Dawson, T.J. (1977) Kidney structure and function of desert kangaroos. J. Appl. Physiol. Vol 42(4). pp 636-642.

See also:
Denny, M.J.S., Dawson, T.J. (1974) A field technique for studying water metabolism of large marsupials. Journal of Wildlife Management, Vol 37, No. 4, pp 574-578.

Denny, M.J.S. (1973) The use of ketamine as a safe, short duration anaesthetic in kangaroos. Br.vet.J., 129, 362-365.

21.3 SEASONAL CHANGES IN DIET PREFERENCES OF RED KANGAROOS, EUROS, SHEEP AND FERAL GOATS

B.A. Ellis (MSc Thesis, 1975, U.N.S.W. Supervised by Dr E.M. Russell, School of Zoology, U.N.S.W.)

Differences between the urine and plasma electrolyte concentrations of the native species, the red kangaroo and

the euro, and the introduced herbivores, sheep and feral goats, reported by Dawson et al (see 21.1.18) suggested that the ruminants were eating greater amounts of plants with high salt concentrations. As the shrubs of high salt concentrations (saltbushes and bluebushes) are necessary for land stabilization in the arid zone, it was considered important to know the different contributions to land degradation made by the varying animal species in their selection of different food plants.

From 1972-1974, a comparison was made of the plants eaten by the four species, in relation to the proportion of different plants present. Possible competition for food between the two species of kangaroo was also investigated.

Quantitative botanical microanalysis of stomach contents was used to compare the differences in diet between species.

Both kangaroo species and sheep selected grasses and forbs when they were readily available. As pastures deteriorated in quantity and general quality of available plants, sheep selected mainly flat chenopod shrubs whereas kangaroos selected mainly grass; with varying quantities of both flat and round chenopod plants. Although few results were obtained from goats, because they were not commonly available, they mainly ate trees and non-chenopod shrubs.

Euros were concluded to be the most selective eaters; they ate grass even when it was at very low levels in the vegetation. Potential overlap in diet between kangaroos and sheep was greatest under very good pasture conditions, and least under the poorest. Through their evident selection for flat chenopods during poorer conditions, sheep would be capable of pasture degradation under unwise management. There was little evidence for separation of the two kangaroo species through food selection at the level of plant groups.

Acknowledgements: This project was supported by a grant from the Australian Research Grants Scheme.

Thesis:

Ellis, B.A. (1975) Diet selection in two native and two introduced herbivores in an Australian Rangeland region. MSc U.N.S.W.

Publication:

Ellis, B.A., Russell, E.M., Dawson, T.J., Harrop, C.J.F. (1977) Seasonal changes in diet preferences of free-ranging red kangaroos, euros and sheep in Western New South Wales. Aust.Wildl.Res. 4: 127-44.

21.4 CARDIOVASCULAR CHARACTERISTICS OF THE RED KANGAROO

A.D. Needham (Part of PhD Thesis study, 1982 U.N.S.W.; Supervised by Prof. T.J. Dawson, School of Zoology, U.N.S.W.)

In this doctoral study of the role of the cardiovascular system of macropodid masrsupials in thermoregulation, Needham conducted investigations to determine the haemodynamic balance of a range of marsupial species in relation to their low metabolic rates. Investigations were also carried out to examine the nature and extent of cardiovascular responses to changing thermal environments in two species of macropodids.

Red kangaroos used in the study were collected from Fowlers Gap.

The vascular anatomy of the limbs and tail of the red kangaroo was examined by means of latex and polyester resin casts. The forelimbs of the kangaroo includes a profuse superficial venous network which appears highly suited to the regulation of heat exchange. It appears that saliva spreading over the surface of the forelimb associated with increased local blood flow could provide an important avenue of heat loss in the heat-stressed kangaroo. Containing a countercurrent heat exchanger and richly vascularised skin, the tail of the red kangaroo is likely to be the extremity of chief thermoregulatory importance.

Cardiac output and its distribution were measured in red kangaroos using radioactive microspheres in response to four ambient temperatures. In the cold, thermoneutral and warm environments, cardiac outputs and heart rates did not change and thermoregulatory requirements were met by a redistribution of blood to and from the skin, ears and nasal mucosa. In response to heat, cardiac output increased and blood was diverted from the gut, kidneys, spleen and liver to the shin, ears, nasal tissues and salivary glands. Blood flow through arteriovenous anastomoses (AVAs) increased markedly in the warm environment, and there is evidence for a dual mechanism of control of AVA blood flow.

Thesis:
Needham, A.D. (1982) The role of the cardiovascular system of macropodid marsupials in thermoregulation. PhD U.N.S.W.

Publication:
Needham, A.D., Dawson, T.J., Hales, J.R.S. (1974) Forelimb blood flow and saliva spreading in the thermoregulation of the red kangaroo, Megaleia Rufa. Comp.Biochem.Physiol. Vol 49A: 555-565.

21.5 A STUDY OF THE FERAL GOAT IN FAR WESTERN NEW SOUTH WALES

I.R. McRae (MSc Study Supervised by Associate Professor J.P. Kennedy, School of Wool and Pastoral Sciences, U.N.S.W.)

In this study of feral goat populations at Fowlers Gap, those aspects of goat behaviour and production relevant to the pastoral industry were examined. The study was commenced in 1978 and fieldwork completed in 1980. A thesis resulting from the study will be submitted to the School of Wool and Pastoral Sciences, University of New South Wales, in 1984, for the degree of MSc.

Goats were captured and tagged at a water trap designed and constructed during the course of the study. Information was collected on the sex, age, body size, body condition, hair length and coat colour of captured animals from the recapture of tagged specimens, the effects of seasonal change and increasing age on these characteristics were calculated. Regular herd observations were also conducted to acquire knowledge of movements, herd structure, breeding activity, times of kidding, and the effects of topography on grazing. Aerial surveying from a fixed wing aircraft proved to be a useful method of locating goats and was used a number of times for census.

The study indicated that the distribution of goats at Fowlers Gap, although dependent upon ample water supplies, was most closely associated with a favoured habitat of rugged, hilly, rough terrain. The abundance of goats was found to be irregular and continually cycling in response to infrequent but heavy harvesting by man, and due to rainfall variability with associated droughts and bush seasons. A super home range behaviour was noted for a total herd which may number thousands of individuals, and not for small herds as in areas of high rainfall. The focal points of these super home ranges were found to be the permanent water sources.

A table was constructed on age determination, based on incision teeth data from goats that had been tagged as kids and then recaptured and measured a number of times over the study period. Age structure was found to be dynamic and changed constantly from one season to the next. Sex ratio data showed a progressive decrease in the number of males to females between the two and eight incisor teeth age classes. The number of males present in each age class was found to be far in excess of the number required for effective breeding, enabling castration or heavy culling of young males to be carried out. Association group sizes were extremely variable and field observations showed groups were continually splitting and amalgamating. Similarly group compositions were constantly changing as a result of non-breeding and breeding periods, and associated kidding.

Liveweight and shoulder height showed marked sexual dimorphism with mean values higher for males in all classes.

Body condition scores for large samples of goats did not fluctuate widely over the field study period even though there were widely fluctuating levels of available feed and water.

22. CRUSTACEAN BIOLOGY

22.1 ASPECTS OF THE BIOLOGY OF THE FRESHWATER CRAYFISH, CHERAX DESTRUCTOR, IN FARM DAMS IN FAR-WESTERN N.S.W.

K.M. Reynolds (MSc Thesis, 1980, U.N.S.W.; Supervised by Dr P. Greenaway, School of Zoology, U.N.S.W.)

Cherax destructor is of considerable scientific interest because of its widespread distribution through a variety of habitats. However, comparatively little is known about the species. It occurs in arid areas, such as the Fowlers Gap region, that are periodically affected by drought. The animal is ubiquitous to inland water sources and has been a source of sport and food to man for many years, as well as a source of irritation in irrigation areas because of its burrowing habits.

This study was intended to investigate some of the basic biological characteristics of C.destructor, and to describe its mode of life in the West Darling region. Its growth, moulting, reproduction, diet and population structure were investigated. Further studies were carried out on the role of calcium, an element that is of great importance to crustaceans and which has limited their distribution in other parts of the world.

As C. destructor is assuming increasing economic importance, this project also investigated the amount of edible fish that could be obtained from an animal to determine the most efficient harvesting age. The protein composition of the flesh was also analysed, as the amount of flesh and its nutritional worth must affect any economic decisions made about the animal.

A mark-recapture study was executed in two dams at Fowlers Gap. The dams contained populations of predominantly older animals. The recapture rate varied with age and sex, with 41% of the males and 37% of the marked females being recaptured.

Results showed that moulting and breeding are antagonistic, with most females breeding in spring and then moulting. The breeding season extends from September to March with recruitment beginning in October. Most females reproduced only once per year but 3% reproduced twice.

The total calcium content of the animals represented only 5.5% of the available calcium in the dam, indicating that calcium concentration in the water at Fowlers Gap would not limit the distribution and abundance of the animals.

As a percentage of the total cooked weight of the animal, the edible flesh varied from 19 to 27%, there being a reduction in this percentage with age. The edible flesh contained 88.6% protein on a dry weight basis.

Analysis of the alimentary tract revealed that the enzyme, cellulase, was present as digestion of cellulose occurred with the passage of the digesta through the tract.

Thesis:
Reynolds, K.M. (1980) Aspects of the biology of the freshwater crayfish, Cherax destructor, in farm dams in far-Western N.S.W. MSc U.N.S.W.

23. PARROT BIOLOGY

23.1 AN INVESTIGATION OF THE WATER AND ELECTROLYTE CONSERVING MECHANISMS IN AN ARID ZONE PARROT, THE GALAH (CACATUA ROSEICAPILLA)

E. Skadhauge, (ex Visiting Professor, School of Zooloy, U.N.S.W., Dept of Veterinary Physiology, University of Copenhagen); T.J. Dawson (School of Zoology, U.N.S.W.).

During the 1977-78 summer, a study was made into the mechanisms used by galahs to maintain their salt and water balance in the arid environment in which they live. The galahs face particular problems because their food is dry grass seeds. Grass seeds provide adequate energy and protein but are low in water and salt.

Galahs have been found to have excellent salt and water conserving mechanisms. Then major area of activity in regard to these mechanisms is the cloaca and the rectum of the bird. Extensive reabsorption and modification of excretory products, of both urinary and fecal origin, takes place in these regions to ensure maximum economy in regard to salt and water.

Acknowledgements: This research was supported by the Danish Natural Science Research Council and "VOVO's Fund". Technical assistance was provided by the School of Zoology, U.N.S.W.

Publications:
Skadhauge, E., Dawson, T.J. (1980) In vitro studies of sodium transport across the lower intestine of a desert parrot. Amer.J.Physiol. 239: R285-R290.

Skadhauge, E., Dawson, T.J. (1980) Excretion of several ions and water in a xerophillic parrot. Comp.Biochem. Physiol. 65A: 325-330.

23.2 EVOLUTIONARY BIOLOGY OF THE AUSTRALIAN ROSELLAS AND RELATED PARROT

J.R. Ovenden (PhD Study. Supervised by Associate Professor R.H. Crozier, School of Zoology, U.N.S.W.)

The sub-family Platyceringe is a group of closely related parrots containing many species, most of which are found in

Australia. The rosellas can be divided into eight species within this group and the ringneck parrots are represented by four species. The rosella species have an unusual distribution in Australia: some species are geographically isolated; some species share the same range; while others form hybrid zones where the ranges overlap. Such features of rosella biogeography along with morphological and ecological factors indicate that relationships within the genus are not as straightforward as the present classification states.

Using biochemical techniques, Ovenden is studying the proteins and nucleic acids of these birds to determine their evolutionary history. Ringneck parrots (genus Barnardius) were included in this study as a control and because they are regarded as the rosella's closest relatives. Six ringneck parrots were collected from Fowlers Gap in late September 1981. All subsequent experiments were performed at the University of N.S.W., Kensington.

Preliminary analysis of data from the liver proteins of the rosellas and the ringnecks suggest that the two genera are not closely related. Convergent evolution could have occurred, producing similar phenotypes from divergent genotypes.

Analysis is continuing.

24. BLOWFLY ECOLOGY

24.1 BLOWFLY POPULATIONS IN THE ARID ZONE AND THEIR RELATIONSHIP TO FLYSTRIKE INCIDENCE

Associate Professor E. Shipp, Dr J.M.E. Anderson (School of Zoology, U.N.S.W.)

24.2 P. Anderson (MSc Study Supervised by Shipp, Anderson).

The arid zone supports 20% of Australia's sheep population and flystrike is a regular and costly occurrence.

Funded by the Wool Research Trust Fund, the project involves the long-term monitoring of populations of blowflies in the arid zone (particularly Lucilia cuprina, Calliphora nociva and Chrysomya rufifacies. As well, the ecology of these blowflies, their reproductive status and their preferred habitats are being investigated. In order to determine the relative importance of high fly numbers versus increased susceptibility as causes of outbreaks of flystrike, records of overt and covert flystrike incidence and sheep susceptibility are collected regularly. The role of carrion in augmenting blowfly populations is also being investigated.

Sheep blowfly populations are being monitored every two weeks at 19 sites along a 65 km circuit at Fowlers Gap, using standard baited traps. Analysis of the reproductive state of

the blowflies is by dissection and classification of ovarian development. Carcass covers designed and built specifically for the project are used to catch adult blowflies emerging from the carcasses of rabbits, sheep, goats and kangaroos. Larvae collected from sheep strike are reared through for identification. The meteorological station at Fowlers Gap is used to obtain accurate weather records, but extra data at specific sites is also collected to augment the central data.

Results to date indicate that two primary blowflies are responsible for most of the flystrike at Fowlers Gap (Lucilia cuprina and Calliphora nociva). As peak blowfly populations occur at different times of the year for these species (L. cuprina in spring-early summer and autumn; and C. nociva in autumn-winter), there is no period of the year free from primary flies.

Strikes appear to occur slightly before the increase in fly numbers, suggesting that L. cuprina numbers increase as a result of flystrike. Hence, sheep susceptibility may be the major limiting factor affecting blowfly numbers and flystrike.

No L. cuprina has emerged from any carcass, which indicates that L. cuprina populations are related to live sheep, at least in periods of drought and high temperatures. But C. nociva populations are mainly derived from carcasses.

Trapping data indicate L. cuprina has constant 'preferred' and 'not-preferred' habitats.

Acknowledgements: This project is supported by funds from the Wool Research Trust Fund to June 1985.

Publications:

Anderson, J.M.E., Shipp, E., Anderson, P.J. (1983) Blowfly populations and strike incidence in the arid zone of N.S.W. Sheep Blowfly and Flystrike in Sheep. Sec. Nat. Symp. Dept. Ag. N.S.W. pp. 91-96.

Anderson, J.M.E., Shipp E., Anderson, P.J. (1983) Preferred habitats of blowflies in the arid zone of N.S.W. Sheep Blowfly and Flystrike in Sheep, Sec. Nat. Symp. Dept. AG. N.S.W. pp. 133-136.

Anderson, J.M.E., Shipp, E., Anderson, P.J. (1983) Blowfly populations and carrion in the arid zone of N.S.W. Sheep Blowfly and Flystrike in Sheep. See Nat. Symp. Dept. Ag. N.S.W. pp. 138-141.

25. ANT ECOLOGY

25.1 ECOLOGY OF TWO SPECIES OF SEED-COLLECTING ANTS, CHELANER WHITEI AND C. ROTHSTEINI

E.A. Davison (PhD 1982, University of New England)

From 1975 to 1978, Ms Davison conducted field and laboratory studies of the ecology of two species of seed-collecting ants, Chelaner whitei and C. rothsteini.

C. whitei colonies contain workers ranging in size from 3 mm to 7 mm whereas a C. rothsteini colony contains workers of about 3 mm only. Nests of both species occur within a few metres of each other; foraging ranges and type of seed collected overlap considerably. Differences in temperature preference, foraging behaviour, colony size, growth and reproduction result in different adaptive strategies for survival in the unpredictable environment of the semi-arid zone.

Two 1-ha plots on the alluvial plains and two 1/2-ha plots on the stony hills were established. Ants' nests and vegetation were mapped and foraging activity recorded to gain an estimate of the foraging range and distribution of harvester ants' nests in relation to other ants, vegetation and soil type. Experimental sub-plots were set up to test the effect of altering seed abundance and distribution. Two nests of each species were excavated (one large and one small). Large nests were excavated to obtain data on nest structure and numbers of individuals per colony; all individuals from the smaller colonies were collected live and placed in two glass-fronted terrariums for observations of brood-rearing behaviour in the laboratory.

It was demonstrated that ants in general, and harvester ants in particular, are a very important and conspicious component of the arid ecosystem. Harvester ants are especially adapted to survive in harsh unpredictable arid environments such as that at Fowlers Gap. Their ability to collect and store large supplies of seeds enables the colony to survive prolonged drought.

The two species of harvester ants studied are able to survive and coexist in the same habitat at Fowlers Gap by adopting different foraging and reproductive strategies.

On Fowlers Gap harvester ants play a positive role in revegetating scald areas (after drought) by breaking up the hard soil (in nest digging) and concentrating nutrients (in the midden mounds surrounding the nest entrance). After good rains new vegetation on scalds occurs typically in clumps on present or recently extinct ant mounds and consists mostly of those plants whose seeds had been collected by ants.

Thesis:
Davidon E.A. (1982) Ecological studies of two species of harvester ants. PhD University of New England.

Publication:
Davison, E.A. (1982) Seed utilizations by harvester ants. In: "Ant-Plant Interactions in Australia". Ed R.C. Buckley. W. Junk, The Hague. pp.1-10.

25.2 MICROENVIRONMENTAL AND ECOLOGICAL STUDIES ON MEAT ANTS
D. Greenaway (School of Zoology, U.N.S.W.).

Entry included under category 27 "Comparative Environmental Physiology": see 27.1.

26. SMALL MAMMAL ECOLOGY

26.1 ECOLOGICAL STUDIES OF SMINTHOPSIS CRASSICAUDATA (MARSUPALIAL DASYURIDAE)
S.R. Morton (PhD Thesis, 1976, University of Melbourne).

The project aimed to identify the major adaptations enabling this insectivorous marsupial to inhabit a variety of open grassland and desert environments. In particular, it focussed on the attributes which the species has developed in response to life in an arid environment. Such attributes can only be identified by comparison between populations in arid environments and those in more temperate mesic environments. Thus, the core of this study was a comparison of a population of the fat-tailed dunnart in southern Victoria with a population at Fowlers Gap Station from the points of view of reproduction and life-history; behaviour; diet and predators; morphology; physiological attributes.

Field studies were conducted at three sites in south-eastern Australia. The major site, near Werribee in Victoria, was used in all phases of the study. The site at Fowlers Gap Station was used primarily to study reproduction as was also the site at Willandra National Park.

In arid habitats such as Fowlers Gap, S. crassicaudata shelters in cracks in the soil, and when animals emerged after dusk to forage, they could be located by spotlighting from a vehicle. The headlights were left on low beam and the vehicle driven at 5-10 kph until an animal was seen running across the ground. A spotlight was then trained on it, and in most cases the animal soon stopped beneath a clump of vegetation where it could be captured by hand. Enough animals were usually captured in three to five nights of each collecting trip to enable the reproductive cycle to be evaluated.

In its various aspects, the work showed that one environmental difficulty - unpredictable variability in food

supply - overshadowed all others, and this difficulty seems to be common to all habitats regardless of their aridity. Thus, only minor adjustments have been made by dunnarts in adapting to aridity.

Acknowledgements: This study was carried out with the support of an Australian Commonwealth Postgraduate Award and grants from the M.A. Ingram Trust.

Thesis:
Morton, S.R. (1976) Ecological and physiological studies of Sminthopsis crassicaudata (Marsupialia: Dasyuridae).

Publications:
Morton, S.R. (1974) First record of forrest's mouse Leggadina forresti (Thomas, 1906) in N.S.W. Victorian Naturalist, Vol 91, No 4, pp 92-94.

Morton, S.R. (1978) An ecological study of Sminthopsis crassicaudata (Marsupialia: Dasyuridae) I. Distribution, study areas and methods. Aust.Wildl.Res. 5: 151-62.

Morton, S.R. (1978) An ecological study of Sminthopsis crassicaudata (Marsupialia: Dasyuridae) II. Behaviour and social organization. Aust.Wildl.Res. 5: 163-82.

Morton, S.R. (1978) An ecological study of Sminthopsis crassicaudata (Marsupialia: Dasyuridae) III. Reproduction and life history. Aust.Wildl.Res. 5: 183-211.

Morton, S.R. & Martin, A.A. (1979) Feeding ecology of the barn owl, Tyto alba, in Arid Southern Australia. Aust.Wildl.Res. 6: 191-294.

Morton, S.R. (1980) Ecological correlates of caudal fat storage in small mammals. Aust.Mammal. 3: 81-86.

Morton, S.R. (1980) Field and laboratory studies of water metabolism in Sminthopsis crassicaudata. (Marsupialia: Dasyuridae) Aust.J.Zool. 28: 213-27.

Morton, S.R. and Alexander, F. (1982) Geographic variation in the external morphology of Sminthopsis crassicaudata (Dasyuridae, Marsupialia) In "Carnivorous Marsupials" ed. by M. Archer, pp. 695-698. Roy.Zool.Soc. New South Wales: Sydney, Australia.

26.2 A COMPARISON OF THE ECOLOGY OF TWO ARID DASYURIDS, PLANIGALE GILESI AND P. TENUIROSTRIS

D. Read (PhD. Study Supervised by Dr M. Archer, School of Zoology, U.N.S.W.)

Prior to 1975, only two small mammal species were known from the Fowlers Gap district. These were the marsupial, Sminthopsis crassicaudata, and the introduced house mouse,

Mus musculus. Since then, four more native species (three marsupial and one rodent) have been found at Fowlers Gap. Very little information on the biology of these species is known and research has focussed on the ecological interactions of two species of the genus Planigale. These tiny marsupials (adults weigh between 5g and 12g) are among the world's smallest mammals. Important scientific considerations relate to the manner by which these sympatric species partition resources and so facilitate survival in the arid environment.

In March 1979, David Read commenced a PhD study of these species. Aspects under investigation are habitat preferences, diet, movement, home range, daily activity patterns and reproduction. In excess of two years of field work, involving trapping and tagging of animals, has been conducted on the alluvial plains of Fowlers Gap. Detailed laboratory studies on activity patterns and reproduction have followed the field investigations.

Results indicate that both species prefer habitats with cracking clay soils but with a range of vegetation type and cover. Both species are opportunistic in diet and eat a variety of insects, spiders and ground dwelling arthropods and even small lizards. In contrast to most other small mammals, planigales are basically wanderers and, except for females burdened with pouch young, appear to have no fixed home range area. The smaller species P. tenuirostris is less active than P. gilesi, and most of its activity is below the ground surface. Breeding in both species is from August to February with females raising more than one litter in a season. The maximum litter size is 12 but most are between six and eight pouched young.

It is hoped that future research will investigate the interactions between these marsupial carnivores and the dynamics of their food resources of ground frequenting arthropods.

Publications:

Read, D.G. (1982) Observations on the movements of two arid zone planigales (dasyuridae, marsupialia). "Carnivorous Marsupials" ed. M. Archer, Roy.Zool.Soc. New South Wales, pp.227-31.

Read, D.G. (1984) Movements and home ranges of three sympatric dasyurids, Sminthopsis crassicaudata, Planigale gilesi and P. tenuirostris (Marsupialia), in semi-arid Western New South Wales. Aust.Wildl.Res. 11: 223-34.

27. COMPARATIVE ENVIRONMENTAL PHYSIOLOGY

27.1/ (25.2) MICROENVIRONMENTAL AND ECOLOGICAL STUDIES ON MEAT ANTS

P. Greenaway (School of Zoology, U.N.S.W.)

This investigation examined activity patterns of the Australian arid zone meat ant, Iridomyrmex purpureus form viridiaeneus, under field conditions in relation to environmental temperatures on the trail and radiation heat loads received.

Several nests were examined from 1976 to 1979 on a north-west facing slope in Sandstone Paddock, Fowlers Gap. Activity of the ants was monitored by counting, at 15 or 30 minute intervals, the number of ants passing a given point on the trail in one minute; incoming and outgoing foragers were counted separately and data were expressed as ants per minute. A number of environmental parameters such as ground and air temperature solar and nett radiation were measured to determine which environmental factors might influence foraging times in these ants.

Results indicate that trailing activity is restricted to the hours of daylight and is further limited by the temperature of the air surrounding the ant and by the net radiant heat load. Activity in winter begins well after sunrise and continues until late afternoon averaging about 7.4 hours per day. Midsummer activity occupies two distinct periods, one commencing at dawn and the other in late afternoon; the two together total about 6.8 hours per day. The upper and lower values of air temperature between which ants are active are 43.5°C and 14°C. Radiation heat input is dissipated from the ants by convective heat loss.

Publication:

Greenaway, P. (1981) Temperature limits to trailing activity in the Australian arid-zone meat ant Iridomyrmex purpureus form viridiaeneus. Aust. J. Zool. 29: 621-30.

28. ENDOCRINOLOGY

28.1 THE HISTOLOGICAL STUDY OF PITUITARY-GONADAL RELATIONSHIPS IN SHEEP.

R.J. Tassell (PhD. Thesis, 1976, U.N.S.W., Supervised by Professor J.P. Kennedy, School of Wool and Pastoral Sciences, U.N.S.W.)

For part of this study, Merino wethers at Fowlers Gap either received an implant of testosterone propionate or were not treated. Wethers were killed in pairs at 0, 25, 36, 50 and 60 days after being implanted. After slaughter the pituitary glands, thyroid glands and seminal vesicles were removed and prepared for microscopic examination. The object was to identify the cellular sources of the hormones produced by the

anterior pituitary gland of the sheep. In this study of wether pituitaries there was a tentative identification of two classes of cells which are involved in gonadotrophin production. This conclusion was then examined further using sheep obtained from other sources.

Acknowledgements: This work was done while Dr Tassell held an Australian Meat Research Committee postgraduate scholarship.

Publications:
Tassell, Robin and Kennedy, J.P. (1972) Tinctorial differentiation of the cell types in the pars anterior of the sheep. Aust.J.Biol.Sci. 25: 1249-57.

28.2 INSULIN AND INSULIN-LIKE HORMONES IN KANGAROOS

A.W. White (PhD Thesis, 1980, U.N.S.W. Supervised by Dr C.J.F. Harrop, Dr A.M. Beal, School of Zoology, U.N.S.W.)

Very little information is available on the role of certain hormones in marsupials, with the exception of reproductive hormones. Insulin is known to be a primary metabolic regulator in eutherian mammals but its role in marsupials has not been demonstrated. This project sought to investigate the function of insulin and allied hormones in kangaroos.

Animals used in the study included red kangaroos, euros, eastern grey kangaroos, brush-tailed possums, cattle, sheep, rabbits and rats. The specimens of red kangaroos and euros were shot at Fowlers Gap. The sheep were slaughtered at the Station.

Acknowledgements:
The work was supported in part by a grant from the Australian Research Grants Scheme.

Thesis:
White, A.W. (1980) Insulin and insulin-like hormones in kangaroos. PhD U.N.S.W.

Publications:
White, A.W. & Harrop, C.J.F. (1975)
The islets of Langherhans of macropodid marsupials: a comparison with eutherian species. Aust.J.Zool. 23: 309-319.

White, A.W. & Harrop, C.J.F. (1978) The ontogeny of the pancreas of macropodid marsupials. Aust.J.Zool. 26: 487-499.

See also:
White, A.W. (1975) Insulin receptor proteins in the erythrocytes of monotremes and other vertebrates. Aust.Zool. 19: 327-334.

White, A.W. and Harrop, C.J.F. (1975) The islets of Langherhans of macropodid marsupials. Abstract of paper presented at the 17th Annual Meeting of the Australian Mammal Society at Armidale. Aust.Mammal.Soc.Bull. 3 (1): 33.

White, A.W. & Harrop, C.J.F. (1977) The ontogeny of the kangaroo pancreas. Abstract of paper presented at 19th Annual Meeting of the Australian Mammal Society at Fowlers Gap. Aust.Mammal Soc. Bull. 3 (2): 18-19.

29. REPRODUCTIVE BIOLOGY

29.1 ULTRASTRUCTURAL STUDIES ON THE UTERINE LUTEAL PHASE IN THE MARSUPIAL, TRICHOSURUS VULPECULA

C.D. Shorey (PhD Thesis, 1970, U.N.S.W.; Supervised by Dr R.L. Hughes, Prof. G.B. Sharman, School of Zoology, U.N.S.W.)

This doctoral study, conducted from 1968-1970, elucidated the difference between the structural and functional aspects of pregnancy and non-pregnancy in terms of the secretory activity of the corpus luteum and the uterine endometrium of the brush-tailed possum.

A number of samples of the species used in this project were collected from Fowlers Gap.

Experimental work involved morphometric measurements on the uterus; ultrastructural investigations on the uterine endometrium and corpus luteum; and the measurement of progesterone and oestrogen concentrations during pregnancy and a normal oestrus cycle.

Thesis:

C.D. Shorey (1970) "Ultrastructural studies on the uterine luteal phase in the marsupial, Trichosurus vulpecula" PhD U.N.S.W.

Publications:

Shorey, C.D., Hughes, R.L. (1972) Uterine glandular regeneration during the follicular phase in the marsupial Trichosurus vulpecula. Aust. J. Zool. 20: 235-247.

Shorey, C.D., Hughes, R.L. (1973) Development, function, and regression of the corpus luteum in the marsupial Trichosurus vulpecula. Aust. J. Zool. 21: 1-19.

Shorey, C.D., Hughes, R.L. (1975) Uterine response to ovariectomy during the proliferative and luteal phases in the marsupial Trichosurus vulpecula. J. Reprod. Text. 42: 221-228.

Thorburn, G.D., Cox, R.I., Shorey, C.D. (1971) Ovarian steroid secretion rates in the marsupial, Trichosurus vulpecula. J. Reprod. Fert. 24: 139.

29.2 TERTIARY EGG MEMBRANES OF THE RED KANGAROO AND THE EURO
R.L.Hughes (Part of PhD Thesis, 1974, U.N.S.W.)

Dr Hughes' doctoral study of the tertiary egg membranes of marsupials entailed microanalytical, histochemical and ultrastructural observations on 65 eggs or embryos of 88 female brush-tailed possums (Trichosurus vulpecula) which were compared with observations on 38 eggs or embryos from six other marsupial species. The largest proportion of material other than that from T.vulpecula consisted of 22 stages from the red kangaroo (Megaleia rufa) and 9 from the euro (Macropus robustus). Specimens of these species of kangaroo were obtained from Fowlers Gap.

Thesis:
Hughes, R.L. (1974) The tertiary egg membranes of the marsupial Trichosurus vulpecula. PhD U.N.S.W.

Publications:
Hughes, R.L. (1969) A light and electron microscope study of the tertiary egg membranes of three marsupial species: Trichosurus vulpecula: Macropus robustus: Megaleia rufa. J.Anat. 104: 407 (Proc.Anat.Soc.Aust & N.Z. May 1968)

Hughes, R.L. (1974) Morphological studies in implantation in marsupials. J. Reprod. Fert. 39: 173-86.

29.3 A STUDY OF THE EFFECT OF TEMPERATURE ON REPRODUCTION IN THE MALE KANGAROO
F.N. Carrick (Part of PhD Thesis, 1977, School of Zoology, U.N.S.W.)

Carrick's doctoral study of the reproductive physiology of male marsupials included investigation of steroid production by the testes of 5 marsupial species; scrotal thermoregulation in Macropus robustus; the kinetics of spermatogenesis in 4 marsupial species and the duration of epididymal transit; spermiogenesis in T. vulpecula; and post-testicular development of spermatozoa of T. vulpecula during epididymal transit.

Specimens of M.robustus and Me.rufa were trapped at Fowlers Gap and sampled at the Research Station Laboratory, usually within a few hours of capture.

Testicular androgen production in both species was examined in spermatic venous blood samples by competitive protein bending assay and radio immunoassay. The presence of 17 β-hydrosysteroids other than testosterone was investigated by sephadex LH-20 chromatography. This research indicated that testosterone is the major 17 β-hydroxysteroid of M.robustus and Me.rufa.

Scrotal thermoregulation in M.robustus was investigated by short-range radio telemetry at Fowlers Gap. Scrotal temperature was maintained below body and air temperatures

when M.robustus was exposed to a high heat load. Scrotal "licking" appeared to be an important avenue for evaporative heat loss.

Thesis:
Carrick, F.N. (1977) Studies in the reproductive physiology of male marsupials. PhD U.N.S.W.

Publications:
Carrick, F.N. (1972) Biotelemetry of temperature in the Euro, Macropus robustus. Aust.Mammal. 1: 65.

Carrick, F.N. & Cox, R.I. (1973) Testosterone concentrations in the spermatic vein plasma of marsupials. J. Reprod. Fert. 32: 338-339.

30. EVOLUTIONARY GENETICS

30.1 A MORPHOLOGICAL AND BIOCHEMICAL STUDY OF THE MARSUPIAL GENERA, MEGALEIA (THE RED KANGAROO) AND OSHRANTER (WALLAROO-EURO)

B.J. Richardson (PhD Thesis, 1970, U.N.S.W.; Supervised by Prof. G.B. Sharman, Dr E.M. Russell, School of Zoology, U.N.S.W.)

This study was undertaken with two intentions. Firstly, to revise the intrageneric taxonomy of two of the three genera of kangaroos. Secondly, to examine the usefulness of electrophoresis in taxonomic, evolutionary and ecological studies.

Euros are the most widely distributed of the larger macropodids. They are found throughout mainland Australia in a variety of habitats. Prior to this study, the taxonomy of these animals was rather confused, with 13 species or subspecies having been described. The red kangaroo has a more or less continuous distribution within the 20" rainfall isohyet of Australia. Although six species or subspecies have been described, only one specific name and three subspecific names are in regular use.

The work at Fowlers Gap which formed a part of this project consisted of collecting blood samples, skulls and ecological data on sets of euros and red kangaroos collected four times a year as part of a wider programme of study of these animals undertaken by the School of Zoology, University of New South Wales. Each animal was aged from molar progression. A series of skull measurements was taken for comparison with data for populations from elsewhere in Australia. The blood samples were used to study genetic variation in these animals. The data was also analysed to detect temporal and microgeographical variation in the distribution of character states in the Fowlers Gap population. The data for each animal is available from the author.

Acknowledgements: The researcher was in receipt of a travel grant from the Nuffield Foundation of Australia, and a University of New South Wales Postgraduate Scholarship.

Publications:

Richardson, B.J. & Czuppon, A.B. (1969) Geographical variation in quantitative red blood cell glucose-6-phosphate dehydrogenase in the euro (Macropus robustus; Marsupialia). Aust.J.Sci. 32: 106-7.

Richardson, B.J. & Russell, E.M. (1969) Changes with ages in the proportion of nucleated red blood cell types and in the type of haemoglobin in kangaroo pouch young. Aust.J.exp.Biol.med.Sci. 47: 573-580.

Richardson, B.J. & Czuppon, A.B. (1970) Interpopulation differences in red blood cell enzyme levels of the wallaroo Macropus robustus (Marsupialia). Aust.J.biol.Sci. 23: 617-21.

Richardson, B.J. & Sharman, G.B. (1976) Biochemical and morphlogical observations on the wallaroos (Macropodidae: - Marsupialia) with a suggested new taxonomy. J.Zool.Lond. 179: 499-513.

Russell, E.M. & Richardson, B.J. (1971) Some observations on the breeding, age structure, disperson and habitat of populations of Macropus robustus and Macropus antilopinus (Marsupialia). J.Zool.Lond. 165: 131-142.

See also -

Air, G.M., Thompson, E.O.P., Richardson, B.J., and Sharman, G.B. (1971) Amino acid sequences of kangaroo myoglobin and haemoglobin. Nature 229: 391-4.

30.2 EVOLUTIONARY GENETIC STUDIES ON ARID ZONE ANTS

Associate Professor R.H. Crozier (School of Zoology, U.N.S.W)

This on-going project, commenced in 1975, may be divided conveniently into four sub-projects:

1. Karyotype evolution. A number of species were collected on the station during 1975 as part of a general survey of Australian ant chromosomes made during the post-doctoral visit of H.T. Imai. This study showed that ant chromosome numbers are probably rising during evolution, and that complex changes occur from time in widely-different lineages.

2. Speciation in the Rhytidoponera metallica group. Rhytidoponera metallica is probably the most widely-distributed species of ant in Australia in general, and on Fowlers Gap in particular. But radical chromosome restructuring in lower Murray Basin populations strongly indicate that these represent different species to ants collected elsewhere in the eastern half of Australia.

3. Isozyme, morphometric and karyotype divergence in a sample of Rhytidoponera species. Measurement and allozyme data were taken from colonies of a wide range of Thytidoponera species, and combined with karyotype information from either the same colonies or conspecific colonies from the study in (1) above. The results indicate a fairly high level of agreement between allozyme and morphometric data, but show that karyotypic change is sufficiently erratic in rate as not to constitute a reliable "clock". The allozyne data tend to cluster species more by habitat than do the morphometric data. A new test for the significance of differences between dendrograms was devised. A morphological study also established the phylogenetic significance of the lack, in Rhytidoponera, of suction pads (arolia) in the feet of females.

4. Relatedness and population structure in Rhytidoponera mayri. Conservation paddock supports a high density of the conical mounds of this large, queenless species, and some 100 nests from a small section (approx 200m square) were sampled for each of three years to ascertain the levels of genetic relatedness within and between colonies. It was found, using a regression method to estimate relatedness and autocorrelation analysis to test for microgeographic variation, that ants from the same nest are only weakly related (b = ca. 0.17), that ants from neighbouring nests are more closely related than those from nests further apart within the study area, and that there is significant microgeographic variation in genetic variation. Ants from different nests are usually hostile, and fighting is often observed, yet tests with marked ants show that ants move between nests, sometimes on a large scale. Such movement involves pairs of ants, one carrying the other. The carrying ants show markedly less ovarian activity than the ants they carry. It is uncertain as to whether nests that have declined in population are likely to be "joined" by ants from any neighbouring nest, or whether nests are combined into "confederations", with such "visiting" occurring only between nests of the same confederation. Tests of marked ants also show that individual ants tend, over a period of a few days at least, to forage in the same direction each trip, and that foraging does not extend far beyond the perimeter established by neighboring nests.

Acknowledgements: This research is funded by a grant from the Australian Research Grants Scheme.

Publications:

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31. PALAEONTOLOGY

31.1 COLLECTION OF VERTEBRATES IN ABANDONED MINE SHAFTS ON FOWLERS GAP STATION

M. Archer (School of Zoology, U.N.S.W.)

Mammals, snakes, lizards and other animals had accumulated as carcasses at the bases of abandoned mining shafts on Fowlers Gap Station. In 1979, Dr Michael Archer and a party of students descended a principal shaft on a wire ladder and retrieved about 30kg of superficial sediments from the shaft bottom. This was sieved in water to remove dust and, when dry, sorted at the Station. Many species were obtained including Sminthopsis macrousa, an otherwise uncommon Dunnart on the Station. Pythons were also common. The material is available for study in the School of Zoology, University of New South Wales.

31.2 PROCESSING OF FOSSIL VERTEBRATE-BEARING SEDIMENTS OF MIOCENE AGE FROM FROME DOWNS STATION, SOUTH AUSTRALIA

M. Archer (School of Zoology, U.N.S.W.)

Fowlers Gap Station was utilised as a work-base for this project conducted in 1980 by Dr Archer and students of the School of Zoology, U.N.S.W.

Approximately two tonnes of Miocene clays and sands were collected by the research party from Frome Downs Station, South Australia. This matrix was carried by truck to Fowlers Gap where it was washed in screen boxes in the sheep troughs to remove the clay and sand. The residue consisted of gypsum crystals and fossil boxes. This concentrate was transported to Sydney where it was sorted for its fossil vertebrates.

Many new species of Miocene mammals were obtained from what were previously unknown sites. A publication reporting the results is in preparation.

Acknowledgements: This research was supported by a grant from the Australian Research Grants Scheme.

32. ARCHAEOLOGY

32.1 ABORIGINAL ROCK ENGRAVINGS, STURTS MEADOWS, N.S.W.

J. Clegg, J. McDonald (Department of Anthropology, University of Sydney); D. Dragovich (Department of Geography, University of Sydney); B. Triggs (Zoologist, "Dead Finish", Victoria)

In the region of Fowlers Gap, there are many interesting ancient Aboriginal rock engravings. In recent years, John Clegg of the Department of Anthropology of the University of Sydney has made a number of expeditions to the area, and particularly to the property, Sturts Meadows, south of Fowlers Gap, using the facilities at the research station as a base. (See also 35.16).

Many of these engravings are of kangaroo tracks. A Fourth Year Honours student in Anthropology, Ms J. McDonald, carried out a research project aimed at identifying the tracks by species of kangaroo. As a result of interaction amongst the Sydney University anthropology expedition led by Clegg, the Zoology party led by Grigg (see 35.13), and the zoologist, Barbara Triggs, a method has been developed and described for this objective.

Dragovich has also carried out investigations of the substance known as "desert varnish" which coats many of the ancient engravings in the arid zone.

Thesis:

J. McDonald (1982) On the write track. B.A. Hons. Department of Anthropology, University of Sydney.

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Clegg, J. (1983) Correlations and associations at Sturts Meadows. pages 214-235 in "Archaeology at ANZAAS 1983" (ed Moya Smith) W.A. Museum.

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McDonald, J. (1983) The identification of species in a Panaramitee style engraving site. pp 236-272 ibid.

Triggs, B. (1984) Mammal tracks and science, a fieldguide for South-eastern Australia. Oxford University Press, Melbourne. (See Fig 22, p 34).

Note also: Clegg's work at Sturts Meadows was featured in the ABC Science Show radio series called "Mungo to Makaratta" in a programme entitled "Prehistoric Pictures". Tapes are available.

33. SOIL CONSERVATION STUDIES

Following is a summary of research activities carried out by the New South Wales Soil Conservation Service at Fowlers Gap. Much of the information in this report has been compiled from original records and some from Soil Conservation Service reports.

The activities have been divided into two sections:

A. Completed research projects.

B. Ongoing projects.

A. COMPLETED RESEARCH PROJECTS

33.1 SHRUB STUDIES IN A KANGAROO-PROOF EXCLOSURE

The aim of these studies was to measure the effect of kangaroo grazing on vegetation establishment on regenerating eroded areas.

The heights and diameters of bladder saltbush (Atriplex vesicaria) were measured along transects inside and outside a kangaroo-proof exclosure, over a period of six years. Both areas were ungrazed by domestic stock.

There was no significant difference between ground cover and bush size inside or outside the exclosure, suggesting that

kangaroos have only a small effect on vegetation in this community. Unfortunately kangaroo numbers were not constant during the study, having reduced in numbers considerably towards the end of the period.

33.2 USE OF A DUNG SAMPLING TECHNIQUE TO MEASURE RELATIVE GRAZING TRENDS

Samples of kangaroo and sheep dung were collected in November 1959 and March 1963 from 13 selected transects in Conservation Paddock. The transects were 100 metres long by 63.5 cm wide and samples collected were divided into "old" and "recent" classes and weighed. The weight expressed in pounds per acres gave a measure of total and recent grazing activity.

The results showed that the technique could be used to show past grazing pressures, at least relatively, and to compare stocking of vegetation communities within a paddock, and could also reflect changes in paddocks with time.

The seedlings were planted in rows with half in a ploughed area with banks and half in a ploughed area without banks. All trees were sprayed with "Zip" animal repellent.

Methods and results are outlined in the publication listed below.

Publication:
Warren, J.F. (1975) J.Soil.Cons. N.S.W. 27(3): 182-6.

33.3 ANIMAL REPELLENT TRIAL

A trial was established in 1958 to test the usefulness of three animal repellents in protecting tree seedlings against grazing, especially during early growth.

Two species of trees were used: River redgum (Eucalyptus camaldulensis) and mulga (Acacia aneura).

Four treatments were used:

1. control
2. resin treated
3. Agserv "Zip" repellent
4. creosote soaked twine

All trees were eaten when exposed to grazing by sheep, kangaroos or rabbits. However, when trees were exposed only to kangaroos and rabbits, the repellents worked.

This trial was only carried out for a small period of time and this, coupled with the prevailing seasonal conditions and heavy stock concentration, produced a somewhat inconclusive result.

33.4 TREE GROWTH TRIALS ON PONDED AREAS

Introduction: A tree growth trial was initiated to determine whether small mechanical works could be used to assist the establishment of trees in the arid zone and which species would prove most useful.

Method: An initial planting of seven species was made in August 1959. The species were:

mulga	- Acacia aneura
cooba	- Acacia salicina
merrit	- Eucalyptus flocktoniae
river red gum	- Eucalyptus camaldulensis
belah	- Casuarina cristata
old man saltbush	- Atriplex nummularia
white cypress pine	- Callitris columellaris

The seedlings were planted in rows with half in a ploughed area with banks and half in a ploughed area without banks. All trees were sprayed with "Zip" animal repellent.

By May 1960 all trees were dead so a second planting was initiated. This time ten species were planted, these being:

mimosa bush	- Acacia farnesiana
western boobialla	- Myoporum montanum
merrit	- Eucalyptus flocktoniae
cooba	- Acacia salicina
river red gum	- Eucalyptus camaldulensis
belah	- Casuarina cristata
red mallee	- Eucalyptus eleosa
	- Eucalyptus campaspe
mulga	- Acacia aneura
old man saltbush	- Atriplex nummularia

As with the previous planting, half the trees were planted behind the area with banks and half without banks.

Results: The last inspection of this area was made in December 1963. Three years after ponding had ceased, only one merrit, one belah and four old man saltbushes were surviving.

33.5 PLANT COLLECTIONS

Extensive plant collections were made during the last 15 years together with a recording of their distribution during the completion of "Plants of Western New South Wales" A check list of plants collected at Fowlers Gap has been made and includes 347 species.

Publication:

Check List of Plants on Fowlers Gap Station. Soil Conservation Service of N.S.W. 1975 (23 pages).

33.6 SCALD RECLAMATION STUDIES WITH CHECKERBOARDING: CONSERVATION PADDOCK

Three treatments were carried out on hard scalds using a ripping implement and sowing a mixture of saltbush (Atriplex spp.) seed. The treatments were on texture-contrast soils with shallow topsoils of sandy loam to loamy sand textures.

Method:

The treatments were:

1. Concentric spirals of 4.6 metres.
2. Checkerboards with 4.6 metre intervals.
3. Criss-crossing at varying intervals.

Species composition, cover and general observations were made.

Results:

The experiment was set up in May 1957 and read only once in October 1957. There was no regeneration of treated scalds during this time. Original photographs taken remain to be located.

33.7 SPECIES TRIALS

Introduction:

Three trials were initiated in Conservation paddock to assess the establishment and survival of a range of pasture species.

Method:

Trial I. In April 1957 seed was sown on the following four areas:

1. The treatment transect (TT) trial transects TT10 and TT11.

2. Waterspreading scheme -
   a. in the rip below the first break
   b. in the top ditch.

3. Treatment Transect (TT) trial transects TT1, TT2, TT3, TT5, TT6, TT7, TT8.

4. Scald reclamation sites.

The species sown in 1, 3 and 4 were:

galenia (Galenia secunda)
satiny bluebush (Maireana georgii)
cotton bush (Maireana aphylla)
creeping saltbush (Atriplex semibaccata)
kapok bush (Aeura tomentosa)

The species sown in 2a and 2b were:

wheatgrass (Agropyron obtusiosculum)
curly mitchell grass (Astrebla lappacea)
queensland bluegrass (Dichanthium sericeum)
perennial veldt grass (Ehrharta calycina)
african lovegrass (Eragrostis curvula)
creeping saltbush

Results:

There was no germination of any species in areas 1, 3 or 4 in August 1957.

Table 1 gives the results of germination in areas 2a and 2b in August 1957.

Species	Site 2a	2b
wheatgrass	good	good
curly mitchell grass	none	none
queensland bluegrass	good	good
perennial veldt grass	good	good
african lovegrass	none	none
creeping saltbush	none	fair

Table 1. Results of germination during August 1957

Trial II. In June 1960, 11 species were planted in marked plots in a windbreak study block. The species were:

buffel grass (Cenchrus ciliaris cv Bileola)
buffel grass (Cenchrus ciliaris cv. Molopo)
buffel grass (Cenchrus ciliaris cv. W.A.)
galenia
birdwood grass (Cenchrus setiger).
sorghum (Sorghum almum)
queensland bluegrass
perennial veldt grass
bluegrass (Dichanthium annalatum)
giant panic (Panicum antidotale)
coolah grass (Panicum coloratum)

Results:

In September 1960, no seeds had germinated. Of the galenia plants which were transplanted, only 25 survived. By June 1974 no galenia or any other species were evident.

Trial III. In June 1960, innoculated medic (Medicago littoralis) seeds were sown in the guard drains of the tree establishment trial. By October all had died without seeding. Some medic plants sown below the top diversion spreader of the tree establishment trial, had seeded in October.

33.8 WATERPONDING TRIALS - CONSERVATION PADDOCK

Introduction:

An experimental waterspreading and ponding project was established in November 1961 in Conservation Paddock. The area over which water was to be spread showed extensive wind erosion damage, being severely scalded with some hummocks.

Aim:

The project was undertaken to assess changes in vegetation after ponding and the performance of sown species.

Methods:

Ten banks were constructed, the details of which are shown in Table 2.

Bank No.	Type	Length (m)	Other specifications
1.	diversion	785	designed for peak discharge of 8.5m^3/sec at max./permis. velocity of 0.8m/sec.
2.	uphill push	201	ponds 30cm water
3.	uphill push	302	ponds 15cm water, spills at both ends
4.	uphill push	483	ponds 15cm water, spills at one end
5.	uphill push	664	ponds 30cm water, spills at one end
6.	uphill push	503	ponds 15cm water, spills at both ends
7.	downhill push	604	ponds 15cm water, spills at both ends
8.	uphill push	302	ponds 15cm water, spills at both ends
9.	uphill push	443	ponds 15cm water, spills at both ends
10.	uphill push	463	ponds 15cm water, spills at both ends

Table 2. Specifications of Waterspreading Banks, Conservation Paddock, Fowlers Gap.

Vegetation Measurements:

Measurements were made in May 1963 of ground cover and species composition using the step-pointing method. A transect was made every 100 paces along the banks at right angles to the bank at that point. The results are shown in Table 3.

Species	Ponded	Unponded
Bare (including furrows)	60.1	77.6
Litter	17.2	15.7
Portulaca oleracea	3.1	0.2
Panicum decompositum	1.6	0.2
Aristida spp.	0.1	-
Atriplex spp.	2.1	0.6
Spergularia rubra	7.0	0.7
Chloris truncata	0.1	0.1
Salsola kali	0.1	0.2
Trigonella spp.	1.4	-
Sclerolaena spp.	3.6	3.1
Citrullus colocynthus	0.1	-
Zygophyllum ammophyllum	0.1	0.1
Enneapogon nigricans	0.5	0.6
Dactyloctenium radulans	1.7	0.3
Babbagia acroptera	0.2	-
Eragrostis dielsii	0.6	0.3
Unidentified Asteraceae	0.4	0.1
Tragus racemosus	-	0.2
Sporobolus spp.	-	0.1

Table 3. Species composition and percentage cover for ponded vs. unponded areas.
Fowlers Gap 3/5/1963. Figure represents the mean of all transects.

Results:

From results in the Natural Regeneration Plots (see 33.12) there would appear to be significantly larger increase in bladder saltbush numbers in NR1 and NR5 which are in the spreader system than NR2 and NR3 which are outside the system. The results in Table 2 show that the main species differences between ponded and unponded occur in the annual such as Spergularia and Portulaca spp.

Discussion:

Many of these banks were broken during high intensity storms in 1973/74 and now fail to perform their intended function. Because the original photographs cannot be located, visual evidence of regeneration is not possible. The trial has therefore been terminated.

TABLE 4. TREATMENT TRANSECTS (TT) CONSERVATION PADDOCK FOWLERS GAP
ATRIPLEX VESICARIA COMMUNITY (BENEATH HILL)

Distance	TT 5 RIPPPING				TT 6 RIPPING BELOW BANKS				TT 7 DITCHING BELOW BANKS				TT 9 CONTROL			
	10/8/57		20/6/74		7/4/57		20/6/74		10/8/57		21/6/74		10/8/57		21/6/74	
	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.
0-10 m	9	330	3	137	0	0	10	*365	8	233	17	449	23	424	9	365
10-20 m	3	96.5	4	94	3	56	10	343	4	182	2	83	23	736	15	624
20-30 m	8	155	12	533	20	607	18	533	3	33	4	147	8	299	15	579
30-40 m	22	332	8	317.5	10	249	13	485	7	122	11	254	9	242	6	165
Total	42	913.5	27	1081.5	33	912	51	1626	22	570	34	833	63	1883	45	1733

* Road graded through transect

TABLE 5. TREATMENT TRANSECTS (TT) CONSERVATION PADDOCK FOWLERS GAP

KOCHIA ASTROTRICHA COMMUNITY (BENEATH HILL)

Distance	TT 1 RIPPING				TT2 RIPPING BELOW BANKS				TT 3 DITCHING BELOW BANKS				TT 4 CONTROL			
	7/4/57		20/6/74		7/4/57		20/6/74		10/8/57		20/6/74		10/8/57		21/6/74	
	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.
0-10 m	7	152	3	* 91	7	226	9	226	7	307	17	314	4	223	3	193
10-20 m	4	162	8	111	8	302	12	327	6	279	5	208	5	129	13	327
20-30 m	1	68	3	106	7	205	8	259	5	137	18	431	18	503	18	518
30-40 m	3	144	5	246	3	76	14	307	3	142	12	322	12	246	7	337
Total	15	526	19	554	25	809	43	1159	21	865	52	1275	39	1281	41	1355

* Road graded through transect

TABLE 6. TREATMENT TRANSECTS (TT) CONSERVATION PADDOCK FOWLERS GAP

ATRIPLEX VESICARIA - BASSIA SPECIES COMMUNITY (LOW RIDGE)

Distance	TT 10 RIPPING				TT 11 DITCHING				TT 12 CONTROL			
	10/8/57		21/6/74		10/8/57		21/6/74		10/8/57		21/6/74	
	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.	Plant No.	Intercept cm.
0-10 m	11	271	18	444	4	177	7	167	2	147	3	122
10-20 m	5	119	21	518	4	236	1	45	3	137	4	134
20-30 m	2	175	1	73	5	254	7	226	7	221	7	226
30-40 m	3	20	2	43	4	25	4	147	9	223	10	284
Total	40	585	42	1078	17	692	19	585	21	728	24	806

33.9 TREATMENT - TRANSECT EXPERIMENTS - CONSERVATION PADDOCK

Introduction:

In April and August 1957 12 belt transects each of 40 metres long were laid down to study the effect of three water erosion control treatments, viz. staggered bank, ripping and ditching on regeneration on native vegetation.

Method:

Transects were laid down on two main areas:

1. A low sandstone range dominated by low bluebush (Maireana astrotricha) and bladder saltbush.

2. The side of a low ridge with a bladder saltbush - annual copperburr (Sclerolaena spp.) pasture.

Both these areas received deep ripping and ditching treatments. Deep ripping has also been carried out between the ditches in the ditching treatment.

Measurements:

The total number of plants of bladder saltbush, perennial bluebushes (Maireana spp.), latern bush (Abutilon spp.) and bush minuria (Minuria cunninghamii) was recorded. Other measurements were made of total intercept (in inches) in a belt 1 foot (30cm) wide recorded for each 10m interval along 40m transect.

The transects were measured in 1958 and 1974. Unfortunately Transect 8 had to be abandoned because the marker peg was displaced, and a road, which was graded through transects No. 6 and 1, affected the observations in the 0-10 metre interval in both transects.

Results

The results for all transects are shown in Tables 4, 5 and 6. Although these results have not been statistically analysed, several trends are apparent.

1. There appears to be no significant increase in perennial native pasture numbers in both the low bluebush and bladder saltbush pastures due to the ripping treatment. However there may have been a slight increase in total cover by perennial native pastures.

2. There appears to have been a highly significant increase in both perennial pasture numbers and total cover for both low bluebush and bladder saltbush for both ripping and ditching treatments located below the staggered banks.

3. There appears to be no significant effect of either ripping or ditching on the bladder saltbush - annual copperburr pasture.

Discussion:

Without a full statistical analysis, which is probably invalid in view of the low number of readings, it appears that the only highly significant increase in perennial plant numbers and total cover occurs below the staggered banks. This may be a result of the fact that any effects may have been missed by the lack of recordings made during the 17 year gap after the experiment was commenced.

33.10 NATURAL PASTURE PLOT EXPERIMENTS (NP1, NP3) - CONSERVATION PADDOCK

Introduction:

In April 1957, two plots NP1 and NP3, 13.7 m x 13.7 m were established to study a natural bladder saltbush pasture.

Method:

Bladder saltbush plants were recorded and measured in a 1.2 m wide belt transect along one diagonal of each plot noting height, diameter parallel to the line and condition (on a scale of 0 to 5). All plants were pinpointed according to distance along the line, side of line and offset distance, with the exception of numerous dense clumps of small seedlings.

All plots were inspected in 1957, 1958, 1964 and 1974 and Plot I was also inspected in 1976.

Results:

Table 7 summarises the main data.

	NPI	NP3
Original shrubs	39	40
New shrubs	112	99
Deceased shrubs	9 (27 from orig. population)	80 (21 from orig. population)
Total live shrubs in 1974	54	59

Table 7. Changes in shrub numbers in plots NP1 and NP3.

1. Of the original population in NP1 (39), 69% of the population (27) have died in 17 years.

2. Of a population in NP3 of 40 plants, 52% of the population (21) have died in 17 years.

3. Overall there has been a 38% increase in bladder saltbush populations in NP1 and a 47.5% increase in NP3.

Discussion:

Measurements of these transects will continue and it is hoped that the information obtained, together with current research on population demography at Fowlers Gap, will provide useful information on growth rates and longevity of individual bushes.

33.11 NATURAL PASTURE PLOT EXPERIMENT (NP2) - CONSERVATION PADDOCK

Introduction:

In April 1957, a plot NP2, 13.7 m x 13.7 m, was established to study a natural low bluebush pasture.

Method:

The method used was identical to that used in the NP1, NP3 experiments. The recordings were made in 1957, 1958, 1964 and 1974.

Results:

Table 8 summarises the main data.

	NP2
Original shrubs	22
New shrubs	13
Deceased shrubs	5 (4 from original population)
Total live shrubs in 1974	30

Table 8. Changes in shrub numbers in plot NP2.

Average measurements (1974) of 18 original plants still alive -

Height	43 cm
Diameter	61 cm

1. Less than 20% of the original population has died in 17 years.

2. The population has increased by 25% in 17 years.

Discussion:

It is planned to continue on this transect for similar reasons as those given for the bladder saltbush plots. The species composition and frequency of dominant plants in each plot has not been tabulated here because of irregularity and inconsistency of observations, the large number of different observers, the wide variety in plant species and symbols used to denote them and the overall lack of uniformity.

33.12 NATURAL REGENERATION (NR) PLOTS, CONSERVATION PADDOCK

Introduction:

In August 1957, five 9 x 9 m plots were established to study natural regeneration of perennial plants, particularly bladder saltbush, on areas where it had either been removed or appeared to be spreading.

Method:

Observations were made in 1957, 1958, 1964 and 1974. Measurements included total number of shrubs in each plot, species composition and frequency of dominant species within each plot. An 18 metre transect was laid down as an extension of one side of each plot and the intercept and number of perennial plants determined.

Two of the plots, NR1 and NR5, were established within a system of spreader banks.

Results:

Table 9 gives the number of bladder saltbush plants in each plot.

Plot	10/8/57	15/4/58	17/12/64	27/9/67	21/6/74
*NR1	6	13	14	14	68
NR2	9	12	4	5	28
NR3	6	8	10	3	20
#NR4	24	19	1	10	25
*NR5	13	25	8	9	110

* Plots NR1 and NR5 are within the spreader bank system.
\# A road has been graded through NR4.

Table 9: Natural regeneration (NR) Plots, Conservation Paddock, Fowlers Gap. Counts of bladder saltbush plants in 9x9 m plots.

Table 9 highlights two points:

1. bladder saltbush plants are regenerating in all plots over the 17 year time period, and

2. there is a much larger increase in plants for NR1 and NR5, those which are inside the spreader bank system, compared with plots NR2 and NR3 which are outside the spreader bank system for the 1957, 1958 and 1974 data.

Transect data are shown in Table 10. Unfortunately there is no record of the type of transect used and no records were made of these transects between 1957 and 1974. It was assumed that the transects were similar to those on the Treatment Transect Experiments. However the results in Table 10 tend to indicate that this assumption may be invalid.

Plot	10/8/57 Plant No.	10/8/57 Intercept (cm)	21/6/74 Plant No.	21/6/74 Intercept (cm)
NR1	24	234	13	617
NR2	9	274	5	231
NR3	35	371	10	351
NR4	7	114	* -	-
NR5	7	137	15	658

Table 10. Natural Regeneration (NR) Plots - Conservation Paddock, Fowlers Gap.
18 metre transect.

* Road graded through transect NR4

Overall Conclusions:

Although the value of this experiment has been reduced because of the lack of reliable measurements, there is considerable evidence to indicate that regeneration of bladder saltbush has occurred due to either to favourable seasonal conditions, or destocking in Conservation paddock or to a combination of these. The experiment also indicates that the waterspreading scheme has aided in the regeneration of bladder saltbush.

As with other experiments, the data on species composition and frequency of dominant plants in each plot has not been tabulated here because of an overall lack of uniformity.

33.13 ARTIFICIAL REGENERATION (AR) PLOTS

Introduction:

Two plots were established in October 1957 on non-eroded heavy clay soils in Conservation Paddock and bladder saltbush seed was applied to half of each plot.

Method:

Records were to be made on species composition and regeneration of saltbush following seeding.

Results:

The results for the last readings are shown in Table 11.

AR1		AR2	
Seeded	Control	Seeded	Control
0	0	0	7

Table 11. Number of bladder saltbush in artificial regeneration plots.

Discussion:

There is little value in this trial and it has been terminated.

33.14 SALTBUSH LANDS OF THE BARRIER RANGE AND MUNDI MUNDI PLAIN

Fowlers Gap was one of the locations included in a survey of the extent of saltbush lands in an area centred around Broken Hill, and the densities of bush on this land.

Table 12 shows the importance of bladder saltbush in the area in terms of total areas with various densities of bush.

	Saltbush Density			
	Dense	Moderate	Sparse	No bush
Area (ha)	363,765	162,266	102,141	846,109
Proportion of area	25%	11%	7%	57%
Conservative carrying capacity (sheep)	65,697	28,231	16,127	117,902
Proportion of carrying capacity	29%	12%	7%	52%
Grazing rate (ha/sheep)	5.4	5.8	6.3	7.2

Table 12. Saltbush Density and sheep carrying capacity - Broken Hill District

The results were presented at a CSIRO field day on saltbush management in 1978.

33.15 TYNE PITTING TRIALS

Introduction:

Tyne pitting trials using a "Paech Pitter" were set up on four soil types to assess the value of this treatment on regeneration of degraded country.

Method:

Trials 1 and 2 were established in "Conservation" Paddock.

Trial No.	Topography	Slope	Soil	Area pitted
1	stony rise	1-2%	well-structured clay-loam soil with gravel pavement	100 x 60m (0.6 ha)
2	scalded area	0-1%	scalded duplex soil with hard surface with small hummocks	100 x 80m (0.8 ha)

Table 13. Summary of Trials 1 and 2 in "Conservation" Paddock.

Table 14. COVER COMPONENTS FOR SCALDED AND STONY SITES, CONSERVATION PADDOCK, FOWLERS GAP, JANUARY 1980. (TRIALS 1 AND 2).

	Control		Pitting only		Pitting + Fertiliser		Pitting + Seeding		Pitting + Seeding + Fertiliser	
	Scald	Stony rise	Scald	Stony rise	Scald	Stony rise	Scald	Stony rise	Scald	Stony rise
Bare ground	43.0	91.0	29.7	70.7	27.0	77.2	38.9	77.4	36.7	76.0
Litter and dung	45.3	6.8	56.3	24.6	55.7	19.0	49.2	17.3	48.5	17.5
Annual forbs	11.7	2.2	13.0	4.7	17.3	3.8	11.6	5.3	14.5	6.5
Grasses	-	-	0.3	-	-	-	0.3	-	0.3	-
Perennial shrubs	-	-	0.7	-	-	-	-	-	-	-
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Following pitting the areas were divided into strips 101 m x 10 m and subjected to five treatments, each with two replications. The different treatments were:

1. untreated control
2. pitting only
3. pitting and seeding
4. pitting and fertiliser
5. pitting, seeding and fertiliser

Both trials were ungrazed.

The pits (occupying 11% of the total surface area) were sown at 8 kg per treated hectare with seed of mainly perennial species collected locally. The most common species sown were: bladder saltbush, old man saltbush, flat-topped saltbush, creeping saltbush, blac, bluebush (Maireana pyramidata), three-winged bluebush (Maireana triptera). Other less common species sown (i.e. those contributing less than 10% of the seeds) were: ruby saltbush (Enchylaena tomentosa), niggerheads (Enneapogon nigricans), cannon ball (Dissocarpus paradoxa), satiny bluebush, pearl bluebush (Maireana sedifolia) and woolly-fruit copperburr (Maireana sclerolaenoides).

Normal superphosphate was applied at a rate of 21 kg per hectare. Both seed and fertiliser were applied by hand.

Trial 3 was set up in "Gap Creek" poaddock on a watersheeted calcareous soil with a 2-3% slope. This trial was subject to grazing and no fertilisation or sowing occurred. Approximately 15 hectares were treated, the pits being on the contour and runs being 10 metres apart. The site supported isolated bladder saltbush prior to pitting. Three areas, each of approximately 1.2 hectares in area were selected on slightly undulating soils. Two were subject to grazing and the third was fenced off.

Trial 4 was established on a gently undulating desert loam soil in "Gap Hill" paddock near the Public Watering Place. The area had suffered moderate to severe watersheeting and supported only sparse copperburrs (Sclerolaena spp.) and annual saltbushes (Atriplex spp.).

Three plots of two hectares were selected and half of each plot was pitted. On two plots located 1400 m from the tank, half of the treated area (0.5 ha) was sown with a mixture of perennial chenopod shrubs comprising bladder saltbush (0.5 kg/ha), old man saltbush (1.4 kg/ha), black bluebush (1.4 kg/ha) and yanga bush (Maireana brevifolia) 1.4 kg/ha).

Measurements:

The four trials were established in July 1970, July 1973, December 1970 and December 1973 respectively. All trials

received regular visual assessments and in January 1980, the step-pointing method was used to provide a final estimate of the effectiveness of the treatments.

Results:

Cover component data are given for trials 1 and 2 in Table 14 and for trial 4 in Table 15. The results of each trial are discussed independently.

Trial 1:

Despite drought conditions, pitting resulted in an increase in ground cover of up to three times that of untreated areas. However, few sown species established and those that did establish failed to persist. The use of fertiliser had no effect on cover.

Cover Component	Ridge Crest		Ridge Slope	
	Pitted	Control	Pitted	Control
Bare ground	45.2	54.2	50.6	59.2
Litter and dung	36.0	31.0	28.8	23.7
Annual forbs	12.6	9.2	19.8	15.7
Grasses	6.2	5.6	0.2	0.7
Perennial shrubs	-	-	0.5	0.7

Table 15. Cover components for ridge-crest and ridge-slope sites, "Gap Hills" Paddock, Fowlers Gap, January 1980 (Trial 4)

Trial 2:

The effectiveness of the pits was short-lived, the sowing method unsuccessful and only two of the four pitting treatments significantly increased cover. Consequently pitting could not be recommended for reclamation of hard scalds in the area.

Trial 3:

Visual assessments only were made on this trial. Pitting of the site increased moisture penetration and enhanced the growth of summer and winter growing perennial grasses by increasing the forage yield and effectively extending the growing season. Pitting of this soil type could therefore be recommended.

Trial 4:

Although pitting significantly increased total cover, only

annual species contributed to the difference and none of the perennial shrub species established successfully. As pitting produced only a small increase in total cover, its value for revegetation could not be justified at this site. Pitting of the more sloping land may help to reduce watersheeting and gully erosion.

33.16 LAND INVENTORY STUDIES

33.16.1 LAND SYSTEMS SURVEYS

An officer of the N.S.W. Soil Conservation Service assisted the Fowlers Gap Research Station with two land system surveys.

(i) Fowlers Gap Station: See 1.1 for details.

(ii) Fowlers Gap-Calindary Area: See 1.2 for details.

33.16.2 WESTERN LANDS LEASE MANAGEMENT PLAN SURVEYS

In 1968 a survey of Fowlers Gap was undertaken as part of the Soil Conservation Service's Western Lands Lease Management Plan Scheme. This includes the preparation of a map and report of the physical characteristics of each lease, and an assessment of the safe carrying capacity of that lease. The grazing capacity assessed is that number of stock which can be safely carried for 12 months into a drought without causing damage to the soils and vegetation.

A recent description of the scheme is given by J.C. Newman in the publication listed below.

A resurvey of the Station was undertaken in 1982 because of the changes in fencing and waterpoint point locations. The safe carrying capacities for each paddock were then revised. Some changes in range condition on saltbush country were noted and in attempting to explain the reasons, an assessment of past stocking rates has been initiated.

Publication:
Newman, J.C. (1976) Land inventory aids and land management. J.Soil.Cons. NSW 32(3): 136.

33.16.3 SURVEY OF "SALT" PADDOCKS

Assistance was provided in 1982 to Professor Max Webster, University of New England, in sheep physiology trials in the "Salt" paddocks (See 18.8). Mapping was undertaken at a scale of 1:10,000 and the long term grazing capacity of each paddock was determined. An assessment was also made of "productivity" (in terms of sheep performance) of each paddock for comparison with actual productivity data from

the trial. Range condition of each paddock was assessed and management recommendations were made in the light of the then-current drought.

Map: Survey of "Salt" Paddocks. Scale - 1:10,000 (Unpublished, but available for inspection at Institute of Rural Technology, U.N.S.W.)

Report: Stanley, R.J. A report on the productivity, condition & management of the "Salt" paddocks, Fowlers Gap Station, 1981-83. (Unpublished, but available from Institute of Rural Technology, U.N.S.W.)

33.17 PATTERNED GROUND STUDIES

Two field excursions in February and April 1975, each of about 3 days, were made to Fowlers Gap Station to collect field data for this study. These excursions coincided with visits by University of NSW staff (see 12.1).

Four sites were selected: "Airstrip" (west of House), and 3 "Highway sites" in Johnstones Paddock (north of House), and 2 of these were sampled at each visit.

Sampling consisted of:

(1) recording vegetation/soil/soil surface changes along each of the transects on each site.

(2) Using this data to map vegetation pattern.

(3) Transect length varied from site to site (40 to about 80 m long x 30 m wide and separated by 5 metres from adjacent transects) to traverse at least 2 gilgai/step units of country.

(4) Distributions of the different vegetation types were prepared and sent to the U.N.S.W.

(5) Assistance was given in mapping and describing the soils and in soil sampling.

(6) Assistance was also given in a stadia survey of the plots, soil/vegetation boundaries being co-ordinated in the study and contours subsequently drawn from this data.

(7) Sites were photographed at each sampling time (some of these are kept at Condobilin).

(8) Data were sent to U.N.S.W.

B. CURRENT AND ONGOING RESEARCH

33.18 RANGELAND STUDY PROGRAMME

Introduction:

The Soil Conservation Service is currently establishing, on an experimental basis, a rangeland study programme in order to gain more objective data on the responses of different land types to grazing and seasonal conditions. This information will be of benefit to land managers in maintaining stability and productivity of arid zone rangelands.

Methods:

Two sites are selected, a Test site and a Reference site. The Test site is located at a distance from water where vegetation changes due to grazing are likely to show up. This is usually about 1.5 km from water. The Reference Site is located far enough away from water that the effect of grazing (by domestic animals) is minimal or zero. Both sites are located on the same country type and preferably in the same paddock.

Both sites, which are permanently marked, are measured twice yearly. Measurements involve determination of ground cover and species composition, by wheel or step-pointing, and seedling establishment by the use of quadrats. A photopoint is also established.

Current Situation:

To date eleven sites have been established on Fowlers Gap, in "Sandstone" and "North Mandleman" paddocks.

Photopoint No.	Paddock	Distance from water
00011	Sandstone	600 m
00012	Sandstone	1200 m
00013	Sandstone	2900 m
00014	Sandstone	1500 m
00015	Sandstone	200 m
00016	North Mandleman	250 m
00017	North Mandleman	450 m
00018	North Mandleman	2500 m
00019	North Mandleman	3200 m
00020	North Mandleman	7000 m

Table 16 Location and distance from water of Rangeland Study Programme Sites at Fowlers Gap.

Site No. 00021, which is located in the ungrazed Beadle Exclosure, is the Reference site for the sites in North Mandleman paddock. Site Nos. 00011-00015, although not falling within the guidelines for setting up Rangeland Study sites, are an early development of the Programme.

Duration of the Programme:

The Rangeland Study Programme will be reviewed in 1984 to assess its usefulness in detecting small changes in vegetation due to grazing animals. It is envisaged that measurements at these sites will continue for some time.

33.19 RANGE CONDITION ASSESSMENT (RANGECON) PROGRAMME

Introduction:

The RANGECON Assessment Programme has the following objectives:

1. to develop a scheme of range condition assessment
2. to assess the error due to observe bias and seasonal conditions.
3. to evaluate its effectiveness, speed and extension value.

Method:

At each site, the following measurements are taken:

1. estimates of canopy cover of shrubs, herbage cover and shrub density/spacing on a fixed transect.

2. wheelpointing 1000 points.

3. shrub density by the Jessup method.

The objective measurements are made in order to assess the reliability and usefulness of making subjective assessments.

Five sites have been selected at Fowlers Gap, as shown in Table 17.

Photopoint No.	Paddock	Distance from water
00001	South Johnstones	1100 m
00002	North Johnstons	1500 m
00003	Conservation	no water points
00004	Gap Hills	3000 m
00005	North Warrens	4000 m

Table 17. Location and distance from water of RANGECON Sites at Fowlers Gap.

Preliminary Results:

For canopy cover of shrubs, no trends are evident as there are only three sites with measurable bush cover. The large number of completely defoliated bushes made estimation difficult.

Estimates of shrub spacing are greater than actual measurements while for density the opposite is the case.

The wheelpointing and step-pointing method both have obvious advantages and disadvantages although the former appears to be less biased. The Jessup Method appears to be a quick and easy way to measure bush density.

Duration of Programme:

The RANGECON Programme will be continued for another two readings, the last one in April 1984, after which the programme will be assessed.

Report: Abraham, N. Development of the Rangecon System - Progress in the Broken Hill District. Unpublished paper presented at the 1982 S.C.S. Western Area Conference (see 34.5), available from Institute of Rural Technology, U.N.S.W.

33.20 BUSH STUDIES

This is an annual study carried out as a training programme for undergraduate studies in the School of Wool and Pastoral Sciences. (See 35.8). The Service has assisted with initial location of the transects, with the annual measurements, and with talks to the students.

The results are analysed by the University, and these will provide some data on population changes of Atriplex vesicaria and Maireana astrotricha.

All the data collected over the five years of the study will be consolidated in a final-year student's thesis in 1984, together with some further investigations by the student (See 13.10).

Stage 1 will conclude in 1984, but the belt transects will be maintained for further measurements at less frequent intervals than in stage 1.

PART TWO

34. CONFERENCES, MEETINGS

35. STUDENT FIELD TRIPS

36. MISCELLANEOUS ACTIVITIES

34. CONFERENCES, MEETINGS

34.1 THE PASTORAL INDUSTRY IN WESTERN NEW SOUTH WALES - RESOURCES AND PROBLEMS OF THE ENVIRONMENT
Broken Hill - July 1969

Organized by the Fowlers Gap Consultative Committee, this Symposium was held in Broken Hill on Thursday, 10 July 1969.

A Report of the Symposium was published by the University of New South Wales and included the following:

Opening Address by the Honourable T.L. Lewis, Minister for Lands.

R.L. Caskey - The Pastoral Industry.

J.A. Mabbutt, J.C. Turner, D.T. Howell - Climate, Land and Water Resources.

P.R. McMahon - The Sheep, Factors Affecting its Productivity.

R.A. Perry - Rangelands Research.

Report:
The pastoral industry in western New South Wales. Resources and problems of the environment. Symposium - July 1969. The University of New South Wales.

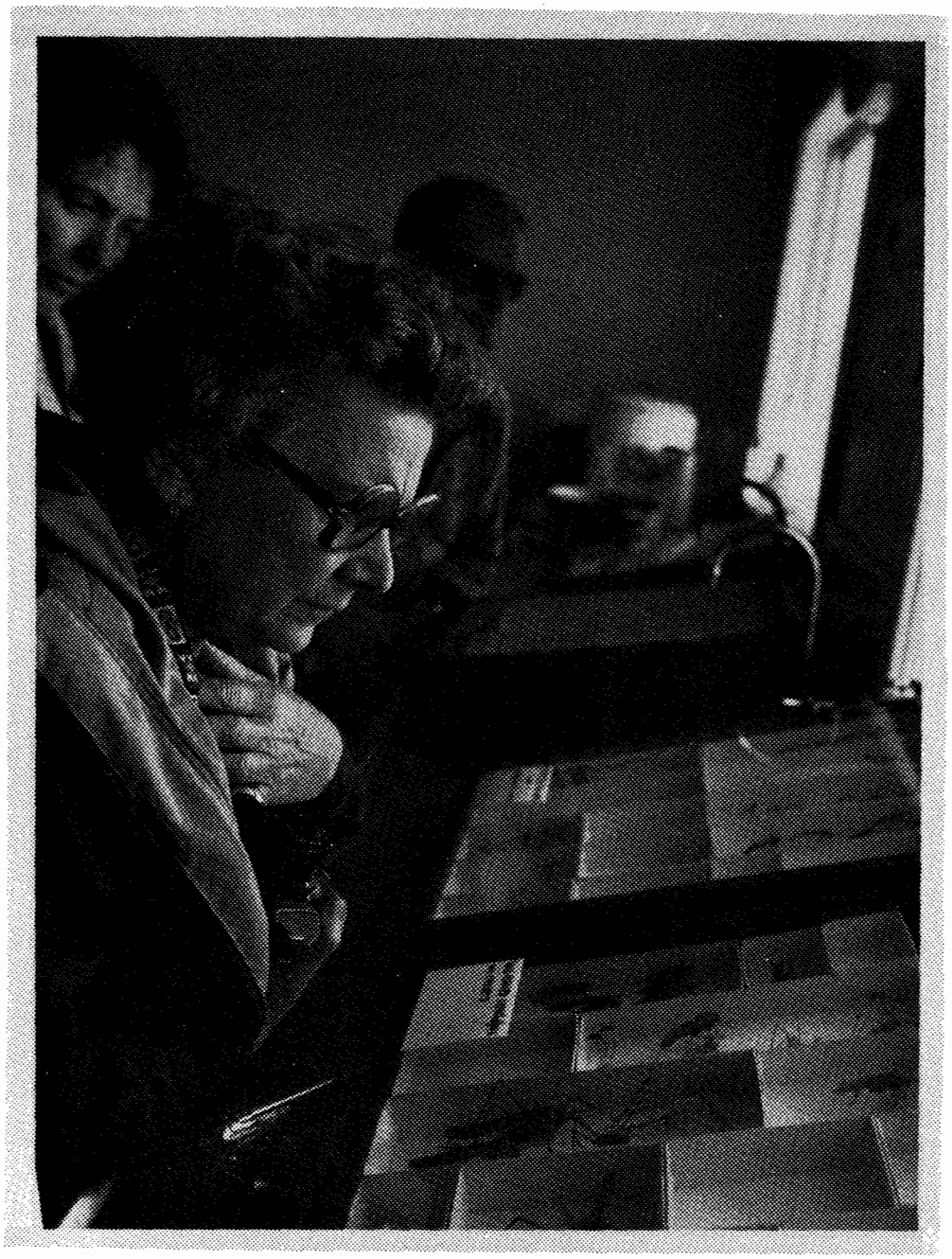
34.2 STATION OPEN DAYS AND FIELD DAYS

Since 1972, Station Open Days have been held annually at Fowlers Gap, or in the case of inclement weather, have been replaced by workshops at the W.S. & L.B. Robinson College at Broken Hill. Attended by members of the Broken Hill community, pastoralists from South Australia and New South Wales, and University and other researchers, the Open Day programmes have traditionally included the presentation of reports by researchers working at the Station; demonstrations and displays; escorted tours of the property; and formal meetings of the Fowlers Gap Consultative Committee, Management Committee and Graziers Committee.

Demonstration field days have included: a demonstration of low-cost fencing techniques by Mr J.W. Brain in May 1975 (see also 18.1); a demonstration in September 1975 of seven types of sheep-handling devices under evaluation by the Australian Wool Corporation (see also 19.5); and in February 1980 a shearing school field day.

34.3 RANGE CONDITION WORKSHOPS - FOWLERS GAP, BROKEN HILL. 1973

The CSIRO Rangelands Research Unit conducted two workshops on Rangelands assessments over the periods 28 May to 1 June and 9-14 September, 1973.



Visitor to 1982 Fowlers Gap Open Day examining insect collection (See 36.4). Photo: K. Doig.

Participating institutions included: University of New South Wales; University of New England; S.A. Department of Agriculture; N.S.W. Department of Agriculture; N.S.W. National Parks & Wildlife Service; N.S.W. Western Lands Commission; CSIRO Rangelands Research Unit; and N.S.W. Soil Conservation Service.

Four methods of assessing range condition and range trends were discussed and applied on three vegetation types (Mitchell Grass, Saltbush, and Mulga scrub) on a sandy soil east of Fowlers Gap. The purpose of each Workshop was to acquaint participants with the concepts and techniques involved, and to evaluate the four methods in terms of their potential usefulness in Australia.

The CSIRO produced a Workshop booklet containing the following working Papers:

I An introduction to range condition philosophy and methodology (R.A. Perry).

II The quantitative climax concept and its application determining range condition (J.C. Noble).

III The 3-step method for measuring condition and trend of forest ranges (G.J. Tupper)

IV A potential production concept and its application in determining range condition (Denning Two-Phase method of range assessment) (P.L. Milthorpe)

V Range condition and trend assessment based on degree of soil erosion, pasture composition and tree/tall shrub spacing (G.M. Cunningham)

Report: (For limited distribution only). Range condition workshops. Fowlers Gap, Broken Hill. 1973. Working Papers. CSIRO Rangelands Research Unit, Deniliquin.

34.4 UNITED NATIONS UNIVERSITY WORKSHOP, FOWLERS GAP, JULY 1980

In 1978, the University of New South Wales became an Associated Institution of the United Nations University. Under this association, the United Nations University has provided financial support for the planning and complementation of graduate programmes in Arid Lands Management for United Nations University Fellows, under the UNU Arid Lands Sub-Programme.

Following discussions between staff of relevant schools of the University, a Workshop was held at the Station on July 5-9, 1980. The Workshop was also attended by representatives of the Soil Conservation Service of New South Wales and the CSIRO Division of Land Resources Management.

The programmes of study drawn up as a result of these discussions are outlined in the booklet listed below. They include formal studies leading to the award of degrees and diplomas of the University; graduate non-degree courses in specified areas, and ad hoc programmes of study to suit individual needs. Although based at the University of N.S.W. campus at Kensington, Sydney, the study programmes also include significant field studies using the resources at Fowlers Gap Research Station.

In addition to UNU Fellows, the programmes are available to a wider range of Australian and overseas students.

Booklet:
Graduate Programs in Arid Lands Management. The University of New South Wales/The United Nations University.

34.5 SOIL CONSERVATION SERVICE WESTERN AREA ANNUAL CONFERENCE 1982

The conference was held at Fowlers Gap in November 1982. Discussions included the range assessment work, in particular the development of the RANGECON study (see 33.19), and a field exercise was held to familiarise all Service officers with the methods that are being developed. The field exercise proved valuable as the results obtained from the various assessment methods showed relatively good consistency between operations.

35. STUDENT FIELD TRIPS/CAMPS

Facilities at Fowlers Gap have been extensively used for student field trips. In some instances, these trips are aimed at providing students with hands-on research experience. Students may be required to produce written project reports or other assessable material for formal credit in their coursework. In other cases, the trips are of a more informal "look-and-see" nature.

Listed below are a number of subject- or course-oriented field trips/camps that are, or have been, based primarily at the Station. In addition to these listings, there have also been numerous briefer visits in which Fowlers Gap has been included within the itineraries of more general arid-zone study tours.

35.1 APPLIED PHYSICAL GEOGRAPHY
(School of Geography, U.N.S.W.)

Since the early 70's, groups of 8-20 third year undergraduates enrolled in subjects of Applied Physical Geography in the School of Geography, U.N.S.W., have undertaken field trips to Fowlers Gap, either as a formal component of their coursework or as volunteer assistance for Fourth Year Honours students conducting research projects at the Station. In the former case, the field trips have been aimed at introducing students

to an arid zone ecosystem and to the soil and vegetation topography of the area. Students have carried out description measurements of soil profiles and vegetation characteristics, mainly in patterned ground areas (see also 12.1), and have collected soil samples for laboratory analysis at the Kensigton campus. Members of staff involved in these trips have included Drs Dodsen, Pain, Melville and Chartres.

35.2 ARID LANDS
(Department of Geography, University of Wollongong)

In 1980, Dr R.W. Young, Senior Lecturer in the Department of Geography, University of Wollongong, led a field trip to Fowlers Gap of approximately 30 second year undergraduate students enrolled in the subject, Arid Lands. The field trip included examination of the soils, vegetation and geomorphology of the area.

35.3 FLUVIAL GEOMORPHOLOGY
(School of Earth Sciences, Macquarie University)

In 1973 and 1976, parties of undergraduate students enrolled in the subject, Fluvial Geomorphology, at Macquarie University made field trips to Fowlers Gap under the supervision of Associate Professor M.A.J. Williams.

A number of field reports resulted from these trips:

Dennis, L., Harvey, G., Owen, R., Palmer, J., Schintz, J. (1973) Fowlers Gap Research Station Homestead Creek geomorphology project.

Wasson, R. (1973) Fowlers Gap excursion route notes.

Butcher, J.A. (1976) Field Project No. 1. The study of a gully in arid New South Wales. An interpretation of possible environment and stratigraphical sequences.

Hodge, N.M., McIlvride, D.J., Kelly, R.J., Black, S.T. (1976) Fluvial geomorphology of Fowlers Gap.

35.4 FINAL YEAR SURVEY CAMP
(School of Surveying, U.N.S.W.)

In 1968, five staff members and five undergraduate students of the School of Surveying, U.N.S.W., conducted a control survey of the property in substitution for a final year student survey camp. (See also 3.1).

35.5 BUILDING CONSTRUCTION
(School of Architecture, U.N.S.W.)

From 1975 to 1977, third and fourth year undergraduates enrolled in the subject, Building Construction, offered by the School of Architecture at the University of New South Wales, participated in the Solarch House project led by Mr John Ballinger (See also 10.1). Students completed the construction drawings for the house and assisted with the construction of the pre-fabricated components at the Faculty of Architecture Research Laboratories at Randwick. Volunteers also assisted with the on-site erection of the house at Fowlers Gap in 1977.

35.6 MECHANICAL ENGINEERING DESIGN
(Broken Hill Division, U.N.S.W.)

In 1980, three undergraduate students of the Broken Hill Division of the University of New South Wales visited Fowlers Gap with Dr L. Jones to study the construction and operation of windmills as an introduction to a windmill design project.

35.7 CONSTRUCTION CAMPS
(Department of Engineering Construction and Management, School of Civil Engineering, U.N.S.W.)

In May of 1981, 1982 and 1984, the Department of Engineering Construction and Management of the U.N.S.W. School of Civil Engineering has conducted construction camps at Fowlers Gap.

The object of each camp is to expose the students to the full range of activities they might be responsible for when carrying out an engineering project in practice. Hence, the students are given a task (eg the construction of a culvert) and are then required to go through all the necessary procedures to complete the task. These procedures include (i) collection of all relevant data, eg geology of the site, flood flows, etc (ii) preparation and evaluation of final design including all design calculations, determination of quantities of materials required, construction schedule etc (iv) drawing up of contract documents and specifications as would be required for the construction of the structure by a contractor (v) procurement of all materials from suppliers and arranging for delivery of same to the site (vi) development of a construction plan so that the project can be carried out in the allotted time, bearing in mind the equipment and skills available (vii) arrangement of transport, supplies, entertainment etc for the students (viii) monitoring of construction performance and comparison with estimates; management of construction.

In 1981, students constructed a culvert at a creek crossing on the Station road leading from the Homestead area to the airstrip. In 1982, the construction camp roofed three water storage tanks, and in 1984, constructed the spillway for Freislich Dam.

35.8 RANGE MANAGEMENT
(School of Wool & Pastoral Sciences, U.N.S.W.)

The School of Wool and Pastoral Sciences offers Range Management as an elective subject at undergraduate level, and also as a postgraduate subject in the Arid Lands Management Programme. In each case, the students spend a week of their mid-year recess at Fowlers Gap as a compulsory component of their studies. The Programme combines field inspections of the Station, experience in some rangeland research techniques, and some formal instruction.

A continuing study of vegetation changes in Gap Creek Paddock has been conducted by successive groups of Range Management students since 1979. The purpose of the study is to monitor vegetation changes since the placing of an additional trough in this paddock in 1979. The saltbush in the vicinity of the new trough was in very good condition as it had been remote from water and consequently subjected to very little or no grazing. (See also 13.10).

As far as practicable these subjects are offered in alternative years rather than each year. The group size has ranged from 10 to 23.

(Note: See also 33.20).

35.9 RANGELAND MANAGEMENT
(Murrumbidgee College of Agriculture)

Included within a general study tour of the Western Division, parties of students enrolled in the Advanced Certificate in Rangeland Management at the Murrumbidgee College of Agriculture at Yanco have made annual visits to Fowlers Gap since 1977. One of the main objectives of these visits is to give students some insight into the nature and variety of research work conducted in the Western Division.

35.10 NATURAL RESOURCES PRACTICE & ARID ZONE MANAGEMENT
(Department of Natural Resources, Roseworthy Agricultural College)

In 1975, 1977 and 1978, groups of 6-10 third year students enrolled in the Diploma in Natural Resources at the Roseworthy Agricultural College visited Fowlers Gap as part of more general and zone field trips. These field trips were aimed at expanding the students' knowledge of the area in connection with the subjects, Natural Resources Practice, and Arid Zone Management.

35.11 ARID ZONE ECOLOGY
(School of Zoology, U.N.S.W.)

For several years, commencing in 1969, staff of the School of Zoology, University of N.S.W. organized annual undergraduate student camps at Fowlers Gap. Students gained valuable field experience by assisting staff in their research projects at

the Station. Although participation in these camps was voluntary, intending Honours students and students planning to enrol in the subjects, Comparative Ecological Physiology and Behaviour and Ecology, were strongly encouraged to participate.

From the early 70's until the commencement of the formal General Ecology field trips (see 35.12), the student camps included more specific student projects, eg vegetation surveys; and kangaroo counting/catching/collaring work. Entymology field collecting was also conducted.

35.12 GENERAL ECOLOGY
(Schools of Botany, and Zoology, U.N.S.W.)

Each December from 1979 to 1983, undergraduate students enrolled in the subject, General Ecology, have undertaken field studies at Fowlers Gap as fulfilment of the laboratory component of this subject. The parties of 25-30 students have been led by four staff members of the Schools of Botany and Zoology at the University of New South Wales.

The students have been required to complete three of four organized projects eg kangaroo tracking; diets of herbivores; blowfly ecology; microenvironment of ants; water potential in plants; pattern analysis of vegetation structure. Following completion of the field work, students have been required to write project reports at the Station under examination conditions.

35.13 ENVIRONMENTAL PHYSIOLOGY
(Department of Zoology, University of Sydney)

In May of each year since 1980, undergraduate students undertaking the course in Environmental Physiology in the Department of Zoology, University of Sydney, have made field trips to Fowlers Gap. Led by Associate Professor Gordon Grigg, the parties have included 25-30 students and support staff.

The students undertake three projects: (1) transect counts of animals (2) radio telemetry of penned animals to study heart-rate and body temperature (3) anatomical studies of kangaroos. Students also conduct a floral survey of the area, collecting various samples for laboratory analysis in Sydney. Samples are analysed for their energy content as an aid to understanding survival of kangaroos in the arid environment.

35.14 BIOLOGICAL ENVIRONMENT
(School of Biological Sciences, Sydney Technical College)

In 1980, an expedition to Fowlers Gap to study the ecology of the Australian arid zone was made by a group of students from the School of Biological Sciences at Sydney Technical College. The students were studying a course involving field technology techniques as part of the Biological Technicians'

Higher Certificate. The training of technicians in this area involves mastery of a wide variety of techniques used in capturing, marking and studying animals and plants. During the field expedition, students set hundreds of small baited wire traps for capturing animals, and captured birds by means of mist nets. A census of kangaroo population levels was carried out at night using spotlights.

35.15 PALAEONTOLOGY EXPEDITIONS
(School of Zoology, U.N.S.W.)

Parties of undergraduate students in the School of Zoology University of New South Wales, accompanied Dr M. Archer on research expeditions to Fowlers Gap in 1979 and 1980 (see 31.1, 31.2).

35.16 ABORIGINAL ROCK ENGRAVINGS
(Department of Anthropology, University of Sydney)

In May 1982, a party of 14 Anthropology students accompanied Mr J. Clegg on an expedition to study ancient Aboriginal rock engravings on the Sturts Meadows property south of Fowlers Gap (See also 32.1).

36. MISCELLANEOUS ACTIVITIES

36.1 CLIMATE STATION

The arid climate at Fowlers Gap is in a sense the reason for carrying out research at the Station and is the main environmental backdrop against which almost all research is carried out. Accordingly, adequate and continuous monitoring of climate is of fundamental importance and has always been accepted as a major responsibility among Station operations. By "adequate" is meant not only the range and quality of observations, but also continuity, maintenance and accessing or records.

The Climate Station

In 1968 a meteorological station was established on an open site close to the Homestead. The initial installations consisted of basic equipment as used at standard climate stations in the Bureau of Meteorology network, and observations were to be made daily at 0900 hours. The objectives of these installations were:-

(1) to accumulate basic data over a span of years so as to gain improved knowledge of the normal climatic conditions at the Station, and of the expected year-to-year deviation from normal, and

(2) to have readily available a store of climatic data that could be called upon in association with a variety of specific research projects being carried out at the Station.

In 1969 additional instruments and recording equipment were installed to monitor global solar radiation and net radiation, rainfall intensity, soil temperature (at 1 and 10 cm), wind direction, and wind speed at 10 m height.

Good quality records with only occasional missing observations have been obtained from 1974, and since 1975 observations have been made at both 0900 hours and 1500 hours. Daily data are recorded on specially prepared forms, and half-monthly and monthly summaries are regularly prepared on the Station. Annual summaries of data for a range of climatic elements are given in the Annual Reports of the Station.

Instruments now at the Homestead Climate Station are as follows:-

maximum and minimum thermometers
wet and dry bulb thermometers
wet and dry bulb thermograph
two-probe soil thermograph (1 and 10 cm depth)
recording raingauge
daily raingauges (2)
totalizing cup anemometers at 2 and 10 m
wind vanes at 2 and 10 m (1 recording)
class A evaporation pan
pyranometer (recording global solar radiation)

Non-instrumental observations include cloud (amount and form), visibility, dew and frost occurrence, and weather phenomena since last observation time. Some additional climatic data are collected elsewhere on the Station. These consist of data from a network of recording and daily raingauges (see 7.1), from instruments associated with the Solarch House (see 10.1), and from soil temperature and rainfall recorders located within a small exclosure at a patterned-ground site near the airstrip (see 12.1).

In 1979 it was considered that there was need for future upgrading of the climate monitoring facilities to include net radiation over selected ground cover types, wind speed at sites with varied exposure (as distinct from wind run as now determined at the Homestead), and soil moisture at selected sites with 'representative' soil and vegetation. Such a programme would however require upgraded technical assistance on the Station if continuity and reliability in the records was to be achieved.

Some difficulty was experienced in early years in acquiring reliable climatic data owing to staffing difficulties and technical faults in automatic digital monitoring equipment.

It was therefore decided that continuous monitoring of net radiation, and of rainfall and wind in digital form on paper tape, was impractical considering the inability to service these instruments adequately at all times.

In 1981, with support from United Nations University funds, preparations were made for the installation at the climate station of a 14-channel data logger to provide routine monitoring of the basic climatic elements at hourly intervals through the day, with the installation of a magnetic tape readout facility and computer interface for programmed analysis of the data at Kensington. It had been intended that this would come into operation early in 1982 but delays have occurred through a need to modify the circuitry and because of problems of installation.

Other Climatic Records

The Homestead Climate Station is supplemented by a network of raingauges (including several automatic recorders) across the Station and by rainfall observations at water-storage sites and runoff plots by the Department of Water Engineering. These provide valuable information on the significant spatial variability and varying intensity of rainfall characteristic of an arid climate.

Access to Records

For access to climate records of Fowlers Gap, contact the Institute of Rural Technology, U.N.S.W.

36.2 FOWLERS GAP HERBARIUM

In 1982, Dr J.P. Burrell of the U.N.S.W. School of Geography commenced a reference plant collection for the laboratory at Fowlers Gap with duplicate specimens to be held in the School herbarium at Kensington.

In 1985, Mrs Caskey bequeathed to the University of New South Wales the extensive arid zone plant collection of the late R.L. Caskey, a foundation member of the Fowlers Gap Consultative Committee.

These collections were augmented in 1976 by specimen collection undertaken by the U.N.S.W. School of Royal Botanic Gardens Herbarium staff.

The Fowlers Gap plant collection is maintained at the Station and represents a definitive plant collection for the property.

36.3 ORNITHOLOGICAL SPECIMEN COLLECTION

Staff of the Australian Museum visited Fowlers Gap in September 1977 to collect specimens for the Museum. Although their primary work was for the Ornithological Department

Dr John Baird, of the Faculty of Military Studies, U.N.S.W. - Designer of a revolutionary wind turbine (See 36.5) here explaining details of the design to members of the B.B.C. Tomorrow's World film crew. Photo: K. Doig.

scientific collection, some specimens were obtained for the Public Gallery, a special Arid Zone Gallery then under construction, and for the Reptile Department. In order to obtain a good series of different species, different habitat types within and around the Research Station were visited.

36.4 FOWLERS GAP INSECT COLLECTION

As a wide variety of insects are available at Fowlers Gap, and because parties of General Ecology students undertake annual field excursions to the Station (see 35.12), the U.N.S.W. School of Zoology decided to establish a reference insect collection. This was commenced in 1979 by Dr J. Anderson and has been augmented regularly since then.

The collection occupies two steel cabinets in the Fowlers Gap Laboratory. As well, there is a small collection of spiders and other arthropods in alcohol.

Although originally established by the School of Zoology, the collection has proved to be a valuable resource for other research and teaching purposes at the Station and is used extensively.

36.5 MONO PUMP WIND TURBINE

Fowlers Gap was utilized as an installation site for one of the first production models of a revolutionary wind turbine developed by Dr John Baird, Lecturer in the Faculty of Military Studies, U.N.S.W. A major advance for farmers in Australia's artesian basin, the turbine features a special clutch which allows it to make the best use of winds of low and moderate speeds, increasing the supply of water over that produced by conventional windmills of the same size. The pump is commercially available from Mono Pumps, who manufacture it under licence to Unisearch Ltd., the research and development company of the University of New South Wales.

36.6 FREISLICH DAM

A most important development of the Station in 1976 was the construction of the Freislich Creek Water Storage Complex. Basically, this complex consists of an excavated ground tank with associated training walls and pipe inlet, and a compacted earth fill embankment forming a dam across Freislich Creek.

The need for an extensive water storage in the western part of the Station had become apparent over the years in order to provide for better stock management in this area. Also, with the rapid increase in the use of the homestead facilities, the existing water supply servicing the homestead had become overtaxed. As a result, investigations were carried out for the purpose of proposing a water supply system to be located in the western part of the Station and which would provide both supplementary water supply to the homestead. (See also 2.4, 5.1, 5.2, 6.1, 6.2, 6.3).

Following these investigations, it was decided to develop a water storage complex at a site where a number of small creeks join to form a single creek (known locally as Freislich Creek).

The design concept for the water storage, based on the results of geological investigations including exploratory bores of the area, was developed by Mr V. Summersby of the School of Civil Engineering, University of New South Wales. Information about the design and construction of the complex is available from Mr Summersby. (See also 35.7).

36.7 LOCUST TRAP

A light trap for locusts was installed at Fowlers Gap in the mid 70's as part of the national plague locust monitoring programme implemented by the Plague Locust Commission. Staff of the Station are responsible for regular counting, identification and reporting of trapped locusts.

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Alphabetically by Researcher (including chief investigators and co-researchers). Bracketed references indicate project entry numbers.