1. Introduction

1.0 Definition

The term Visual Flight Rules (VFR) used in this document, is an official set of rules maintained by aviation authorities for navigation by identifying and following the visible features of the landscape including topographic features, such as rivers and mountain peaks and manmade structures, such as railway lines.

1.2 Predator Control

Predator control in the natural environment is driven by both intrinsic and extrinsic factors, including availability of food supply for reproduction and survival of both the predator and the prey. Extrinsic or top down habitat modifications by human intervention includes various techniques that form the basis of both lethal and non lethal control programs at the local community level.

Non lethal predator control strategies used against wild dogs throughout the world include: guard dogs (Andelt and Hopper 2000), llamas (Meadows and Knowlton 2000), donkeys, predator proof fencing, lamb shedding, shepherding, night penning, fright tactics, removing carrion, culling, change bedding, frequent checks (Shivik 2004) and sterilization of animals (Conner et al 2008). Additional tactics include; zoning land, compensation schemes, insurance, animal armour (known as a King Collar), hiring night guards, timing breeding of domestic animals when predation is reduced, selective pasturing using fields that are less susceptible to predation, changing herd or flock composition and eliminating food sources. Also a range of fright strategies have been employed such as noise, chemical repellents, electronic guards, fladry (flags), biological repellents , harassment, aversive harassment, conditioned taste aversion, diversionary feeding, reproductive inhibition and translocation (Shivik 2004). In Italy electrified fencing (Rondinini and Boitani 2007) and lighting systems (Cugno 2002) have been tried. While in California, Blejwas et al (2002) used coyote removal with some success, however, predation continued after about 43 days when other animals re-established territories. Human activity such as trapping without success near depredations may be sufficient to discourage attacks (Harper et al 2008) and shock collars were fitted to wolves by Hawley et al (2009) but the deterrent effect was not apparent after they were removed.

Lethal controls include aerial gunning, selective removal of adults before birthing (Conner et al 2008), traps, snares and night shooting (Frey and Conover 2007), Coyote Lure Operative Device (CLOD) (Berentsen 2007), M-44 Ejectors (Shivik 2004) Carbon Monoxide Gas Cartridges for den fumigation, Cyanide Capsules, and Sodium fluoroacetate (1080) in livestock Protection collars (Fagerstone 2004) and in poison baits.

1.3 History of Wild Dogs in Australia

Free living dogs (*Canis familiaris dingo* also known as *Canis familiaris familiaris* or *Canis lupus dingo*) have been present in the Australian landscape for approximately 3500 years (Breckwoldt 1988; Breckwoldt 2001). There is ethnographic evidence that these animals were transported over water from the Indonesian archipelago to the Australian mainland by humans for both companionship and food (Breckwoldt 1988). Throughout its history, the wild dog remained a semi domesticated dog, useful for hunting (Corbett 1995), food and companionship (Breckwoldt 1988). With the arrival of European settlement in 1788, wild dog management became necessary to reduce predation of domestic livestock (Breckwoldt 2001).

1.4 Poisons

From the early 1800s, strychnine was used for wild dogs control; this necessitated cooperation between landholders because strychnine was expensive and could only be imported in large quantities (Fleming et al 2001). Carcasses of dead sheep and cattle were poisoned with strychnine so scavengers such as wild dogs were killed. In 1946, a manufactured brisket fat and strychnine bait wrapped in paper known as the 'Minty bait', was developed in Queensland and subsequently used in Queensland, New South Wales, Western Australia and the Northern Territory. Aerial baiting began with experimental drops of these strychnine baits in Western Australia and Queensland in 1946 (Tomlinson 1954). It was used on the coast and tablelands of New South Wales from 1957. Strychnine is highly toxic to a wide range of native animals and birds.

Since the mid-1960s, 1080 (sodium fluoroacetate) replaced strychnine in baits. 1080 was more canid specific with less non target impact and, it was closely regulated, through government agencies (Fleming et al 2011). Meat baits containing 1080 were first distributed by aircraft in the Northern Tablelands of New South Wales in 1964. Prior to the use of 1080 landholders relied heavily on trapping, strychnine and exclusion fencing for wild dog control. Aerial baiting was generally successful and many exclusion fences were allowed to fall into disrepair. Fixed-wing aircraft were used in New South Wales until 1986, when helicopters became mandatory for aerial baiting in the eastern tablelands because baits were claimed to be placed with greater accuracy (Thompson et al. 1990). Aerial baiting with 1080 was generally accepted as a cost-effective, safe method for the strategic management of wild dogs (Thomson 1986; Thompson and Fleming 1991), and was used in Queensland, New South Wales, Western Australia and the Northern Territory (Fleming et al 2001).

1.4.1 Past Management Strategies

Before research into dingo movements and behaviour in the 1960's, many landholders believed that the dingo migrated from far distant ranges and "breeding areas" to the grazing leases (Tomlinson 1958b). Major expeditions were mounted to seek out 'dingo breeding areas' (Tomlinson and Blair 1952), sometimes hundreds of kilometres from the nearest livestock. Tomlinson (1954) recognised that coordinated, community based approach to wild dog control was the most effective strategy. Tomlinson (1958b) wrote: *'Wild dog baiting drives, organised on a district- wide basis and combining all available manpower and aids such as aerial baiting, are without doubt the most effective destruction method.... Careful planning and organisation to ensure the work is properly coordinated, is carried out at the best possible time, and gives the most effective coverage, is essential. Possibly, the most important requirement is to secure the participation of the landholders in these drives and the continuation of control work afterwards.'* Over the last 20 years, this strategy has been promoted and adopted; however, the strong desire to kill wild dogs in the "breeding areas" still prevails in some landholders. (Fleming et al 2001).

When the release of the book, Silent Spring (Carson 1962) helped launch the environmental movement, concern with poisons and pesticides increased. Public concern resulted in aerial baiting for wild dog control being temporarily suspended pending a review in 1976 (Saunders et al 1985). The Dingo Destruction Boards along with bounties was abolished and the role was taken over by the Livestock Health and Pest Authority (LHPA). Policy 42 of the Australian Conservation Foundation submitted to that review (dated November 1984) provides some key insights into the direction that wild dog policy was going, it included recommendations that dingos be classified as "protected wildlife"; no killing without justification; removal from noxious animal, pest and vermin lists; elimination of bonus and bounty systems; conservation management plans to be developed; management to minimise hybridisation; forest and national parks required for survival of pure dingo populations; development of non lethal control measures; broad scale and indiscriminate control measures not to be employed and funds for research (Saunders et al 1985).

In 1992, NSW Department of Primary Industries, using a planimeter, conducted an audit of maps supplied by all wild dog control groups to standardise the application rate of meat baits for aerial baiting for wild dog control. The results of the audit were presented to the Wild Dog Control Associations and showed an average application rate of 10 kg / km (range 2.8 kg / km to 14.9 kg / km). About the same time an audit of bait size and number was conducted (Barnes 1992; 1993). Following these two audits the wild dog groups agreed the maximum application rate for meat baits should be 40 baits or 10 kg of meat baits per km (Barnes 1992, 1993) (Korn 1992). The baiting density or number per linear km was determined by consensus and not scientific methodology.

When research was undertaken on efficacy of aerial baiting, only one bait rate was applied at the consensus rate of approximately 40 baits or 10 kg per km (Fleming 1992). Around the same time, the accuracy of bait placement using fixed wing and rotary wing aircraft was compared. Helicopters were shown to provide more accurate bait placement and their use was mandated in eastern NSW (Thompson et al 1990).

The environmental groups were now a generation old and began agitation on changing the status of the dingo to that of 'threatened species'. Corbett writing in his classic book, 'The Dingo in Australia and Asia' raised the possibility that the dingo may be rendered extinct by dilution of genes through cross breeding with domestic dogs (Corbett 1995). In response, in 2000, many public land managers again suspended aerial baiting for wild dog control. A 'New South Wales Symposium on the Dingo' was convened (Dickman and Lunney 2001) in 2001 and conservation of dingo habitat was implemented in those lands nominated under Schedule 2 of the Wild Dog Pest Control Order, an order issued under the Rural Lands Protection Act. This order stated that stakeholders including the Livestock Health and Pest Authority representing private landholders, National Parks and Wildlife Service and NSW Forests were required to have a wild dog management plan where public and private land managers agreed to strategies for control of wild dogs in Schedule 2 areas 'to the extent necessary to prevent damage to any lands'. Those areas in Schedule 2 mainly comprised contiguous areas of both National Park and State Forest on the eastern escarpment and Sturt National Park in far north west NSW. Following this resolution of the threatened species issue, some dingoes would be conserved in Schedule 2 lands and aerial baiting for wild dog control in public lands was recommenced.

Environmental groups hypothesised that the carnivorous spotted-tailed quoll (*Dasyurus maculatus*) would be endangered from the use of 1080 poison because quolls were found to either eat, or disturb, both fresh meat and manufactured baits placed on trails to control foxes and wild dogs (Belcher 1998) (Glen and Dickman 2003). Quoll studies were completed and aerial baiting for wild dog control recommenced.

1.4.2 Present Management Strategies

Currently (2011), the Wild Dog Policy of the National Parks and Wildlife Service (*National Parks and Wildlife Act 1974*) ensured that a management plan for wild dogs was required for lands within Schedule 2 areas of National Parks and the dingo was recognised as a native species under the

Threatened Species Conservation Act 1995, although not a protected species under that Act. The *Rural Lands Protection Act 1998* allowed wild dogs to be declared *pest animals* under the Pest Control Order for Wild Dogs

In the Western Division, the Wild Dog Destruction Board was established under the *Wild Dog Destruction Act 1921* for the maintenance of the 584 kilometres of the NSW Dog Fence along the NSW-South Australian and NSW-Queensland border. This Board is funded by rates on Western Division landholdings and State Government subsidies (Fleming et al 2001).

A review of the vertebrate pesticide 1080 by the Australian Vertebrate Pest Committee recommended that the aerial application of poison baits, previously determined by consensus in NSW, be reduced from 40 baits / km, to 10 baits / km across Australia (Vertebrate Pest Committee 2002). This led to strongly political agitation for retention of the application rate at 40 baits / km by the private landholder community. The issue was partly resolved in 2008 with the Australian Pesticides and Veterinary Medicines Authority issuing a permit to certain divisions of Livestock Health and Pest Authority in New South Wales to allow baiting at up to 40 baits / km until scientific research could determine the most effective aerial baiting density.

1.5 This Study

The preceding overview sets the socio-political environment that affects wild dog control and management in New South Wales. All lobby groups are well organised and highly political and into this atmosphere this study was introduced.

1.5.1 Aims

This study itself compared navigation using visual flight rules (VFR) with global positioning systems (GPS) navigation. Prior to 2007 little navigation of aerial baiting in northern NSW was assisted by GPS. There were some Livestock Health and Pest Authorities that relied solely on GPS; others used the technology in conjunction with rangers from the National Parks and Wildlife Service for navigating in National Parks (Sam Doak, pers comm. 2007). The Wild Dog Control Associations in northern NSW had used VFR navigation and there was a need to demonstrate the move to navigation by GPS would not affect the current accuracy and the system could be more accountable for land managers. To achieve this, aerial baiting transects drawn by members of wild dog control associations on topographic maps were compared to the aircraft flight logs.

The aims of this study were to:

1. Develop a method to analyse the aerial bait transects for track error between proposed bait transects and the aircraft flight log and compare navigation by traditional visual flight rules with data collected by GPS on the aircraft.

2. Examine the aerial baiting application process and define the errors associated with the planning, application, collection and transcription of data during navigation by VFR and compare it with GPS.

2. The Wild Dog

2.1 Physical Characteristics

The wild dog has four basic colour types: ginger (75%), black (1%), black and tan (12%) or white (2%); colours such as brindle, patchy black and white or sable maybe indications of hybridisation (Corbett 1995; Newsome and Corbett 1985; Fleming et al 2001). The average wild dog stands about 570 mm high and weighs about 10-20 kg and lives to about 10 years of age (Corbett 1995).

2.2 DNA of the Wild Dog

Wilton (2001) studied the DNA evidence for the wild dog and hybrid crosses with domestic dogs, and used supporting evidence from Corbett (1995) to state that approximately 78% of the wild dog population in some areas of eastern Australia is hybrid to some extent. Indeed, Corbett (2001) using a skull morphology score claimed that totally pure populations can no longer be recorded anywhere and 48 – 65 % of the sampled population in south east Australia were hybrids. Corbett (2001) was concerned that hybridisation with domestic dogs remained the greatest threat to the continued existence of pure wild dog populations; at the same time claiming pure wild dogs were no longer available. In the first continent wide DNA survey, Stevens (2011) using a sample size of 3637 wild dog genotypes stated that 99% of wild dogs in eastern Australia were hybrid and almost all showed dingo ancestry indicating poor survivorship of domestic dog genes in the Australian environment and the extent of hybridisation could threaten the existence of the pure dingo.

2.3 Reproduction

Wild dogs are seasonal breeders producing one litter per year. Jones and Stevens (1988) examined reproductive tracts of females trapped in the eastern highlands of Victoria and provided autopsy evidence that births occur from March to September but peak in June, (24.1%), July, (32.8%) and

August (20.7%) each winter. In this study breeding did occur at other times but at the following relatively low levels, March (1.7%), April (5.2%), May (12.1%) and September (3.4%). Domestic dogs (*Canis familiaris*) have two oestrus periods per year, however, two litters per year is probably uncommon in the wild where competition for food supply limits bodyweight and reproductive potential (Corbett 1995). In the eastern highlands of Victoria, only about 36% of females begin breeding before 2 years of age while 70% of females are sexually mature between 2 – 3 years (Jones and Stevens 1988). During times of drought and low food supply all young females either do not breed or come into oestrus about 2 months later (Catling et al 1992). Oestrus lasts about 10 - 12 days (Corbett 1995). Ovarian weight and body weight have a significant positive correlation and reproductive performance of wild dogs is lower than domestic dogs of comparable size, with ovaries of wild dogs being about 3 times smaller and lighter than their domestic counterparts (Kaiser 1977).

Males are sexually mature at 1 - 3 years and reach maximum testis weight, epididymides weight and number of active seminiferous tubules during the main mating season in April to June (Jones and Stevens 1988). Males in eastern Australia can breed all year round but in central Australia the prostate gland limits the amount of seminal fluid that can be ejaculated from August to January (Corbett 1995). Males less than one year old have prostate glands half the weight of older males and reach peak testis weight in April and May. Younger dogs have a similar cycle but reach peak testis weight about two months later. Similarly, the uterine weight of female wild dogs increases substantially in May and June (Catling, Corbett and Newsome 1992).

Gestation lasts between 61 - 69 days for most captive wild dogs and the average litter size is five, across a wide range of habitats (Corbett 1995). Slightly more males are born than females (Corbett 1995). The pups are usually born in dens such wombat burrows, hollow logs and stumps, caves, rocky overhangs and under dry debris or tree roots in creek banks. They are often close to water sources and not easily seen (Corbett 1995).

Regurgitation of partly digested food is a mechanism that both wild and domestic dogs display when providing food for their pups (Malm 1989). While wild dogs can go without water for considerable periods of time, reabsorbing water from their prey, females have been observed carrying water in their bellies to regurgitate to keep pups hydrated (Corbett 1995). Faeces and urine in the den are recycled by females licking the anal and urethral openings of the pups to stimulate them to void (Corbett 1995).

2.4 Dietary Ecology

Wild dogs can be opportunistic (Whitehouse 1977) or selective feeders (Robertshaw and Harden 1986) and prey on a wide range of species particularly those medium sized mammals from < 25 kg to 90 kg weight range (Corbett and Newsome 1987). Corbett (1995) provides a good summary of 11 dietary studies from 1966 to 1980 that totalled 12,802 samples of either gut contents or faeces collected in 6 major habitat types across Australia. These studies included Allen (1997), Catling (1995), Caughley et al (1987), Coman (1972), Corbett (1995), Denny (1980), Jarman and Wright (1993), Harden et al (1985), Marsack and Campbell (1990), Newsome et al (1973), Newsome et al (1983), Newsome et al (2001), Pavlov (1987), Robertshaw and Harden (1986), Whitehouse (1977) and Woodall (1983).

Pursuit and capture of food is an energy intensive activity for wild dogs. In Western Australia, 9.2% of single dog captures and 18.9% of multiple dog captures were successful when wild dogs chased kangaroos. In contrast, 66.2% of captures were successful when wild dogs pursued sheep and only 15.4% of calves because cows were more defensive of their young (Thompson 1992c). In Victoria, predation of domestic livestock accounted for 8.2% of the diet (Coman 1972). In another study in the same area Newsome et al (1983) recorded 4.8% sheep and 2.4 % cattle in the diet of the wild dog. The low occurrence of domestic livestock in the gut contents or faeces of wild dogs ignores the impact that predation has on landholders dependent on these animals for income for essential supplies and does it account for the financial, psychological and social cost of livestock lost from surplus killing.

2.5 Behavioural Ecology

A group of related interacting wild dogs form a pack usually comprising a dominant male, dominant female, some subordinate females, and young males less than 12 months old and weaned pups in the breeding season. In addition, there are often outcast members or loners (Corbett 1995). Pack structure is maintained by a hierarchy of dominance and submission (Corbett 1995). Dominance is displayed by posturing, head and tail held high and includes snarling, snapping, lunging, baring teeth, hip slamming, standing over and threatening. Contact is not always made. Submission involves crouching, rolling, tail down and lips stretched backwards. (Corbett 1995)

Howling and moans are the main methods of vocalisation. Howling is used to determine the location of other wild dogs and may involve either single dogs to locate mates or groups to repel rivals from the territory (Corbett 1995). Both Corbett (1995) and Breckwoldt (1988) mention that wild dogs can bark often referred to as a yip and maybe accompanied with a howl. Moans are used when approaching water to warn other wild dogs that may want to drink. Snuffles are used by the female to warn pups of intruders (Breckwoldt 1988). In the wild dog pack, most of the females breed and the dominant bitch may attempt to kill the pups of other subordinate animals. During drought or shortage of food, possibly due to low body weight of subordinates, only the dominant female breeds (Catling et al 1992).

2.6 Territories and Dispersal

The wild dog pack occupies and defends a territory. Territory is defined by Burt (1943) to denote an area defended by its occupant or occupants against competing members of the same species. Thompson (1992) using radio tracking over 9 years identified 5 packs with territories ranging from 45 km^2 to 113 km^2 in semi arid Western Australia. Harden (1985) also using radio tracking, concluded the average size of a territory in the north eastern New South Wales was 27 km^2 (2700 ha). McIlroy et al (1986) found that territories for wild dogs averaged 2194 ha in Kosciusko National Park (McIlroy et al 1986) and claimed wild dogs living more than 12 km to 20 km inside National Parks were unlikely to move onto adjacent farm land. Killing wild dogs inside this area was, according to

McIlroy et al (1986), a "waste of time". Corbett (1995) lists 7 studies of territories ranging from 10 km^2 in the Nadgee Nature Reserve (range 9 km^2 to 14 km^2) to 77 km^2 in Fortesque River of Western Australia, and cites increasing aridity and corresponding decrease in food availability as the main reason for the size of territories. Home range, Burt (1943) is defined as the area traversed by each individual in its normal daily activities of food gathering, mating, resting and caring for young. Wild dogs travel approximately 12 km / day throughout the home range (11.2 km / day in a home range of 21.93 km^2 in Kosciusko National Park) (McIlroy et al 1986). Claridge et al (2009) placed average home range size in 4 National Parks in south east NSW and northern Victoria at 10,000 ha (9923 ±7776). However, 10 out of 24 wild dogs GPS tracked in this experiment exceeded the average 10,000 ha home range size and 8 out of 24 were less than 5,000 ha home range. This paper may have more accurately described highly variable home range sizes that ranged from minimum convex polygons of 1022 ha to 26,209 ha and home range size was smallest where the pellet count of prey was highest (Claridge et al 2009). . However, recent GPS tracking of wild dogs in the northern tablelands of NSW indicates that territories appear less defined and movements within an area of 30-40 km quite common with sporadic forays of 90 - 100 km through territories occupied by other wild dogs (G. Ballard pers comm.. 2012).

Wild dog density as determined by radio tracking and mark and recapture studies ranged from a low of 0.1 to 0.3 wild dogs km^2 in north eastern NSW (Fleming et al 2001). Packs use vocalisations to establish and defend territories and seldom meet on the boundaries, Thompson (1992) found of two overlapping home ranges that wild dogs rarely came closer that 2.6 km. Wild dogs spend 90% of the time in 10% of the home range (D. Jenkins pers. comm. 2005).

Wild dogs have a highly developed sense of smell (Fleming et al 2001). Wild dogs generally follow defined paths and tracks when travelling through the home range. Territories are established by marking objects such as grass tussocks, small bushes, logs, fence posts, certain rocks and faeces of other animals with urine, faeces and scents. Scent marking and scent posts are located near shared resources such as water, hunting grounds, tracks and roads intersections (Thomson 1992b; Corbett

1995). Wild dogs often rake soil to mark territory and raking is more abundant during autumn and winter in response to mating (Corbett 1995).

Dispersal is the mechanism by which wild dogs move out of the home range and search for vacant territories to form packs. Thompson (1992d) found the average distance of dispersal was 21.7 km to 11.0 km (male and female respectively) from the home range in the Pilbara (range from 1 km to 184 km). High population pressure, lower food availability per animal and availability of vacant areas influenced dispersal (Thompson 1992d). Using 47 radio collared wild dogs, Allen is reported to have recorded about 25% of strong, young males, less than 2 years old dispersing distances of several hundred kilometres (Benjamin 2009). Newsome (2001) argues that the wild dog cannot increase in numbers in a linear way in response to increased numbers of prey such as the rabbit and kangaroos because they are limited by density dependant issues such as territories, social systems and dispersal sinks (Newsome 2001).

The wild dog was reported to have an influence on excluding the red fox from territories; however, Mitchell and Banks (2005) found no evidence to support landscape scale exclusion. Fleming et al (2001) cite a number of studies that showed marked differences in habitats and management in areas of high fox abundance. The red fox is favoured by short pastures in agricultural land and rabbits while non agricultural land provides the seclusion, shade and shelter for wild dogs (Fleming et al 2001).

2.7 Parasites and Disease

Echinoccocus granulosus, the hydatid tapeworm, is a parasite that maybe transmitted to humans and is of importance to public health. In a large 2 year study, Coman (1972) found 62 % of 204 wild dogs were infected. In Australia, hydatosis is mainly perpetuated via a predator / prey interaction between wild dogs and the smaller macropod marsupials (Jenkins and Morris 1991). Examination of wildlife around Kosciuszko National Park by Jenkins and Morris (2003) found high levels of *E. granulosus* in swamp wallaby (*Wallabia bicolor*) (69%) and fertility levels within the hydatid cysts of 100%. Approximately 25% (9 out of 40) of *Wallabia bicolor* were found infested with *E. granulosus* in eastern Victoria, and when no cysts were found in similar areas free of wild dogs, Coman (1972) suggested that this wallaby species was an intermediate host. With high numbers of *E. granulosus* cysts among both wild dogs (100% infection rate) and 40 out of 46 swamp wallabies in Bondo State Forest; Jenkins and Morris (1991) indicated the wallaby is pivotal in maintaining the hydatid infective cycle. Jenkins and Morris (1991) reported hydatid cysts in all other macropodid species examined and wild pig (49%) and not in either wombats or goats. Jenkins and Morris (1991) state that the wildlife reservoir of this important tapeworm is sufficient to maintain the cycle through infected wild dogs defecating on pastures. With worm eggs being eaten by livestock or larvae by domestic dogs through being fed offal from infected wildlife and pest animals such as the feral pig (*Sus scrofa*) (Jenkins and Morris 1991) transmission may continue domestically. There is already a large biomass of parasites in wild dog populations in and near towns could provide a ready source of hydatid infection around camping grounds and public parks (Jenkins 2006; Jenkins et al 2008; Morrison et al 1988). Transmission of eggs and larvae of *E. granulosus* from wildlife to domestic stock had at least strong circumstantial links in a study of sheep adjoining crown land and national park at Mansfield in Victoria (Grainger and Jenkins 1996). Two populations of sheep with a total of 756 animals from 32 farms were studied. One group from 17 farms with a high incidence of hydatosis had sheep killed by wild dogs, 14 of 15 wild dogs, 4 of 17 kangaroos (*Macropus giganteus*) and 2 of 10 Wombats (*Vombatus ursinus*) sampled from the surrounding farms had high incidences of hydatid infection while an area of 15 farms with no wild dogs predation had 2 farms infected that may indicate translocation of sheep from a farm in an infected area (Grainger and Jenkins 1996).

Other species of helminth parasites present in a survey of Victorian wild dogs include the cestodes *Taenia pisiformis* (40.5%); *T. serialis* (18.5%), *T. hydatigena* (7.5%), *Spirometra erinacei* (7%), *Dipylidium canim* (2%) and nematodes included *Uncinara stenophala* (49.5%), *Toxocara canis* (13.5%), *Trichuris vulpis* (1%) and *Cyathospirura dasyuridis* (2%) (Coman 1972).

Brown and Copeman (2003) examined 12 dogs caught near an urban area on a Department of Defence establishment in Townsville and found several internal parasites that included *Echinoccocus granulosus, Ancylostoma caninum, Dirofilaria immitis* (75% of dogs examined), *Dipylidium caninum, Spirometra erinacei* (44% of dogs examined), and the tick species *Haemaphysalis bancrofti* and

Amblyomma triguttatum. All these parasites had potential to affect the health of people that came in contact with them (Brown and Copeman 2003).

2.8 Wild Dog Management

The economic loss of predation on domestic livestock tend to fall disproportionably on groups of landholders that operate enterprises close to forested or natural terrain that provides good refuge for food, shelter and breeding (Fleming et al 2001). In these areas home ranges of wild dogs generally overlap with agricultural holdings and the predation of domestic livestock is a constant threat. Because wild dogs are found across all land tenures, effective control is best achieved on a landscape scale (Braysher 1993; Fleming et al 2001). Planning a control program without property boundaries allows more effective control and equitable cost sharing (Braysher 1993). Adoption of this nil tenure approach where ownership boundaries are removed and wild dog tracks and scent paths identified reduced predation by approximately 75 % in the Brindabella Wee Jasper area of the southern highlands NSW (Hunt 2002; Buller et al 2005).

2.9 Non-destructive Control Methods

Most attempts at using fertility control for pest animal control have been unsuccessful because of high reproductive rate of the pests, failure of the chemical control agent, high compensatory reproduction by those animals not treated in the population or social restraints of the human communities where control is attempted. The use of deslorelin was found to postpone mating until the next breeding season in wild dogs in Africa, however, the results were not consistent across all female dogs and there appeared to be a latent period of about 4 weeks before the drug took affect (Bertschinger et al 2002). Fertility control in males was more consistent and the drug lasted for 12 months but the initial latent period was about 6 weeks (Bertschinger et al 2002).

2.9.1 Livestock Guarding Animals

Moving sheep to mountain pastures over summer in the south west Alps of Italy has been a traditional way of life (Cugno 2002). Flocks were left unattended until the time to retrieve the animals. However, over the years increasing attacks from wild dogs has restricted where these animals can graze and management practises have had to change. Electric fencing with lighting systems and livestock guarding animal practises has been adopted from Switzerland and Slovenia to secure some protection. Cugno (2002) states the presence of wolves is important for tourism in Italy and these will have to be integrated in the flock management policy.

Livestock guarding animals have an increasingly important function in some areas against foxes and wild dogs (Jenkins 2002; van Bommel 2010). Other animals have been used for livestock protection in Australia including alpacas, donkeys, llamas and mules; however, there is little objective evidence of benefits (Anon 1994; Braithwait 1996; van Bommel 2010). Dogs in particular are susceptible to 1080 poison and any wild dog control needs to be part of an integrated approach using poison baits outside the paddocks, M44 ejectors, other guard animals such as llamas and finally livestock guarding dogs. Livestock guarding dogs must be fed or the guardor may eat the guardee. To support the role of livestock guard dogs the Invasive Animals Cooperative Research Centre funded the publication of a manual on training and education of guard dogs (van Bommel 2010).

2.9.2 Trapping

Trapping is used to target wild dogs when poison baiting is less effective particularly where high or continuous losses are being sustained or proximity to built up areas and habitation limits poison baiting and shooting. Traps with padded jaws have proved to be more effective, more humane and cause less injury to the captured animal than steel jawed traps (Fleming et al 1998).

Domestic dogs can locate and mark by urination, defecation or scratching, the scent of another dog (Hunt and McDougal 2002) (Lapidge et al 2006). Padded jaw traps are set where the domestic dogs have located the scent of another dog. To aid trapping novel smells such as urine from other dogs, extracts from anal glands, proprietary lures such as synthetic fermented egg and organocarbons are added to the scent marks (Hunt et al 2007). An experienced trapper can, by placing different novel smells either side of a track, lure one wild dog out of a group and leave the others to carry on travelling (Roger Roach pers comm. 2006). Newsome et al (1983) used a large scale trapping experiment to determine the most effective lures contained a proportion of dog urine and that the Oneida Victor ® soft jaw trap type had the advantage of catching two thirds (⅔) less non-target animals than the larger Lanes ® trap (Newsome et al 1985). Few studies have looked at comparisons of trapping and other methods. McIlroy et al (1986) used trapping to compare with poison baiting. Trapping captured 15 out of 27 wild dogs or 56%, known to be in the area in comparison to poison baiting reduced abundance by 44%. However, in relation to this experiment, Fleming et al (2001) argued that neither method was particularly effective because such a large proportion of the known wild dog population remained and the reduction in damage to livestock, the impact, was not measured. Fleming et al (2001) claimed the return from trapping was often less than 5 wild dogs per 1000 trap nights, however, if those were the most damaging wild dogs in the population, the economic advantage of removing them could be substantial.

2.10 Lethal Control

2.10.1 Poison Baiting

Marsack and Thompson (1987) state that success in baiting depends firstly, on placing sufficient baits where the wild dog would encounter them, and secondly, on the baits being attractive and palatable enough for consumption by the target animals. The highly developed olfactory glands of wild dogs can detect poison baits buried about 100 mm deep, at intervals of 250 m along known wild dog tracks (Anon 2008; Fleming et al 2001).

Larger scale poison baiting programs in NSW is mostly targeted for autumn and winter (Fleming et al 2001), Fleming and Korn (1989) concluded, after studying predation patterns from 1982 to 1985 in NSW, the best time for an annual broad scale aerial baiting control program was April just before the main peak in predation. Poison baiting in winter has a number of other advantages, due to lower ambient temperatures and humidity poison baits distributed in autumn and winter last longer than those placed in spring and summer (Saunders and Fleming 1988 in Fleming et al 2001 p. 102); insect and microbial activity that detoxify 1080 is generally lower in winter; some non target animals such as goannas (*Varanus* spp) are less active in cooler conditions (Fleming et al 2001); populations of wild dogs should be at the lowest prior to the breeding season and mustering of livestock is usually finished by early winter and consequently, there is less threat of working dogs eating poison baits (Fleming et al 2001). However, a change in predation patterns occurred in cattle on the north coast of NSW where predation peaked in November (Fleming and Korn 1989). In most years, extra large scale poison baiting programs in the spring have been shown to be beneficial.

The poison 1080 (sodium fluoroacetate) is the preferred toxin for control of wild dogs in Australia. 1080 has a half life of about 42 days; although under some dry conditions the poison can persist up to 226 days in the environment. Fleming and Parker (1991) showed that the greatest loss of 1080 poison occurred over the first hour after bait injection (61%) however, the level rises again to 73% of the initial dose at 150 hours probably due to adsorption of poison onto the meat.

Both moist and dried meat are injected with 1080 and there are two manufactured baits based on meat products; Dogone® (Animal Control Technologies) and DeK9® (Paks National [Aldi G C Pty Ltd]). In NSW fresh meat baits are cut into 250 gm pieces and injected with 6 mgs 1080 poison using an injection gun (Fleming et al 2001; Croft 2005). Experiments with tumble mixing, where baits were sprinkled with 1080 solution, determined that this method of application gave meat baits a highly variable poison content compared to the injection method and tumble mixing was discontinued (Korn and Livanos 1986).

The general recommendation is to air dry baits until a firm skin is present on the outside. This has the advantage of making them less attractive to non target marsupials such as quolls and birds (Fleming et al 2001). . Sun drying meat baits had little effect on ants that can cause a weight reduction 70% to 100% in 5 days and Merks and Calver (1989) concluded that this ant activity may detoxify baits before they could be taken by wild dogs. Larvae of the beetles *Callipora augur, C. stygia, S. hilli* and *C. tibialis* also decompose the sodium fluoroacetate found in meat baits. However, despite rainfall, meat baits can remain toxic to dogs for up to 32 days during winter when *Callipora spp. larvae* are absent and from 6-31 days during summer when these larvae are present (McIlroy et al 1988).

Using indices of footprints per kilometre of transect on sand plots and a "sightability" of those footprints on each sandplot, Fleming (1996) demonstrated that a replacement baiting program using 1080 impregnated meat baits resulted in a reduction of 76.1% in the index of wild dog abundance and a 90.8% reduction in the index of red fox abundance during a ground based bait station experiment. The baits were replaced daily and minimum populations before and after baiting were estimated using an index manipulation methodology (Fleming 1996). The risk to non-target animals using this technique was low because wild dogs and foxes were freely given meat without poison in the baiting stations prior to using poisoned bait. Bait stations visited by non target animals, identified from foot prints, were closed down (Fawcett 1994; Fleming et al 2001).

Ninety two percent (92%) of baits placed along roads in Kosciusko National Park for wild dog control were removed by foxes over the first 4 days. Birds, dogs and pigs also removed baits and 99% of baits were removed by day 21 (McIlroy et al 1986). Birds removed more undyed baits than those to which dye had been added. Bird species included pied currawong *Strepera graculina*, Australian ravens *Corvus coronoides*, Australian magpies *Gymnorhina tibicen*, and wedge-tail eagles *Aquila audax* (McIlroy et al 1986). McIlroy et al (1986) found that, only two dogs out of eight were killed as a result of the 1080 poison (22%). Twelve wild dogs out of a total population of 27 known to be in the area were not accounted after baiting. Toxicity of the baits declined rapidly after Day 0 from 4.69 mgs 1080 per bait to 1.5 mgs 1080 per bait after day 5. Most of the 1080 was lost due to leakage shortly after injection. In this study, McIlroy et al (1986) claimed to remove more wild dogs by trapping than baiting (56%). However, due to the latency period of 30 minutes to 4 hours during which 1080 poison does not cause obvious signs of toxicity and bodies are difficult to locate, it could be conceived that the 12 animals not observed after this experiment may have succumbed to the 1080 poison giving a mortality of 74%, consistent with the results of Fleming et al (2001).

2.10.2 Impact on Non Target Animals

In early 2000 researchers in southern NSW hypothesised that the carnivorous spotted-tailed quoll (*Dasyurus maculatus*) may be endangered from the use of 1080 poison because they were found to eat fresh meat placed on trails to control foxes and wild dogs (Belcher 1998) (Glen and Dickman 2003). NSW National Parks and Wildlife Service commenced a three year radio tracking experiment with VHF mortality collars fitted to spotted tailed quolls in 1080 poison baited areas (Koertner et al 2003). Initial results from fox baiting experiments using the manufactured bait, Foxoff®, showed that spotted tailed quolls did dig up the bait but left it a short distance away, one bait out of 26 was consumed (Koertner et al 2003). The aim of these experiments, located in both northern and southern tablelands of New South Wales, was to determine if fresh meat baits distributed to control wild dogs, containing the poison 1080, were eaten by spotted tailed quolls and to quantify the mortality. The study demonstrated that at a population level there was minimal impact of 1080 poison baiting on spotted-tailed quoll mortality (Koertner and Watson 2005). However, seven quolls out of the 36 radio collared did die from a variety of causes and one was probably the result of 1080 poison. A further 5 quolls had eaten meat baits, determined by Rhodamine B staining of vibrissae, and had survived. It appeared that foxes, wild dogs and other quolls were responsible for most of the fatal injuries suffered by spotted tailed quolls (Koertner and Watson 2005). A parallel study in Queensland found 5 out of 200 baits were taken by quolls, 65 out of 76 quolls were known to be living one month after baiting, 2 quolls out of 76 were confirmed to have died from 1080 poisoning and 6 died from unknown causes (Cremesco 2005). While there may be an impact on individual quolls, the poison 1080, did not have an effect that would change populations.

2.10.3 Aerial Baiting using Poison Meat

First mention of the use of aeroplanes for baiting for wild dog control was in 1954 where Tomlinson (1954), advocates the use of bovine brisket fat or udder tissue, processed in brine and cut into 2.45 cm cubes. Half a strychnine pellet was inserted into the meat cube and the bait wrapped in paper to improve handling. Baits were dropped around water holes and areas where wild dogs visited. Targeted baiting was advocated rather than wholesale baiting. The conclusion was that aerial baiting when carefully planned and supported by ground baiting was a successful method of reducing wild dog populations (Tomlinson 1954).

Fleming (1996) used aerial baiting during 1991-1993 to compare and measure abundance indices using the raw count of footprints per kilometre of transect and "sightability" of signs index methodology. Both methods showed aerial baiting was efficacious and reduced abundance of wild dog signs between 66.3% to 84.5% for the 'sightability index' and 76.1% to 91.1% for the count of footprints. Poison baits were dropped at the density of about 38 baits per km of transect. The abundance indices showed wild dog activity returned to pre baiting levels by the following year (Fleming 1996). Fleming et al (2001) concluded that aerial baiting was an effective means of delivering baits into remote and inaccessible areas where ground based operations are impractical.

When Thompson and Fleming (1991) did an economic assessment of aerial baiting for wild dog control in north east NSW, >70% of the cost was borne by helicopter and labour hire while the cost of the meat was approximately 20%. Total operating costs could be accurately predicted from the bait quantity and the costs to livestock producers when compared with stock losses suggested the operation had an overall cost benefit. Fleming et al (2001) reported that control effort had effectively fallen from 39.3 hours per property per year in 1962 for all wild dog control to 11.6 hours per property per year in 1988 using aerial baiting.

2.10.4 Global Positioning Systems

The first 11 Global Positioning Systems (GPS) satellite vehicles were developed and launched by the United States Department of Defence between 1978 and 1985. Since then these have been replaced by 24 satellite vehicles launched about 1997. All orbits are evenly spaced 20,200 km above the earth and enclose it like a birdcage (McElroy et al 2007). With the high orbit it is possible for 4 – 12 satellites to be electronically 'visible' from anywhere on the globe. The satellites travel at 4 km / sec and rise and set twice daily. The satellite vehicles contain radio transmitters that transmit on two microwave frequencies, L1 of 1575.4 MHz and L2 of 1227.6 MHz (McElroy et al 2007). A navigation code is transmitted from the satellites that relay the position of the satellite in x, y, z coordinates plus a status signal to indicate that all systems are functioning satisfactorily. A different code is transmitted from each satellite vehicle so a receiver can detect which satellite is transmitting (McElroy et al 2007). The

GPS receiver calculates position by measuring the distance to the satellite vehicles and using the equation; distance = velocity x time. The microwave signals travels at the speed of light from the satellite to the receiver, taking approximately 0.07 seconds, and the GPS receiver calculates latitude, longitude and height to give the position on earth. While modern GPS receivers are very efficient they can only calculate a historical position. If the receiver is moving, such as, an aircraft, they use filters to predict the next location based on a history of positions, direction and speed with emphasis on the most recent data (McElroy et al 2007). If the area is in heavily obstructed terrain, calculation of position may lead to slower response time by the receiver. Some contractors and surveyors use Differential GPS (DGPS) for higher accuracy. DGPS measures the size of the GPS errors at a base station and applies them to other GPS receivers called the rovers. The base station has an accurate fixed location that calculates the distance to each satellite as it comes into view, from each it calculates the error and sends it usually via mobile phone, wifi or satellite link to the GPS receiver. The base station applies correction factors that take into account the rate of change of the distance to the satellites. Base stations located further than 100 km from the operation may need additional correction processes applied to achieve precision. DGPS can achieve accuracies of greater than +/- 25mm compared with about 5 m – 10 m for uncorrected GPS. A network of stations for DGPS is becoming available to support precision agriculture in NSW and could be a valuable addition to aerial baiting (Anon 2011).

In addition, navigation in steep sided topography may result in multipath errors and inaccurate computation of GPS position as satellite signals reflect off rock faces and the GPS position received is computed to move from the actual position. When satellites cannot be seen for several minutes due to terrain, receivers must either wait for a correct signal or extrapolate the position based on speed and direction of heading of the most recent GPS readings to get an estimate of the position. On a number of occasions baiting was interrupted in steep valleys when the GPS signal was not detected by the receiver, the signal returned when the aircraft climbed out of the valley to higher altitude. To help offset these topographic errors NSW Environment Protection Authority were reported to give approval for a bandwidth of ± 500 metre in which the aircraft could operate. However, inaccurate reporting of the position continues to be an issue for landholders involved in aerial baiting.

2.10.5 Accuracy of Aerial Baiting

Two types of aircraft, fixed and rotary wing (helicopter) were compared for altitude, velocity, and 'terrain characteristics' against baiting accuracy by Thompson et al (1990). It was concluded that helicopters were more suitable for tablelands and the eastern escarpment of NSW while fixed wing aircraft could be satisfactorily used in the flatter plains of the western division. In these experiments helicopters drop 48% of simulated baits within 5 m of the target line while fixed wing aircraft could only achieve 18%. Again, the helicopter had 27% of simulated baits further than 10 m from the target line compared with 61% for the fixed wing aircraft. To ensure the simulated baits (bags of lime) could be more easily located, this experiment used one clearly defined ridge line, bare of most vegetation, as the target. The ridge line was flown at 90 km / hr for the helicopter with 5 replications of each treatment, accuracy improved and helicopter placement improved from 26% to 48% within 5 m with successive flights and a Global Positioning System (GPS) was not used for navigation (Thompson et al 1990).

While aircraft accuracy for distribution of baits along pre planned GPS flight paths for rabies vaccination of wildlife in the United States of America and Canada appears to be assumed, most of the other papers quoted refer to the accuracy of positional fixes with very high frequency (VHF) radio tracking or GPS collars. Sager-Fradkin et al (2006) compare fix success in GPS collars fixed to bears against simulated conditions and found that simulated test collars at fixed locations were 32% more successful than those on animals. Such factors as elevation and unobstructed view of the satellite as well as microhabitat issues of over storey canopy reduced success of GPS fix. In this study, horizontal errors of greater than 800 m occurred when elevation changes between fixes were greater than 400 m and the authors urged caution in interpreting GPS fix data (Sager-Fradkin et al 2006). To add to the issue of positioning error, Cargnelutti et al (2006) also urged caution in interpreting results of positions. When comparing simulated and mobile data location, accuracy was highest when the number of satellites contacted was high, canopy cover was low and residual dilution of position (RDOP) was low. In Cargnelutti's study, mobile collars performed less well than static collars due to frequent positional changes and orientation (Cargnelutti et al 2006). In evaluating 8 GPS collars, Hansen and Riggs (2006) determined the greatest single limiting factor was availability of sky in terms of canopy cover and satellite acquisition, rather than slope, slope position, aspect, conifer basal area, tree height, canopy depth or elevation. Morgan (1994) compared radio fix location with GPS navigation and found GPS was more successful at delivering a uniform coverage of carrot baits to control the Australian brush tailed possum (*Trichosurus vulpecular*) in New Zealand. Uniform bait coverage was essential to control animals with smaller home ranges such as rabbits and possums. However, wild dogs can detect meat baits using their highly developed olfactory organs over quite large distances and a uniform distribution of bait over the landscape may not have the same effect as strategically placed baiting on those locations where wild dogs are known to travel.

Gantz et al (2006) using fixed wing aircraft showed how inexperienced observers had mean errors of 214 m compared with a mean error of 101 m for experienced observers in good conditions for point source VHF telemetry. In a parallel study, Gantz et al (2006), determined the locations of coyote carcases with a mean horizontal error of 275 m. Gantz stated that their results approach those of Leptich et al (1994) who achieved 49.9 m for aerial GPS and 73.1 m to 80.7 m in uncorrected GPS reported in Carrel et al (1997) (Leptich et al 1994).

Other fixed wing aircraft studies have examined the role of GPS in tracking landing paths and Gibbs and Sweltink (2002) assess the track error of the Boeing 747 landing area in Holland and determined that GPS had standard deviation of 0.05 NM (93 m) compared with 0.23 NM or (426 m) contained within the 95 percentile using the distance measuring equipment used up until selective availability of GPS was switched off in 2000. While these large fixed wing aircraft have little in common with small helicopters it does illustrate that there is a track error associated with GPS that needs to be taken into account when using the system.

Aerial baiting requires frequent changes of direction at the relatively high speed of 80 km / hr. During aerial baiting aircraft could face limitations when the flight path impinged on any factors that affect availability of satellite signal such as heavily vegetated, steep sided gorges with limited view of the satellites. Gantz et al (2006) evaluated the accuracy of VHF radio telemetry in a range of terrain from steep mountains, deep narrow canyons, high mountain valleys and flats. Factors identified that might affect aerial locating were air turbulence, terrain, map quality, observer experience and familiarity with the area (Hoskinson 1976; Cochran 1980). Observer experience and continuous learning (Hoskinson 1976) explains the improvements in accuracy after 5 replications experienced by Thompson et al (1990). Gantz et al (2006) adds ground cover for locating animals, constraints of flight time and safety and, in mountainous areas, precision and accuracy are sacrificed in the interests of maintaining safe flying conditions. In Ganz et al (2006), errors were 2 to 3 times larger for canyons and hillside locations compared with flat and ridge-top situations. Gantz et al (2006) concluded that interpretations should not exceed the data collection capabilities of the process (Gantz et al 2006).

Robley (2011) assessed both the accuracy and effectiveness of aerial baiting in Victoria. This study used 13 meat baits with micro transmitters and 17 fluorescent dyed pink baits, so baits could be accurate located on the ground. Thirty drop points were located by helicopter and baits were spaced at 1 km intervals. Airspeed for the bait drop was 30 knots (~60 km / hr) and height was stated as 100 feet. Reported accuracy was 0.5 m to 18 m with a mean of 5.6 m ± 0.9 m. The technical report while detailing the materials and methods fails to mention the coefficient of variation or statistics used to generate the data.

2.10.6 Administrative Processes for Aerial Baiting in NSW

The administrative process of aerial baiting for wild dog control is outlined in the section 'Wild Dog Biology and Control' in Croft (2007). The use of the pesticide 1080 for pest animal control on private land in New South Wales is administered by the Livestock Health and Pest Authority (LHPA). Aerial baiting in NSW required landholders to form control groups known as Wild Dog Control Associations (WDCA) and strategic baiting was organised across land tenures including private landholders, crown lands, State Forests and National Parks (Croft 2007). The Wild Dog Control Associations submitted applications and maps of proposed aerial baiting transects to the LHPA. Aerial baiting in NSW required the consent of the Director General of New South Wales Department of Primary Industries (NSW DPI) or their delegate and the LHPA submitted both the application and a map of proposed bait transects to the NSW DPI for approval (Croft 2007).

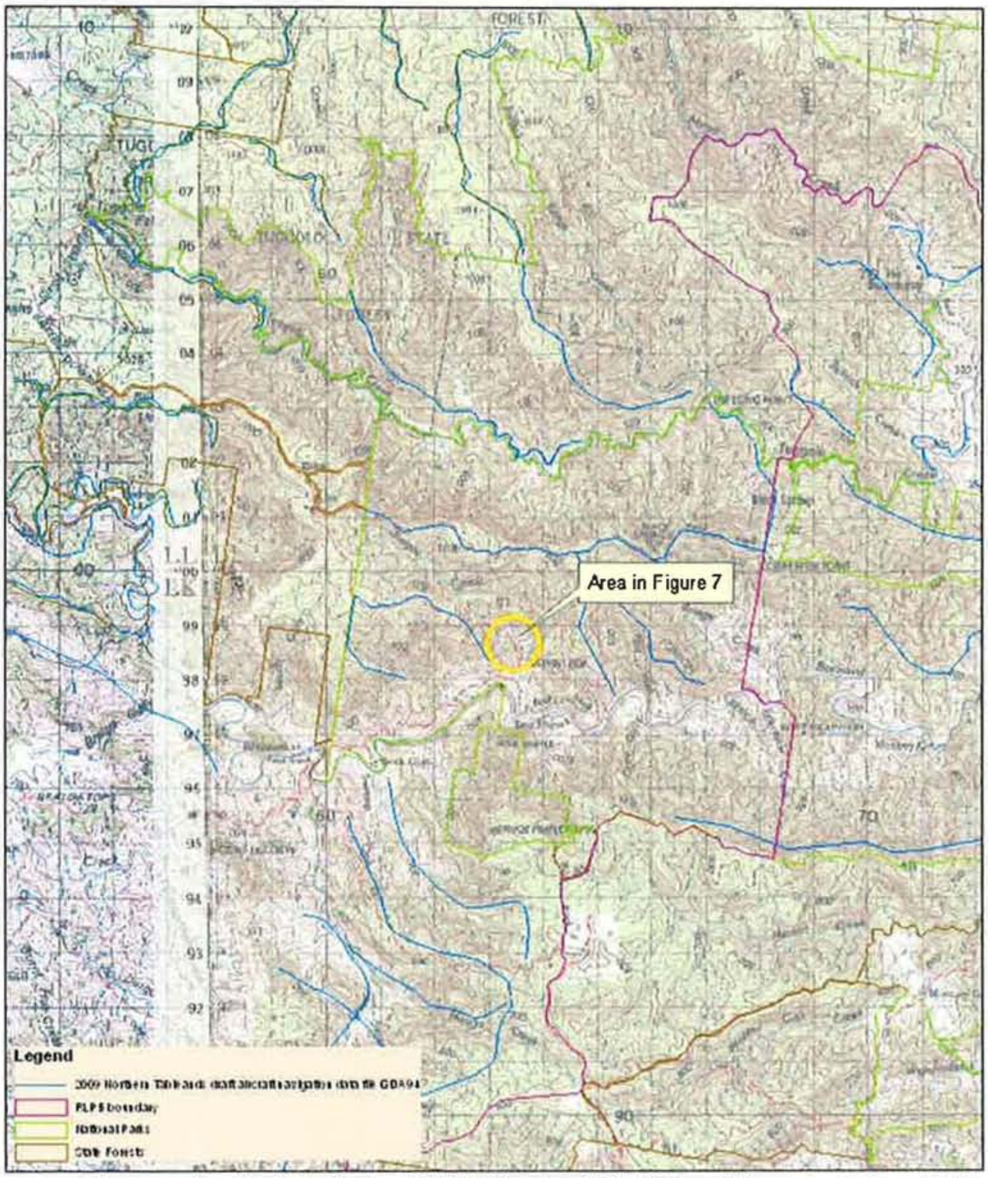
The aerial baiting applications for wild dog control required particular details for the use of aircraft, such as, steep or inaccessible terrain; bait quantity; length of proposed bait transects; history of predation over the last 12 months, a list of group participants and a map of the area (Croft 2007). The application maps were scanned and georeferenced to standard 1:100,000, and 1:25,000 scale maps using ArcGIS9.2 according to the method outlined at www.esri.com (2008). From 2007 to 2009 the proposed bait transects were digitised from the maps and the navigation file was sent to the aircraft contractor.

2.10.7 Potential Sources of Error in the Applications

2.10.7.1 Map Scale

Much of the aerial baiting application process was based on 1:100,000 scale maps for mapping aerial bait transects. These maps were a convenient size; about 55 x 55 km square and Wild Dog Control Associations (WDCA) could usually fit all the bait transects on the one paper map sheet. Most of the Australian Standard map series known as AUSLIG or Natmap in 1:100,000 scale used by the WDCA's were produced in the late 1970's. While most of the natural features do not change, many of the roads, houses and other human made features have changed with increased urbanisation. The fine topographic details, such as saddles where wild dogs cross ranges are often difficult to locate at this scale and more difficult when travelling at 80 - 90 kilometres per hour in a helicopter, Figure 1. Note that the saddle identified in the following photograph was missed by the aerial bait transect immediately to the south west of the circled area, Figure 2.

Figure 1 Typical wild dog habitat in Barnard River WDCA



Topo graphic map produced by Philip Gardner at 1:100,000 scale on 2/12/2009 from Natmap sheet 9134 and 9234

km
0 0.5 1 1.5 2

2009 Barnard River Wild Dog Control Association

New England Livestock Health and Pest Authority

Figure 6. Area of wild dog activity identified in the photograph in Figure 5

2.10.7.2 Bait Transect Width

The width of the proposed bait transects for each Wild Dog Control Association depended on the drawing medium used. In the early stages of the study the width of proposed bait transects varied from 0.4 mm (40 m at 1:100,000 scale) for the average ball type pen to 6 mm (600 m at 1:100,000 scale) for some thicker felt pens. Errors of 1 mm (100 m) were relatively easy to make while freehand drawing on 1:100,000 scale paper maps. Freehand drawing on maps that did not have cadastral property boundaries was common, Figure 3. By 2009 many WDCA's were using 1:25,000 scale maps and Spot 5 images supplied either by NSW DPI or NPWS.

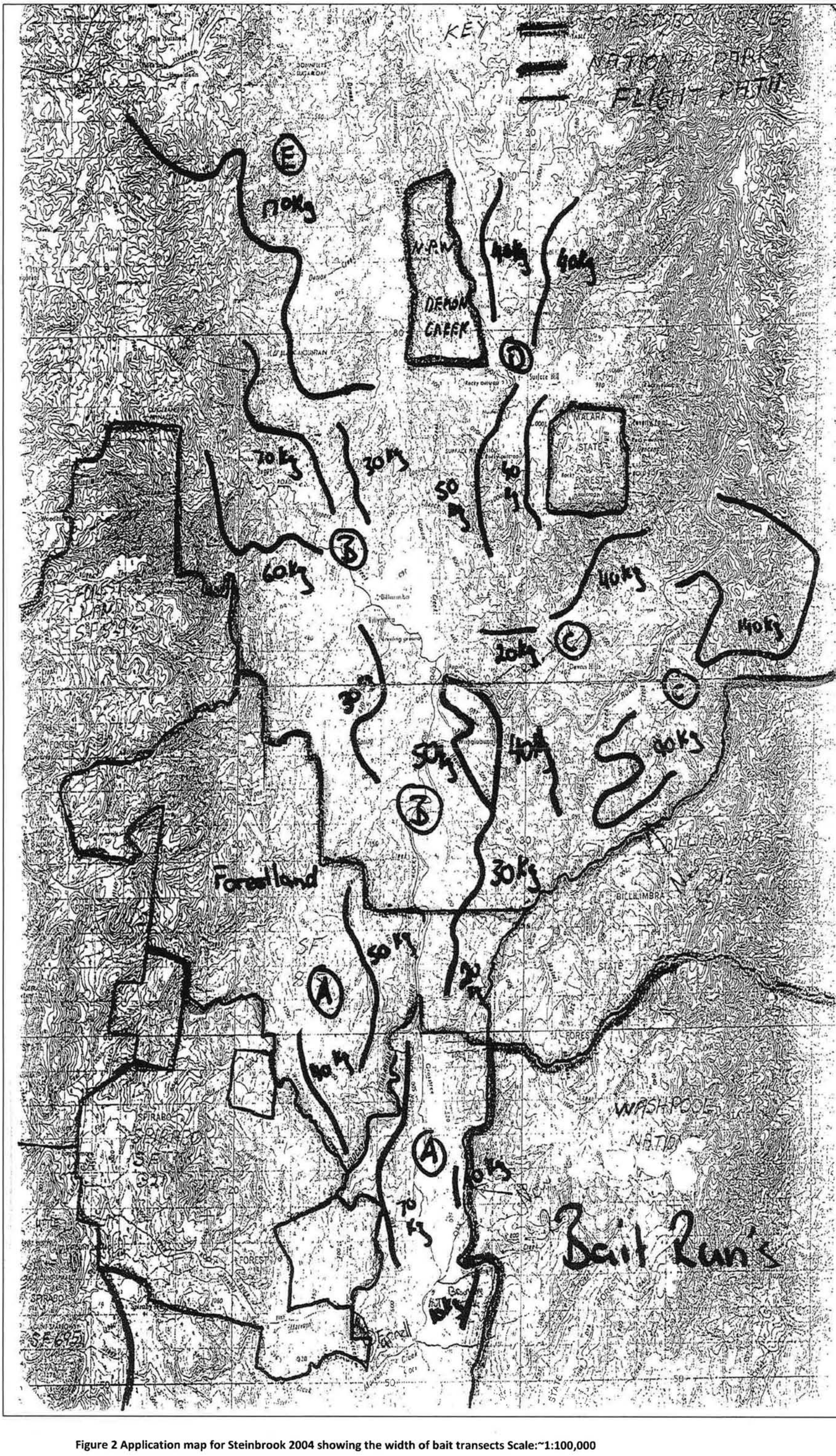


Figure 2 Application map for Steinbrook 2004 showing the width of bait transects Scale:~1:100,000

2.10.7.3 Datum errors

The 1:100,000 scale Natmap paper map series were produced in Australian Geodetic Datum 1966 (AGD66). Use of these paper maps could lead to projection errors of approximately 200 m (Anon undated) when used with the commonly used aeronautical datum World Geodetic Series 1984 (WGS84) if bait transect lines were not reprojected to WGS84 or GDA94, Figure 4. In 2000, the Australian Commonwealth government adopted the Geocentric Datum of Australia 1994 (GDA94) as the standard datum for Australia. While most NSW Government departments converted to GDA94 datum, at the beginning of the study, many National Parks and Wildlife Service rangers and field staff still used the AGD66 datum extensively.

ESRI ArcGIS 9.2® allows transformation of the datum when adding features to the data frame ('on the fly'), however, this does not change the original projection. If the feature is used in another program, for example, Oziexplorer® navigation software, the original projection will still apply unless the feature is reprojected and saved with a corresponding datum (.prj) file.

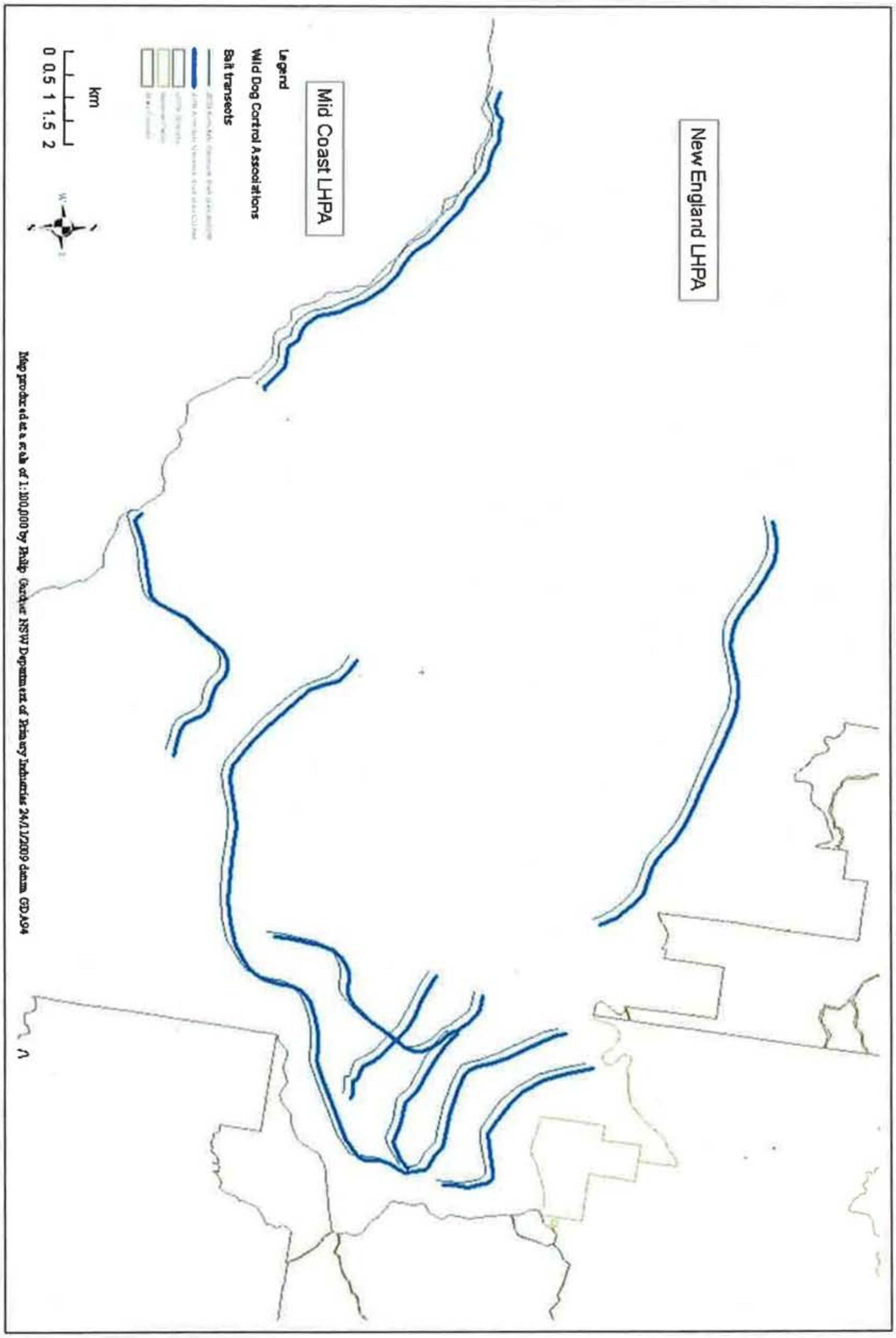


Figure 3. An example of the possible effect of a datum error

3. Materials and Methods

3.1 Study Area Description

The study area is located in the northern region of the Great Dividing Range of NSW and the 15 wild dog control groups were located in the Livestock Health and Pest Authorities (LHPA) of New England, Central North and Mid Coast, (Figure 5). The landform is generally high flat tableland plateaus of the Great Dividing Range with elevations of 400 m to 1400 m above sea level and snow falls during winter. The Great Dividing Range is intersected to the east by deeply dissecting sinuous gorges and river valleys up to 1000 m deep that fall to the coastal plain around the towns of Grafton, Gloucester and Kempsey thence to the Pacific Ocean. In the west the drainage lines flow more gently and uniformly through undulating drier slopes to the flat plains of the inland.

Vegetation is described as tall open forest interspersed with small areas of tall closed forest in higher rainfall valleys and extending into open woodlands on the western slopes. Tall strata is dominated by Eucalypts, particularly *Eucalyptus viminalis, E.obliqua, E. fastigata, E. andrewsi,* and Acacias, *Acacia meloxylon, A. mearnsii* with *Casuarina cunninghamiana* along rivers and streams. In the west open woodlands of *E. albus, E. melliodora, E. dealbata, E blakelyi, E. camaldulensis, Callitris glauca, C. endlicheri* and *Casuarina luehmannii* are common.

Large areas of forested public and private land tenure ensure good conditions for wild dogs to survive undetected for long periods of time. Cooperative aerial baiting programs using poison meat baits provided by public and private land managers have been used for more than 40 years to control predation of domestic livestock by wild dogs.

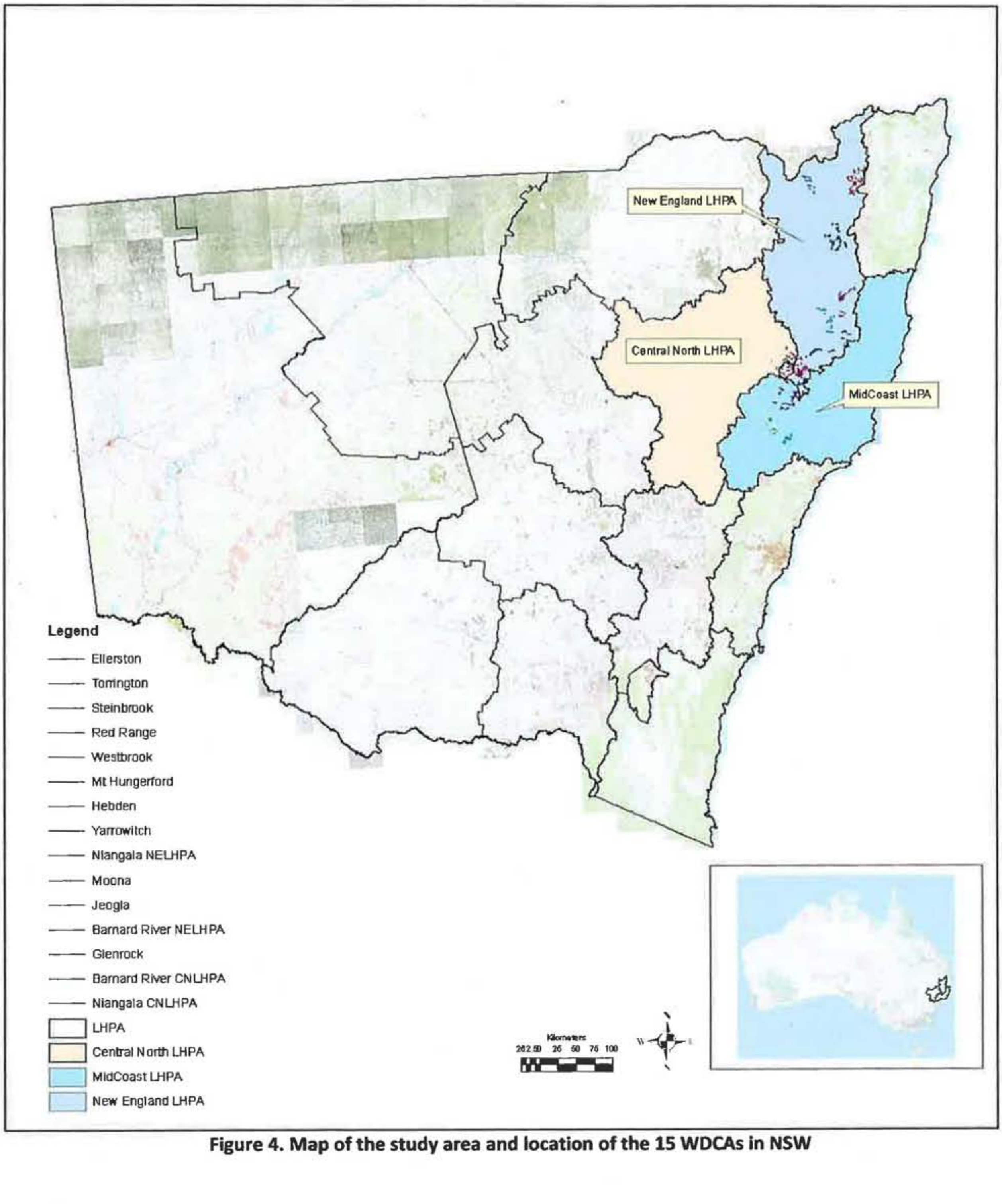


Figure 4. Map of the study area and location of the 15 WDCAs in NSW

3.2 Desktop Audit of Application Maps

To assess errors in the application maps a desk audit was performed on all application maps related to the study (Appendix 1).

3.3 WDCA's

For the purpose of this study 15 WDCA's were chosen from 53 possible Associations because these Associations had a complete set of aircraft flight log data for the six years and the locations covered a wide distribution of the aerial baited area. Other WDCA's did not have complete data sets because Associations enter or leave the scheme as wild dog predation increases or decreases or other social changes modify landholder management.

Following approval by NSW DPI, a Bell Jet Ranger helicopter was contracted by the LHPA to carry out the aerial baiting. A navigator was appointed by either the LHPA, National Parks and Wildlife Service or WDCA to direct the pilot to the areas of the bait transects and following the direction of the navigator, the bait dropper in the rear seat of the helicopter, gathered a 250 gram meat bait from a large hopper of poisoned meat baits and dropped it down a tube to the outside of the aircraft. The recommended height for flying the aircraft during bait deliver was approximately 100 to 200 m. The bait delivery rate or baiting density was one bait / sec on private land tenure and NSW State Forest and 0.25 baits / sec in National Parks (Anon 2010). The recommended average speed of the aircraft was 80 km to 90 km / hr, and 1 bait / sec equates to an indicative spacing on flat land of 25 m / bait or 40 baits / km. At the lower rate of 1 bait / 4 sec a spacing of 100 m equates to 10 baits / km.

3.4 Navigation

For the years 2004 – 2006 navigation was by VFR, using visual clues from the landscape, a knowledge of the terrain where wild dogs were known to travel gathered from members of the community and the

1:100,000 topographic application maps. The aircraft contractor, Commercial Helicopters, recorded GPS position for aircraft flight log of bait transect data to Satloc® proprietary software by pressing a switch on the control column of the aircraft to indicate the start and finish of each bait transect. In 2007 to 2009 navigation by a Global Positioning Systems (GPS) was by another aircraft contractor, Fleet Helicopters. At the same time Mid Coast LHPA employed a professional navigator for all except one (Westbrook) of the WDCA's in this study. The contractor in New England and Central North LHPA, Fleet Helicopters, used a Garmin® 76C GPS receiver coupled to a laptop computer running Oziexplorer® moving map software and NSW Lands Department Topoview digital topographic maps at 1:25,000 scale recording GPS position at one second intervals. Proposed bait transects were displayed on the laptop computer screen in front of the navigator, in full view of the pilot who pressed the space bar to indicate the start and finish of each transect. The other contractor, Commercial helicopters, changed to a Garmin® 292 GPS and Garmin® proprietary software for recording GPS position in the Mid Coast LHPA. The pilot pressed the GPS buttons in series to indicate the start and finish of each transect. In addition, from 2004 to 2009, an aircraft flight log with GPS position recorded all ferry times to and from bait transects and landing sites. At the conclusion of baiting the GPS data log from the aircraft was sent to NSW DPI for analysis.

Table 1 Wild Dog control Associations and Proposed Bait Transects (km) 2004 - 2009

LHPA	WDCA	2004 (km)	2005 (km)	2006 (km)	2007 (km)	2008 (km)	2009 (km)	Total (km)
Mid Coast	Ellerston	128.99	123.87	119.52	95.88	90.19	111.84	670.29
	Hebden	46.08	55.21	58.80	56.74	45.52	56.18	318.53
	Mt Hungerford	75.93	67.10	50.27	31.62	89.79	118.28	432.99
	Westbrook	37.07	39.59	39.59	39.59	45.64	37.78	239.26
New England	Barnard River	126.78	148.46	147.28	161.76	138.76	138.08	861.12
	Glenrock	58.87	38.98	58.67	63.13	62.19	63.35	345.19
	Jeogla	69.80	103.37	104.72	90.27	93.19	91.73	553.08
	Moona	30.45	47.34	51.35	46.30	59.13	63.46	298.03
	Niangala	55.42	61.12	85.53	85.01	85.93	80.61	453.62
	Yarrowitch	15.41	25.64	43.51	53.01	83.23	87.92	308.72
	Red Range	151.96	120.88	139.52	139.52	136.24	154.25	842.37
	Steinbrook	93.12	119.78	124.61	123.50	141.38	152.89	755.28
	Torrington	59.73	56.37	58.66	51.93	43.39	88.92	359.00
Central North	Barnard River	69.18	76.13	48.91	67.02	69.01	96.46	426.71
	Niangala	18.54	18.51	18.51	36.85	36.96	48.20	177.57
	Total (km)	1037.33	1102.35	1149.45	1142.13	1220.55	1389.95	7041.76

LHPA: Livestock Health and Pest Authority

WDCA: Wild Dog Control Association

Table 2 Wild Dog Control Associations and Aircraft Flight Log (km) 2004 - 2009

LHPA	WDCA	2004 (km)	2005 (km)	2006 (km)	2007 (km)	2008 (km)	2009 (km)	Total (km)
Mid Coast	Ellerston	94.20	64.94	78.69	92.66	91.37	87.35	509.20
	Hebden	29.16	28.32	41.28	38.38	34.53	56.71	228.37
	Mt Hungerford	54.95	46.25	34.37	57.24	79.48	94.89	367.19
	Westbrook	31.11	35.40	33.68	33.40	43.94	43.94	212.31
New England	Barnard River	139.07	143.03	144.03	155.63	103.63	128.36	813.74
	Glenrock	39.84	43.82	63.64	66.00	53.10	32.72	302.88
	Jeogla	60.34	105.57	83.37	85.30	85.40	90.88	510.86
	Moona	38.93	42.74	48.17	54.69	63.46	57.13	305.12
	Niangala	52.78	64.78	79.16	148.95	80.60	79.35	505.62
	Yarrowitch	17.41	26.51	59.75	58.59	68.51	84.05	314.82
	Red Range	114.07	98.48	97.73	123.23	115.40	132.34	681.25
	Steinbrook	159.00	89.27	153.21	68.81	125.06	112.26	707.62
	Torrington	56.58	38.45	51.75	11.64	38.55	84.20	281.18
Central North	Barnard River	65.13	43.57	49.19	62.61	50.82	82.63	353.93
	Niangala	16.41	17.73	19.30	31.14	36.80	41.58	162.97
	Total (km)	968.97	888.87	1037.34	1088.03	1070.64	1203.23	6257.09

LHPA: Livestock Health and Pest Authority

WDCA: Wild Dog Control Association

3.4.1 Proprietary Navigation Systems

For this study two proprietary navigation systems, Satloc® and Garmin® were used. In each navigation system the GPS position was recorded to a data logging file at one second intervals. The Satloc® binary file was converted to a polyline for length calculations using the ESRI Arcview version 3.2® extension, 'Spray Advisor' available from United States Department of Agriculture Forests Service. Both aircraft companies changed to Garmin® GPS software in 2007. Garmin® files were output to a track log file and converted to shapefiles in the program Oziexplorer®. To check for differences in the accuracy of the two GPS logging systems would have required flying with both systems in parallel using the one aircraft, flying conditions and terrain. With a shortage of equipment and flying time for checking accuracy, an assumption was made that there was no significant differences between the Satloc® and Garmin® GPS logging systems.

3.5 Field Operations of Aerial Baiting

In this study the experience of operators was not controlled and additional variables of fatigue, anxiety and motivation were not tested. Experienced WDCA personnel and LHPA rangers provided advice to navigators and bait droppers. Navigators and pilots were not instructed in the experimental procedures or trained to carry out their respective duties and it was not possible in the confines of the aircraft to provide any directions while flying. It was trusted to nature to randomise individual differences across all WDCA's (Burns 1997). There was no attempt to add experimental controls in 2008 or 2009 so the effect of learning the GPS navigation system in 2007 could be statistically analysed. The 2004 aerial baiting transects were flown in the year prior to the arrival of the researcher and these lines were located with the aircraft company, 2 years after the analysis had started. Baiting was done at the average speed of 80-90 km / hour, however, it appears from the small number of aircraft flight logs that included air speed, the speed varied from 60 km / hr to 140 km / hr due to gravity effects, aircraft speed was slower up hill and faster downhill.

3.6 Weather Conditions

Aerial baiting was carried out in May and June (winter) in 2004 to 2009. Prevailing weather conditions at the time were heavy frosts followed by fine, clear and sunny winter skies with calm winds for the New England, Central North and Mid Coast Livestock Health and Pest Authority. From 2007 to 2009 the weather in Steinbrook and Torrington WDCA's (NELHPA) was overcast, wet and misty with aerial baiting done between short breaks in the low cloud layer.

3.7 Geographic Information Systems

To measure differences between the proposed bait transects and the aircraft flight log all aerial baiting application maps from 2004 to 2009 were scanned on an A3 scanner and georeferenced to standard 1:100,000 and 1:25,000 scale maps from the 2006 NSW Lands Department Topoview series using either ESRI ArcGIS 9.2® or Manifold version 8.0®. Manifold 8.0® had the advantage of allowing a number of scanned images to be placed on the one map sheet when a large number of 1:25,000 maps were georeferenced for Steinbrook in 2008. ESRI ArcGIS 9.2® was limited to one image at a time. Following scanning, all the proposed bait transects were digitised in GDA94 datum, Figure 6.

3.7.1 Buffers and Intersects

Using the Proximity buffers tool in ESRI ArcGIS9.2® (ArcToolbox > Analysis Tools > Proximity > Multiple ring buffers), multiple ring buffers were generated around the proposed baiting transects at 100, 200, 300, 400, 500, 600, 700, 800, 900 and 1000 metre intervals. This created a polygon shapefile with multiple buffer distances, the multiple ring buffers command dissolved intersecting rings to form continuous polygons around each proposed transect, Figure 7. The aircraft flight log for each bait transect was overlaid across the buffers, Figure 8 and clipped by the buffer polygons with the Intersect tool (ArcToolbox > Analysis Tools > Overlay > Intersect) to provide a number of short baiting transect segments within each polygon. The length of the intersect within the buffer was measured using the

XTools extension. Using Microsoft Excel, the database file (dbf) for the shapefile was sorted into the 10 buffer segments. The total length of intersection in each buffer interval was calculated and converted into a percentage of the total aircraft log for each WDCA.

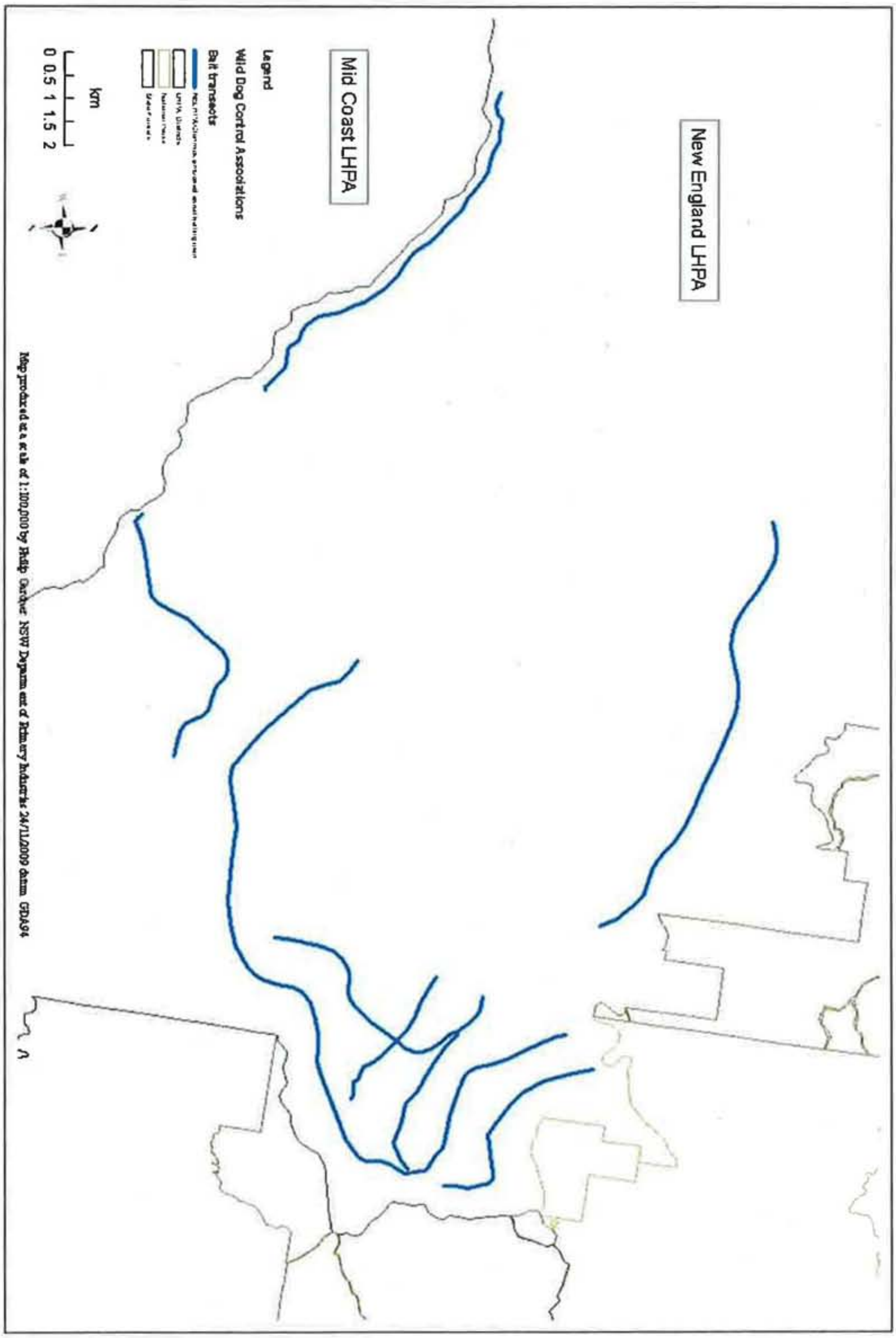


Figure 5 Proposed bait transects in Glenrock WDCA were digitised (2009)

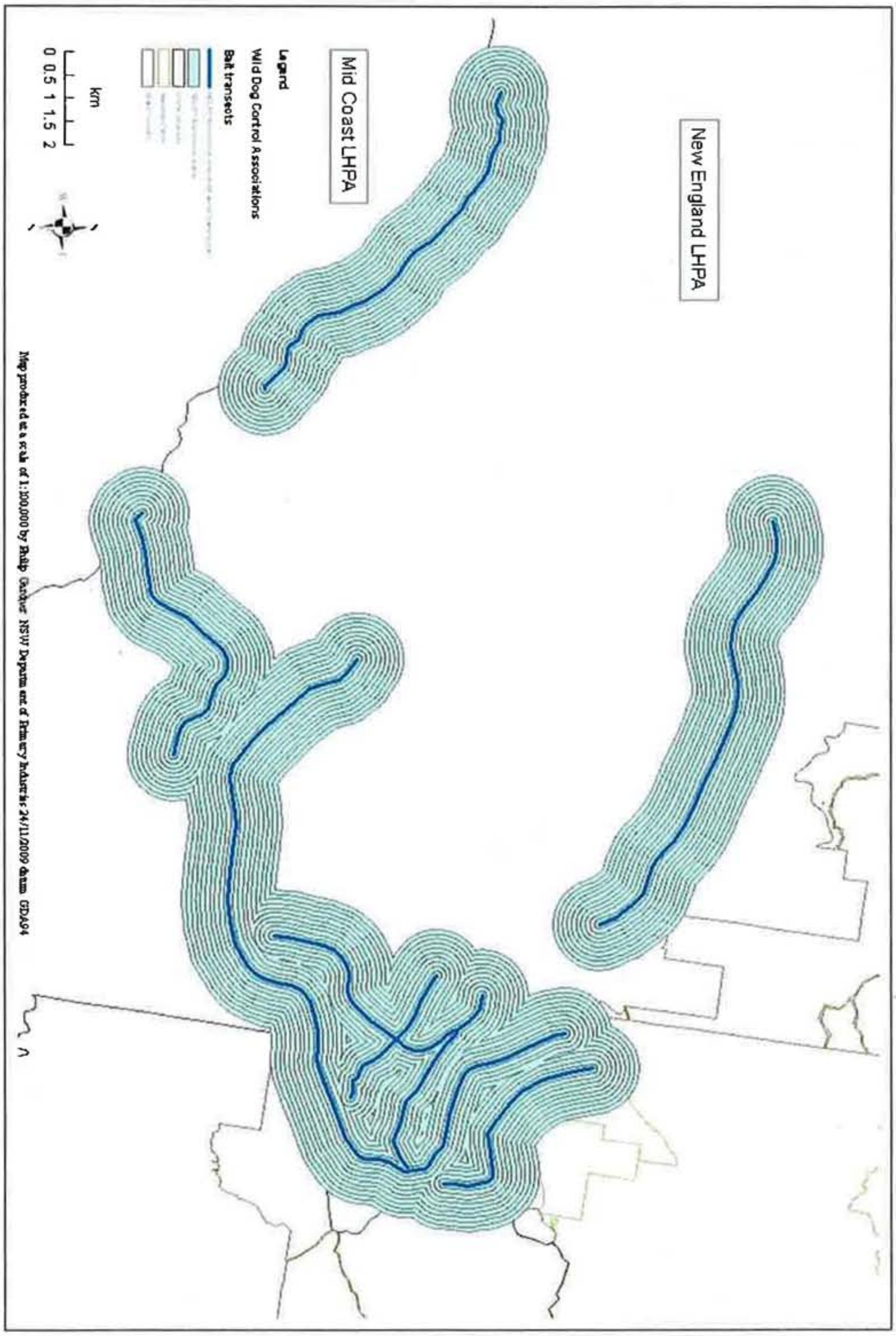


Figure 6. Multiple ring buffers were constructed around proposed bait transects in Glenrock WDCA (2009)

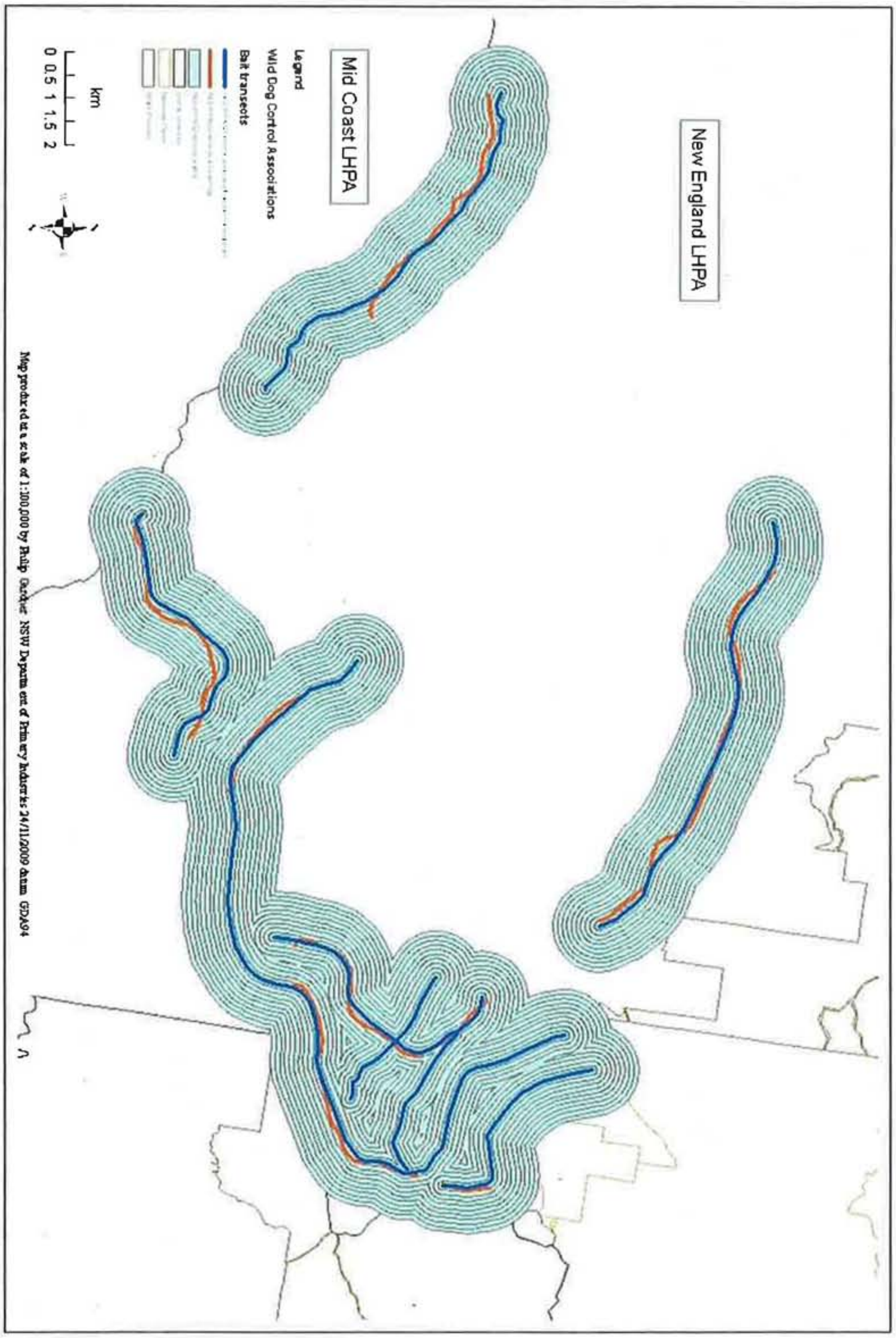


Figure 7. The Aircraft flight log was overlayed on the multiple ring buffers Glenrock WDCA (2009)

3.8 Statistical Analysis

The worksheets were processed in Microsoft Excel® and graphed to determine if the data was skewed and if it would require transformation. It was then imported into 'R' using the odbcConnectExcel interface. The data was analysed using the mixed modelling package ASREML® in the statistics software 'R' on a computer running Microsoft XP® operating system. The data was skewed and required transforming to ensure the distribution was approximately binomial. The data was transformed using an arcsin transformation to the square root where the data set contained percentage distance information by Site and Year. ASREML® uses an average information algorithm to calculate the mid points of each distance of the transformed data and fit the curve to the data. Mid points were set at 50, 150, 250, 350, 450, 550, 650, 750, 850, 950 and 1050 m. The track error at these mid points was used to generate the spline. Variance components were partitioned out including z-ratios and this was followed by an analysis of variance using Wald statistics to determine the p values associated with the model terms. The model generated in ASREML® was interrogated to predict how the proportions Year, Site and Track error interacted in the transformed model. Finally the predicted proportions were retransformed using an inverse arcsin transformation and the splines shown in the results were generated.