2000 Fowlers Gap Research Report

Determinants of Reproductive Success in female Red Kangaroos.

Investigators: Amanda Bilton and David Croft, School of Biological Science, UNSW

Over the past three years information on the reproductive success of at least 33 radio-collared, free-ranging female Red Kangaroos on Fowlers Gap has been collected. Of the 102 young known to be born during this period, only one-third survived to weaning, the remaining two-thirds dying before 12 months of age.

With a weaning rate of only 0.43 young per female per year, and an average reproductive life span of 7.55 years, the expected lifetime reproductive success of a female Red Kangaroo on Fowlers Gap was calculated to be 3.3 young in a lifetime. Based on the reproductive life-history traits of these animals, they are in fact capable of rearing a maximum of 7.6 young to weaning in an average lifetime. Thus female Red Kangaroos on Fowlers are only achieving 40% of their maximum reproductive potential.

Results so far suggest that environmental conditions, in particular, rainfall and the abundance of good quality feed (esp. green grass), have a significant impact on the survival of young to weaning. It was found that those females that successfully reared their offspring to weaning were doing so at times when the amount of green grass available in the habitat, and the rainfall over that period, was significantly higher than for those females that lost their offspring. Given the highly dependant relationship between rainfall and plant growth in the semi-arid regions of Australia, and the high energy and nutrient requirements of growing young, it fits that the survival of the young is greatest during times of relatively good pasture conditions.

Sex of the offspring also seems to play an important role in the scheduling of maternal reproductive effort. Those mothers weaning male offspring were older than those weaning female offspring, a life-history trait also observed in the Eastern Grey Kangaroo. Also, those mothers successful at rearing male offspring to the stage of permanent pouch exit, 8 months, were doing so at times when there was more green grass available in the habitat compared to those mothers rearing females. These results suggest that females may manipulate their investment in male or female offspring according to the relative costs and benefits of rearing the different sexes. Continuing work on maternal care and behaviour will hopefully elucidate to what degree the sex of a mother's young may affect her lifetime reproductive success.

The importance of this research lies in its contribution to a more thorough understanding of Red Kangaroo population composition and dynamics; and its application in terms of population modelling and management will be vital to the process of ensuring the sustainable use of this species.

Wildlife Tourism with Rangeland Kangaroos: Product development and implementation
Investigators: David Croft, School of Biological Science, UNSW

The large populations of kangaroos in the boundless expanses of the outback will be used to build a unique tourist experience, comparable to an African game-viewing safari, but with animals and a safe healthy environment unlike anything found elsewhere. This project focuses on the far west of NSW, which offers both high abundance and diversity of large kangaroos, as it supports Australia's greatest densities of red kangaroos and euros alongside smaller populations of eastern and western grey kangaroos. Large protected areas, especially Sturt National Park, are set aside for their conservation but pastoral leases also support kangaroo populations. An attitudinal survey of visitors to the region demonstrated a strong attraction to wildlife tourism based around kangaroos, and demand for products to enhance knowledge and the quality of viewing opportunities. Fowlers Gap (UNSW arid zone field station) and Sturt National Park will create such products based on the best designs in arid lands in Africa and elsewhere. The objectives of this project are: (1) to research product designs for access ways, viewing platforms, interpretative materials and accommodation to create and support a high quality experience in wildlife tourism with kangaroos (2) to test market the products to clientele derived from education groups (Study Abroad), alumni and a local operator at Fowlers Gap and to trial some products with Sturt National Park visitors, (3) to assess patterns of usage and visitor satisfaction with the products, (4) to assess and apply remedial action to any adverse impact on wildlife or habitat through the tourism enterprise created around the products, and (5) to create a model for wildlife tourism enterprises on public and 'private' lands in the rangelands, and (6) to promote the products to stakeholders from the National Parks and Wildlife Service, pastoral leaseholders, local and national tourism operators from the development site at UNSW arid zone field station, Fowlers Gap. The main outcome will be to underpin tourism ventures in the region with well-researched products that create new demand for wildlife tourism and strong visitor satisfaction.

Work competed in 2000 includes guides to the flora and fauna encountered along the eco-trails on Fowlers Gap and the Olive Downs walking trail at Sturt National Park, guides to the kangaroos of Fowlers Gap and Sturt National Park, checklists of amphibians, reptiles, birds and small mammals for both sites, and a checklist of plants at Fowlers Gap. Wildlife viewing platforms have been constructed in the form of a bird hide at Lake and a hide at a night-illuminated water hole in Connors at Fowlers Gap. Adaptive re-use of surplus pastoral infrastructure such as homesteads and Shearer's quarters has been investigated with the Tibooburra Area of NPWS for development in 2001.

Publications:
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Willy Willies in the Australian Landscape: Environmental Controls and Dust Transport Characteristics.

Investigators: Alison Curl, David Dunkerley, and Nigel Tapper.
School of Geography and Environmental Science, Monash University , Clayton, VIC 3168.

An extensive census and sampling program conducted on the Fowlers Gap Research Station provided quantitative information on willy willy characteristics and environmental constraints. Willy willies are local convective circulations visually defined by the entrainment and transport of dust and surface debris. They are common in most Australian arid and semiarid landscapes and their American counterpart the 'dust devil' has been observed in the Mojave Desert, California (Maxworthy, 1973) and the arid lands around Tucson, Arizona (Sinclair, 1973) . Willy willies are potentially significant geomorphic agents in Australia given the slow rate of the erosion processes active across large areas of the continent. Despite this potential significance very little is known about these atmospheric phenomena, with only one other study having been completed in Australia . Given the lack of understanding in this field, the study completed at Fowlers Gap constitutes an exploratory rather than definitive study of the characteristics of willy willies in the Australian semiarid landscape.

A 20-day census was conducted from the 16th of January 2001 to the 4th of February 2001 in a 35-km2 study area on the lower eastern slopes of the Barrier Range . The results from the census in which 557 willy willies were observed, indicated that willy willy frequency, size, shape and duration vary according to local environmental conditions. An air temperature lapse rate, measured between 12 and 252 cm of the surface, of 0.9 °C m–1 was required for the initiation of the willy willies, with the frequency increasing with lapse rate. Willy willies were also found to be restricted to wind speeds between 1.5 and 7.5 m s-1, with some wind required for their initiation but too much shearing the tops off the columns. Analysis of the spatial distribution of willy willy initiation sites with respect to vegetation cover of the study area showed that willy willy frequency increases with decreasing surface cover. Very few willy willies were observed in the thick tussock grassy areas compared to areas with exposed bare ground.

In addition to the census, the dust being transported in the lower 160 cm of 20 willy willies was sampled using a tape-based vertical profile sampler developed as part of this study. The analysis of the samples using visual based digital analysis method revealed that almost 40% of the particles counted were being transported within the first 5 cm of the columns and over 80% overall were between 6 and 63 mm in major axis diameter. The results from this analysis when considered in terms of the characteristics of the surface being traversed during sampling show that the sediment load carried in the willy willies increases with decreasing vegetation cover.

The increased frequency and sediment loads of willy willies with decreasing vegetation combined with the preferential entrainment of silt sized particles could, over time, make willy willies a potent mechanism for the local differentiation of surface textures. Willy willies may be contributing to the maintenance of the patchy plant cover that characterises much of inland Australia . Their increase in frequency and sediment carrying capacity with decreasing surface cover indicates that they may also become more potent with increasing aridity either during drought or with a movement inland into Australia 's arid core.

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Vegetation, hydrology, and erosion mechanisms in arid zone streams and shrublands

Investigators: David Dunkerley
School of Geography and Environmental Science, Monash University Victoria 3800

Across the extensive low-gradient landscapes that occupy much of the Australian arid and semi-arid lands, surface runoff is developed episodically during heavy rains. Despite the gentle slopes, the runoff provides an important agency for the movement of litter, seeds, and eroded soil particles. Runoff redistributes surface water and so influences the distribution of soil moisture within the landscape.

Despite these important roles, relatively little is known in detail about the landscape characteristics that control the speed of surface runoff or influence its capacity to entrain and carry sediment. Furthermore, relatively subtle variations in soil microtopography, infiltration capacity, and litter abundance appear to be critical in deciding whether an area of sloping landscape sheds runoff downslope or absorbs runoff arriving from upslope. There are many landscapes in the Australian drylands where plants grow in patchy communities related to such patterns of runoff and runon.

Using both field experiments based at Fowlers Gap, and laboratory experiments using natural plant litter collected there, the properties of shallow overland flows have been investigated. There are significant challenges in measuring the depths and speeds of flows that may be as little as 0.2 mm deep, resulting from small rain events. A new measuring system, comprising a computer- controlled XY gantry as well as a Z (elevation) sensor, has been developed for use in studying such features. The system allows runoff depths and soil surface elevations to be recorded at any number of nominated grid points lying within a runoff plot, with a depth resolution of 25 µm. During a series of experiments, litter loadings have been manipulated, and flow rates varied, on experimental plots sloping at about 1.2 degrees. From the measured flow characteristics, parameters such as the Darcy-Weisbach friction coefficient can be determined.

Results to date have shown that plant litter can reduce runoff flow speeds significantly more than an equal cover of quart stones, another common soil surface feature in the Australian drylands. Indeed, under some flow conditions, it has been shown that the stones actually increase runoff flow speeds, by channelling the flow across a narrower zone of soil lying between the stones. Results of this kind are helping to shed light on the generation and movement of surface runoff. They are also highlighting the important role played by seemingly minor features of the landscape – the residual organic litter and the veneers of surface stones (gibbers).

The experimental program is continuing, and further experiments with the measuring gantry are planned for Fowlers Gap in 2001/2002.

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The Western NSW Archaeological Program (WNSWAP) at Fowlers Gap

Investigators: Trish Fanning[1] and Simon Holdaway[2]
[1]Graduate School of the Environment, Macquarie University , Sydney
[2]Department of Anthropology, University of Auckland , New Zealand

The Western NSW Archaeological Program (WNSWAP) was initiated in 1995 to investigate Aboriginal stone artefact scatters in a landscape context. Techniques based around the close integration of archaeological and geomorphological data sets using electronic survey technology and Geographic Information System (GIS) software were developed over a four-year period at Mt Wood in Sturt National Park . We then moved to Fowlers Gap in order to apply these techniques to investigating the Late Holocene archaeological record in one location with a variety of landscapes as a way of assessing variation in Aboriginal occupation intensity, mobility and resource use. Pilot surveys in 1999 lead to the selection of six upland land systems for more detailed investigation in subsequent years.

During a four week field season in June, 2000, our team of student volunteers from Auckland University in New Zealand and Macquarie University in Sydney, assisted by Ray O'Donnell and

Paul Menz from Broken Hill Local Aboriginal Lands Council and Dr Dan Witter, now retired from the NSW National Parks and Wildlife Service, surveyed and logged around 7,500 artifacts at three locations: Sandy Creek gorge (Nundooka Land System), downstream of Nelia Dam (Sandy Creek Land System), and on Fowlers Creek upstream of the Gap (mapped as Nuntherungie Land System, but more in common geomorphologically with Old Homestead Land System). In addition, we took advantage of a rather unique situation by undertaking a repeat survey of an area in Sandy Creek gorge that we had previously logged in 1999. We did this because, in February 2000, one of the largest rainfall events on record was experienced. We wanted to see if we could detect any changes to the artefact densities and distribution that might have occurred as a result of erosion triggered by a large magnitude storm event. We also described and sampled charcoal from the remains of 30 heat retainer hearths, and sent these samples to the Waikato Radiocarbon Laboratory in New Zealand for radiometric dating.

Analysis of the results of the artefact surveys has confirmed our first impressions that the stone artifacts are not randomly nor uniformly distributed across the landscape, but are clustered in different ways in each land system investigated, reflecting the different ways in which Aboriginal people interacted with the varied landscape in the past. For example, artifacts on the Fowlers Creek study site are manufactured predominantly from quartz nodules that are available locally. Those from the Nundooka Land System, are made from a variety of materials, some of which were brought to the location from sources several kilometers distant. These differences may represent differences in the activities performed at different places in the landscape but they also reflect differences in the length of occupation at these places. More complex sets of artifacts represent places that were returned to more often and were used for longer periods when compared to locations that have less varied artefact assemblages.

The most interesting and exciting results, however, come from the radiocarbon dating of the hearth charcoal samples. They demonstrate that Aboriginal people repeatedly occupied certain areas on what is now Fowlers Gap Station throughout the mid to late Holocene. The oldest date obtained so far is 5243 ± 164 y BP from the Fowlers Creek study site, and the youngest is less than 200 years old (i.e. modern) from the Nelia Creek study site. However, it is not the time span of these dates that is of most interest, but the pattern of dates in relation to the inferred ages of the landsurfaces on which the hearths and associated artifacts are found. On landsurfaces where geomorphic processes of erosion and deposition are relatively active, such as the apex of the Nelia Creek floodout, and the channel marginal elements of Sandy Creek gorge, the dates are relatively recent and the record relatively short, reflecting the dynamic geomorphic environments at these locations, whereby sediments accumulate over short periods of time, perhaps a few hundred years, and are then removed by erosion during infrequent, high magnitude flood events. By contrast, the longest record is found on the relatively stable terrace surface adjacent to Fowlers Creek, reflecting the relatively less active geomorphic environment at this location.

But even here, the record is not continuous: apart from the 5243±164 y BP date, there is a cluster of eight dates between 3661 and 3130 y BP, one at 1857±62 y BP, one at 898± y BP and one at 213±40 y BP. This suggests that Aboriginal people moved into and out of the region throughout the mid to late Holocene, occupying areas that had not been occupied for several

centuries. This contrasts with the commonly held view from elsewhere in Australia that Aboriginal occupation of some regions was more or less continuous from the late Holocene onwards, reflecting increasing population and a more sedentary lifestyle. On the contrary, our research shows that, at least in the area around Fowlers Gap, Aboriginal hunter-gatherer groups remained relatively mobile, moving away from then back into previously occupied areas on a fairly regular basis throughout the mid to late Holocene and right up to the time of European contact around 250 years ago.

Confirmation of this pattern of land use and mobility will be sought from further radiocarbon dating of hearth charcoal collected during the 2001 field season. We eagerly await the results, and will report them in the next Fowlers Gap Field Station annual report.

The Roles of Mitochondria and Capillaries in Determining the Maximum Aerobic Capacity of Red Kangaroos (Macropus rufus)

Investigators: Brock Misfud and Terence Dawson
School of Biological Science, UNSW Sydney 2052

Red kangaroos (Macropus rufus) are perceived to be highly athletic mammals since they have an efficient mode of locomotion. However, it is possible they also have a high aerobic capacity as evidence suggests they have a high mass-specific maximal oxygen consumption (O2max) and the appropriate cardiovascular characteristics to go with it. In placental mammals, total mitochondria and capillary volumes have been shown to be strong indicators of aerobic capacity. To gain further insights into the aerobic capacity of red kangaroos, we investigated the capillary structure and mitochondrial capacities of red kangaroo heart and skeletal muscles. The red kangaroo had a high whole body mass specific mitochondrial volume (37.5 ml.kg-1) similar to other athletic species, such as the dog (40.6 ml.kg-1; Hoppeler et al., 1987), and much greater than less athletic species, such as the goat (13.8 ml.kg-1; Hoppeler et al., 1987). Although capillary length density varied proportionally with mitochondria volume density, specific capillary length (221 km.kg-1) and specific capillary volume (3 ml.kg-1) were low in comparison to both athletic and less athletic species. Therefore, it is suggested that the red kangaroo uses other physiological mechanisms to match capillary O2 supply with mitochondrial demand, such as high hemoglobin concentration during exercise and, possibly, a higher pressure difference for O2 diffusion in the capillaries. In regard to mitochondria and capillary structure within the kangaroo, the heart has the greatest mitochondrial and capillary volume, reflecting its important role in continuous and variable transport of O2 to muscles. Interestingly, the multifidi lumborum, a large back muscle, had relatively high mitochondrial and capillary volumes when compared with the other skeletal muscles. This muscle has an important tail counterbalance function during hopping. Overall, the data suggests that a high mitochondrial capacity in the red kangaroo is an adaptation, which facilitates a high aerobic capacity. However, the delivery of oxygen from the capillaries needs further examination in order to complete our understanding.

Thermoregulation in Juvenile Red Kangaroos (Macropus rufus) after Pouch Exit: Higher metabolism and evaporative water requirements

Investigators: Adam Munn and Terence Dawson
School of Biological Science, UNSW Sydney 2052

The population dynamics of red kangaroos (Macropus rufus) in the Australian arid zone is tightly linked with environmental factors, which partly operate via the survival of juvenile animals. A crucial stage is the young-at-foot (YAF) stage when kangaroos permanently exit the pouch. We have examined the thermal biology of YAF red kangaroos during ages from permanent-pouch-exit (PPE) until weaning. Over a wide range of environmental temperatures (Ta -5°C to 45°C) YAF red kangaroos had a mass-specific metabolism that was generally twice that of adults, and considerably higher than would be expected for an adult marsupial of their body size. The total energy requirements of YAF red kangaroos were 60 – 70% of those of adult females, which were three times their size. Over the same range in Ta YAF red kangaroos also had total evaporative water losses equal to those of adult females. At the highest Ta, 45°C, differences were noted in patterns of dry heat loss (dry conductance) between YAF red kangaroos and adult females, which may partially explain the relatively high levels of evaporative cooling by YAF. By weaning age young kangaroos showed little change in their basal energy and water requirements (at Ta 25°C), but did show reduced mass-specific costs in terms of energy and water use at extremes of ambient temperature (-5°C and 45°C respectively). In their arid environment, typified by unpredictable rainfall and extremes of Ta, young red kangaroos may need to remain close to water points, in turn restricting their ability to find the high quality forage needed to meet their high energy demands.

Acquisition and analysis of rainfall and waterborne pathogen data from Fowlers Gap.

Investigators: Ian Cordery, Jerry Ongerth, Jim Tilley and Alf Wojcik
School of Civil and Environmental Engineering, UNSW Sydney 2052

Arid Zone Rainfall and Runoff

In early February 1999, Jim Tilley (PO , Civil & Environmental Enginering (C&EE), UNSW) installed new automatic rainfall monitoring equipment at four of 11 historic Water Engineering rainfall recording sites at Fowlers Gap. Historic rainfall and runoff data are available from 17 sites through 1989, including 11 pluviometer and runoff plot sites as well as 6 water storage recording sites. The current four rainfall sites are at Sandstone West (the old Frieslich Mort site), Nelia III plot site, Mating large plot site and the North Mandleman large plot site. Previous observation indicates that a denser network of rainfall sites would provide for more sophisticated hydrologic analysis. However, the current sites were chosen to provide a baseline consisting of a north-south and east-west cross sectional representation of rainfall at the Station. The continuation of monitoring provides an important continuing data base on rainfall-runoff relationships in the arid zone of western New South Wales .

The four existing instruments are tipping bucket rain gauges complete with data loggers. These instruments require operator inspection at a minimum of quarterly to check on their operation and retrieve data after events as required. The data loggers record the time and date of bucket tip. At present, station staff remove the loggers and replace them with units

posted out from Kensington and return the used units to Kensington to download and disseminate the data. The data is stored in the School's large HYDSYS time series database and can be accessed from there to forward to the station for on site records or to others on campus as required. The data is available electronically for insertion into spreadsheets etc. or as hard copy graphs etc. directly from HYDSYS.

Data from the above system have been recorded since mid February, 1999. Data from the recent period have been incorporated into technical publications prepared by Professor Ian Cordery (see below). Data can be obtained by special arrangement by contacting Mr. Alf Wojcik, P.O. at the School of Civil and Environmental Engineering, (02) 9385 5025, 0415 271 723, or a.wojcik@unsw.edu.au.

Future plans include submission of quotations, to the management committee, for a complete compact weather station to be installed at the site of the old homestead weather station. This would use a data logger on site connected, if required, to a PC in the office for instant read outs and/or alarm conditions. Technology has moved a long way in the last decade or so such that the current cost of a state of the art, simple to operate, weather station is now only a fraction of the cost of the original weather station installed in the early 1980's. Likewise telemetry is now another real option to be investigated that would be capable of connecting all the outlying sites to the same system.

Catchment Management for Pathogen Control

In September of 2000, Jerry Ongerth (A. Professor, Water Engineering, C&EE, UNSW) traveled to Fowlers gap to collect animal faecal samples to determine the presence and characteristics of protozoan cyst-forming pathogens, Cryptosporidium and Giardia. These organisms are wide-spread infecting agents common in domestic animals and responsible for outbreaks of waterborne gastrointestinal illness in many parts of the world. Dr. Ongerth’s current work is focussed on identifying pathogen subgroups identifiable by molecular typing (Doctoral studies of S. Blasdall , C&EE, UNSW), and studying the host population specificity of pathogen subtypes. Additional interests include identifying major attenuation and transport mechanisms relating pathogen production by domestic animal herds to pathogen loading in local surface water.

Results of the September, 2000, sampling indicate that sheep, feral goats and kangaroo populations at Fowlers Gap all carry both Cryptosporidium and Giardia. The prevalence found is similar to that found in the same species in non-arid areas elsewhere both in Australia and overseas. Further, molecular typing indicates that the Cryptosporidium type carried by Fowlers Gap sheep is shared by both red and grey Kangaroos.

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Surveying at Fowlers Gap Using Rapid Static and Kinematic Stop-Go Geodetic GPS

Investigators: Gresley Wakelin-King[1], Ken Johnston[2], Alisdair Walker[2], Phil Collier[2]
[1]Dept. Earth Sciences, La Trobe University , Bundoora, Vic. 3088
[2]Dept. Geomatics, University of Melbourne , Parkville , Vic. 3052

As part of a larger project investigating the geomorphology, landscape history and fluvial process of Fowlers Creek, a geodetic-quality GPS (Global Positioning System0 survey was undertaken in 1999 and the results analysed in 1999 & 2000. Sites surveyed included pre-existing sample locations, previously marked with star pickets; and the flat country in and around the creek’s terminal fan. In addition, a number of permanent survey markers had their eastings and northings established (heights being known) or their full coordinates established (Table 1). The project was commissioned and supported by GWK, and two final-year Geomatics students (KJ & AW) collected data in the field, and processed the results in Melbourne under the supervision of PC.

The large area under investigation, combined with the line-of-sight problems presented by the creek’s treeline, would have made it difficult to collect the desired data by standard (EDM theodolite) surveying in any feasible timeframe; making GPS an attractive alternative. However, because of the very low relief of the landscape, a high degree of vertical accuracy was desired. Geodetic-quality GPS is fundamentally different to the more commonly used hand-held GPS, both in position computation and accuracy. Whereas hand-held receivers used in a differential GPS mode rely on the use of the GPS pseudocode to resolve position, geodetic-quality receivers use phase measurements of the of the two carrier phases in the GPS signal. The best possible accuracy that can be expected from hand-held receivers in differential GPS mode is + 1m in the horizontal plane, and upwards of + 10m in height, due to the geoid-ellipsoid separation. The geoid-ellipsoid separation is the difference between the actual height of a point as determined from a specific datum (usually mean sea level), and the height from GPS measurements based on the datum WGS84.

Accuracies in the order of 1mm per kilometre of baseline length are achievable (where a baseline is the vector between two GPS receiver stations). However, geodetic-quality GPS requires considerably more field time and post-processing time, and must be done by qualified surveyors.

Despite time constraints, access problems, and the relative inexperience of the field party, a very fair degree of accuracy was achieved, with many locations being recorded at accuracies of + 0.03m or less in the vertical plane. (A more detailed description of this project is currently in prep by Wakelin-King & Collier.) The local geoid-ellipsoid separation was provided by the

AUSLIG service Ausgeoid, and was found to be accurate to a maximum error of 5mm over the entire survey area.

As part of the process some highly accurate bases were established on pre-existing concrete surveyors' markers. These markers were either unofficial, with no pre-existing location data (which we named Homestead and Boundary Beacons); or State Survey Markers with pre-existing height data only, installed during the construction of the Silver City Highway (numbers prefixed with SSM). Full coordinates or horizontal coordinates were propagated onto these markers, which were then used as reference points. The coordinates (in Geodetic Datum of Australia '94 and AHD) are presented here for use by other Fowlers Gap researchers (Table 1). Homestead Beacon is between Cottage 5 and the Managers' Cottage; Boundary Beacon is on the boundary fence between Fowlers Gap Station and the Selection. (A beacon is the boxy metal structure, mounted about 4m high on 3 or 4 strong metal legs; under the beacon is the concreted marker with a metal central point). The other concrete markers are along the Highway: these are identifiable by SSM number, and some have beacons above them. Information regarding these markers is available from the Land Information Centre, New South Wales .

TABLE 1. Co-ordinates of Surveyed markers (datum: GDA94 and AHD)

Name	Easting	Northing	Height
Homestead Beacon	567069.407	6560725.418	179.968
Boundary Beacon	582477.831	6570791.939	133.368
SSM30033	576089.119	6573239.430	141.744
SSM31900	568026.879	6562067.178	(available from
SSM31901	571504.111	6563437.561	LIC, NSW)
SSM3655	-	-	160.496
SSM3658	574487.333	6567509.764	149.328
SSM3659	572821.183	6564789.799	157.941
SSM3660	570513.118	6562440.630	167.692
SSM3661	568031.953	6561003.789	177.178
SSM3662	566651.418	6558407.577	198.567
SSM3665	561767.141	6546453.532	237.034
SSM3666	559991.830	6543696.012	264.721
SSM3667	-	-	242.336
SSM3668	-	-	256.168