Conserving koalas in the Coomera-Pimpama Koala Habitat Area: a view to the future

Final report prepared for Gold Coast City Council

March 2007
Executive Summary
The Coomera-Pimpama Koala Habitat Area (C-PKHA) covers approximately 3640ha of which 2148ha are designated Urban Koala Area (UKA) and 1492ha designated Koala Conservation Area (KCA) for purposes of the Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016.

Comprehensive koala habitat and population assessments carried out during 2006 established the presence of a large koala population in the C-PKHA, the size of which we have estimated at over 500 individuals. The koala population within the C-PKHA is in excellent condition, age classes are approximately normally distributed and there is a high level of reproductive success with few animals showing outward signs of disease.

Approximately 70% of the C-PKHA’s koala population is currently residing within the designated UKA, the extent and configuration of which suggests that it functions as the major source population for the C-PKHA. Pre-approved developments that have either commenced or are likely to get under way within this area over the next two years will result in the loss of 416 ha of habitat and the displacement of up to 140 koalas. Longer-term development expectations for the remainder of the UKA will invariably result in a further significant reduction in the extent of koala habitat and the ongoing displacement of many more koalas. Remaining areas of koala habitat within the C-PKHA are currently not large enough to accommodate the numbers of animals likely to be displaced by the development process, nor are they presently capable of supporting a viable koala population in the long-term.

Population Viability Analysis (PVA) over 50 year time frames using baseline data derived from koala populations inhabiting the Coomera-Pimpama and Coombabah KHA's (which do not differ significantly) confirms that in an undisturbed state, the current koala population in the C-PKHA has a low probability of extinction such that it could reasonably be assured of long-term population viability. PVA also indicates the population’s theoretical ability to endure the extent of habitat loss and commensurate reduction in carrying
capacity associated with currently approved development commitments, subject to the qualification that any incidental harvest (annual mortalities due to motor vehicles and dogs) remains below 3% of population size. However, this value will be exceeded as a consequence of increasing urbanization within the UKA. Indeed, PVA modelling using the EPA’s incidental harvest rate data from elsewhere in developed areas of south-eastern Queensland confirms that the C-PKHA’s koala population will invariably decline towards extinction independently of population size once the incidental harvest approximates 6%.

In order to retain at least the Minimum Viable Population (MVP) of 170 koalas within the C-PKHA long term, a large and virtually unroaded habitat patch approximating 1500ha in size will need to be established within a relatively short period of time (10 – 15 years). This report advocates establishment of a large habitat area in the north of the C-PKHA, ideally involving negotiated Voluntary Conservation Agreements with existing landholders, but realistically requiring a process of land acquisition in order to secure the large area of habitat that will ultimately be required in order to provide long-term viability and security of tenure for a biologically meaningful koala population. Urgent and extensive habitat restoration works will also need to be enacted on the bulk of these landholdings if they are to realize their potential carrying capacity within an envisaged 10 – 15 year time frame, itself driven by the corresponding development timeframe for the UKA. Two-population PVA modelling supports the potential for the MVP to be established within the KCA, predicting a stable source population of approximately 200 individuals over a 50 year timeframe, subject to adequate habitat being available and a low rate of incidental harvest being maintained.

Additional to the above, the need to maintain effective habitat linkages between the UKA and the KCA is also advocated, as is the need for minimizing the potential impacts upon koalas within remaining areas of the UKA not yet approved for development, by enforcement of koala friendly provisions such as larger lot sizes, retention of preferred koala food trees, restrictions on the keeping of domestic dogs and traffic calming devices for all
future developments. However, we stress that such measures in themselves will not guarantee long-term population persistence within the UKA given that the primary source population of the C-PKHA will have been effectively displaced and/or extirpated and that the incidental harvest will exceed that able to be sustained by the population as a whole.

The ethical and moral dilemma posed by the short-term displacement of up to 140 koalas from bushland areas within the UKA over the next few years also warrants urgent consideration, as does the ongoing displacement of additional animals as development proceeds within the remainder of the UKA over time. To address this matter, we propose a coordinated and assisted translocation program as a means of ameliorating the impact, with a proportion of those animals immediately affected by pending development being moved to specific areas of the KCA and elsewhere in the LGA. The literature on translocation is reviewed and an experimental protocol proposed to assist this process, the results of which will be expected to inform the need for further translocations as development within the UKA proceeds over time.

Consideration of the abovementioned results leads to a number of key recommendations focused on the overriding objective of ensuring the long-term presence of a viable koala population within the KCA portion of the C-PKHA. The recommendations have been listed in order of priority and are proposed for implementation over a time frame of 10 years. We conclude that in the absence of a timely and assertive response to the recommendations contained in this report that the long-term persistence of koalas within the C-PKHA will not be able to be guaranteed.

The time to act is now.
Introduction
This report has been prepared for Gold Coast City Council (GCCC) as a variation to an existing contract associated with a concurrent shire-wide koala habitat and koala population assessment. The need for the report has come about as a consequence of comprehensive koala habitat and population assessments in the Coomera-Pimpama Koala Habitat Area (C-PKHA) that have provided evidence for a significant ecological impact to be enacted upon resident koala populations arising from development of the proposed Coomera town centre and associated urbanization of adjoining areas.

This report examines the management options available to GCCC and relevant Government agencies in order to ensure the persistence of a koala population within the Coomera-Pimpama planning area in perpetuity. In compiling this report, we recognise that development commitments discussed herein have arisen from a long and arduous planning process, but must otherwise decry the lack of ecological foresight that has resulted in what can only be described as a significant conservation dilemma.

The report has also been deliberately structured for ease of reading; with detailed discussion of issues such as translocation, conservation offsets, management guidelines and the like provided as a series of Appendices rather than embedded in the body of the report. Our underlying intent has been to present the relevant information and associated conservation/management recommendations as succinctly as possible. As to whether we have achieved this and effectively communicated both the essence of a solution and the need for urgent action, only time will tell.

The study area
The C-PKHA (Figure 1) covers an area of approximately 3640ha of which 2148ha are designated Urban Koala Area (UKA) and 1492ha designated Koala Conservation Area for purposes of the Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016.
Fig. 1. The Coomera - Pimpama Koala Habitat Area
Bushland areas that contain Eucalypts within the C-PKHA currently cover a total area of only 1716ha, the balance comprising mainly cleared lands with isolated trees and small patches of native vegetation. The preferred koala food trees within the C-PKHA are Tallowwood *E. microcorys*, Forest Red Gum *E. tereticornis*, Swamp Mahogany *E. robusta* and Grey Gum *E. propinquua*. The greater proportion of bushland (1035ha) occurs within the boundaries of the UKA, with that remaining in the KCA (681ha) mostly disjunct, remnant bushland patches (Figure 2).

**Status of the C-PKHA’s koala population**

Comprehensive koala habitat and population assessments* carried out during the course of 2006 have established the presence of a large koala population in the C-PKHA, the size of which we have estimated at 510 ± 129 (SE) koalas. Koala densities within the C-PKHA average 0.23 animals/hectare overall, but are highest within the designated “redline” areas (i.e. areas supporting resident koala populations) delineated in Figure 3, wherein the average density is 0.30 koalas/ha (range: 0.24 – 0.33 koalas/ha). Extrapolation of this density data suggests a maximum carrying capacity for the C-PKHA at this point in time of approximately 674 koalas.

Moreover, the C-PKHA’s koala population is in very good condition; few animals exhibit outward signs of disease, there is a high level (50 – 70%) of annual reproductive success (evidenced by the large proportion of females observed/captured with back or pouch young), while other demographic data alludes to an approximately normal distribution of age classes.

Factors that we believe have contributed to the current population size estimate include a relatively long inter-fire period, the extent and distribution of koala habitat within the C-PKHA generally, and the fact that the majority of koala habitat currently exists in a largely rural residential setting with low traffic flow, all of which suggest that incidental harvest due to motor vehicle strike and dog attack is currently at sustainable levels.

* methodologies and interim results have been communicated to GCCC, EPA and OUM staff via project proposals, interim reports and presentations; full details will be provided in our final report.
Fig. 2. Vegetation Cover (solid polygons)

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Figure 3. Koala Meta-population boundaries
**Future development within the UKA**

*a) Imminent Development Footprint (IDF)*

Approximately 70% of the C-PKHA’s koala population currently resides within the UKA. That area within the UKA currently affected by existing development approvals (Figure 4) encompasses an area of approximately 582ha. This area currently supports 27.6% of the C-PKHA’s resident koala population(s) – approximately 100 koalas - the bulk of which primarily occur within the 416ha of native bushland affected by the IDF. An additional 30 – 40 animals currently residing in lower quality habitat outside of redline areas will also be affected.

As a result of current development approvals within the IDF, this report accepts that the majority of koala habitat contained therein will be cleared and that the resident koala populations currently inhabiting this area will be displaced. Clearing in these areas is already underway or imminent and will likely be completed by the end of 2008 (related report by GCCC refers). We estimate that in the absence of intervention, habitat destruction in this area will likely result in at least 30 - 50% mortality of the displaced animals, with the remainder forced to disperse elsewhere within and/or outside of the C-PKHA.

*b) Secondary Development Footprint (SDF)*

The remainder of the UKA (1566ha in total; 619ha of vegetation containing eucalypts) is expected to be subject to development proposals and associated works over the ensuing decade. Based on current population data, these subsequent development activities will potentially affect a further 216 koalas (not including those displaced by development works within the IDF).

**Summary**

Development of the proposed Coomera town centre and associated residential infrastructure within the UKA will invariably involve the removal and/or modification of 1035ha of native bushland and displace approximately 356 koalas over the next 10 – 15 years. This will potentially result in the death of at least 106 - 178 koalas (assuming 30 - 50% mortality of the current population within the UKA).
Figure 4. Interim Development Footprint (IDF)

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Currently, 681ha of remnant bushland containing eucalypts exists outside of the UKA (i.e. within the designated KCA), of which 244ha (35.8%) is already occupied by resident koala populations (approximately 154 koalas). In contrast to those of the UKA however, redline areas (i.e. koala meta-population cells) within the KCA are small (mean size = 29.1ha, range 0.7 – 141.8ha), disjunct and widely distributed, consistent with their having stemmed from the larger source population(s) resident in the UKA. More important though is the need to recognize that areas of habitat within the KCA not currently supporting resident koalas are too small to accommodate the number of animals that will be displaced by development activities in the adjoining UKA.

**Population Viability Analyses**

Population Viability Analysis (PVA) enables modelling of the effects of demographic, environmental and stochastic events on the dynamics of wildlife populations (Miller and Lacy 2005). Based on a thorough understanding of the biology and demographics of a given population, PVA can be used as a predictive tool for estimating the probability of extinction (or persistence) and their associated timeframes. Accordingly, PVA is widely applied to animal populations, to small populations in particular (Miller and Lacy 2005) and to threatened species conservation planning (e.g. Lindenmayer et al 1993, Possingham et al 1993, Phillips 2002, Biolink 2005, IUCN Standards and Petitions Working Group 2006). While few examples of PVA of koala populations are published in the peer-reviewed literature, the technique has been widely utilised to examine the relative influence of threatening processes upon koalas and the potential effects of differing management regimes when applied to populations of interest.

Modelling of koala populations can provide insight into their response to processes influencing survival and reproduction and thus allows managers to identify populations under particular threat. The threatening processes most commonly associated with koala populations include habitat clearing, wildfire and incidental harvest arising from motor vehicle related mortalities and dog attacks. Lunney et al (2002) and Lunney et al (in press) modelled populations
at Port Stephens and Iluka respectively to examine their probability of persistence over 50 years. PVA returned a 0% probability of survival for the apparent stronghold population of 800 animals in Port Stephens, while the modelled time to extinction of the Iluka population was 17 years with a 0.3% chance of survival to year 50. The former study particularly highlighted the need to question the apparent security of large populations, just as we are now doing for the C-PKHA.

Although the threatening processes affecting many koala populations are similar, responses of each population to threats and/or management strategies differ according to the population’s size and demographics. PVA is particularly useful for assessing the relative importance of different factors affecting a population (Coulson et al. 2001; Lindenmayer et al. 2003; Lunney et al. in press) and the possible effect(s) of hypothetical management strategies. By example, Lunney et al. (in press) determined that high levels of mortality had greater influence on population persistence than did fertility rates at Port Stephens and revealed that a decrease in the frequency of large fires did not necessarily reduce the probability of extinction as might have been expected. In contrast, PVA modelling for a small, endangered koala population at Hawks Nest NSW (n = 30 individuals) indicated a positive response by the population to a combination of reduced fire frequency as well as a program of short term (5 years) supplementation through assisted recruitment of two animals/year (Biolink 2005).

Caution must be exercised when interpreting results obtained through the use of PVA however, as the process is essentially one of modelling and therefore a simplification of the real world. Consequently, PVA’s capacity to accurately predict time to or probability of extinction for a population is limited (Reed et al. 2002, Fieberg and Ellner 2000). Moreover, the reliability of predictions is reliant upon comprehensive demographic data relating to the subject population. To this end it has been established that a correct estimate of initial population size is a significant factor in the outcome in terms of estimates of population persistence such that is more important in determining the final
outcome than are variables such as survival and reproduction (McLoughlin and Messier 2004).

PVA is of particular relevance to the current study in which the relative importance of a number of threatening processes is being examined and management options investigated over various timeframes and levels of intensity. Our demographic data and estimate of population size are both current and comprehensive, thus affording a high level of confidence in the outputs of the various scenarios modelled below.

**Methods**

PVA was carried out using the software package Vortex 9.60 (Lacy et al 2006) and employed 500 iterations over 50 year time frames for each run. Baseline demographic data for the C-PKHA’s koala population was derived from data collected from koala population assessments in both the Coomera-Pimpama and Coombabah KHAs. Demographic data did not differ significantly between these populations and therefore was pooled to provide a dataset of sufficient size to effectively minimize variance and hence provide meaningful data for modelling purposes. Data not obtained from the present study (i.e. age-class specific mortality and age at first reproduction) was sourced from that used in previous koala PVA studies (Phillips 2002, Biolink 2005; Lunney et al, (in press). The basic input data assumptions that underpin the various scenarios we considered are detailed in Appendix I.

A number of scenarios were modelled based on envisaged development outcomes for the C-PKHA and included varying scales and timeframes which could be reliably associated with each scenario based on ecological knowledge and discussions with Council’s planning staff. Varying levels of male-biased incidental harvest were modelled, consistent with mortality data for southeast Queensland derived by Dique et al (2003) and used in modelling of koala populations by Penn et al (2000), Lunney et al (2002) and Lunney et al (in press). For purposes of modelling the *status quo*, a background annual incidental harvest rate of 2% was incorporated to reflect current conditions. Information provided by the Queensland Fire and Rescue Service indicated
that the frequency of intense fire within the C-PKHA has been low over the past 50 years, with no major wildfires during this timeframe. Thus, a five percent probability of a stochastic event (namely 1 year in 20 chance of a severe fire event) was assumed for all scenarios. It is difficult to predict the severity of a wildfire event in terms of its effect on reproduction and survival of a koala population, however in a large and partially fragmented area such as the C-PKHA we considered it unlikely that greater than 25% of the koala population would be affected by a single wildfire event, therefore the severity effect was set (at a worst case scenario level) at 25%.

The Scenarios

1. **Status quo**

   **Input**
   
   Modelling utilized existing baseline data, assumed no impending development and incorporated a low rate of incidental harvest due to dog and motor vehicle mortality (a 2% proportion of the population annually), this figure based on our observations in the field and the relatively low density of roads traversing the area. For comparison, the effect of varying rates of annual incidental harvest (up to 6% of the population size) was also examined.

   **Output**
   
   The population stabilized over the modelling period at approximately 400 animals. The effect of increasing incidental harvest rates above 2% annually was an increase in the rate of decline of the population over the 50 year timeframe (Fig. 5). An incidental harvest of 6% resulted in the population size falling below our estimated Minimum Viable Population (MVP) of 170 animals within 50 years.

2. **Imminent Development Footprint (varying levels of harvest)**

   **Input**
   
   Modelling utilized existing baseline data but in order to reflect the effect of development of the IDF (582ha) the starting population size was reduced to 440 animals (assumed 50% mortality of displaced animals), along with an associated reduction in carrying capacity (commensurate with habitat loss) to
488 ± 122 (SD) koalas. A number of incidental harvest rates were also examined.

**Output**
This scenario results in an initial decline across all modelled levels of incidental harvest, however the population undergoing 2% harvest appears to stabilize around 300 animals (Fig. 6). A harvest rate exceeding 6% results in a population decline to below MVP within 20 years and localized extinction as early as 2033 at a 12% harvest rate.

**3. Secondary Development Footprint (varying levels of harvest)**

**Input**
Modelling utilized existing baseline data but incorporated a significant reduction in carrying capacity commensurate with a loss of 75% of remaining habitat (1174ha) in the UKA subsequent to (2) above over a period of 15 years. Incidental harvest rates from 2 to 12% were modeled to examine the influence of increasing mortality due to urbanization.

**Output**
At the baseline rate of harvest the population shows rapid decline over 15 years and stabilizes at approximately 170 animals (Fig. 7). At a harvest rate of 6% the population falls below MVP size within 25 years while a doubling of that rate results in likely extinction within 50 years.

**4. Modelling the future**

**Input**
While it is difficult to predict the outcome of populations 20-50 years hence on the basis of a number of unknown variables, we modeled one hypothetical scenario detailing the possible future of koala populations in the KHA should the recommendations in this report be implemented. This model is based on the following:
- that the koala population in the KCA can be manipulated to eventually function as a source population while the UKA becomes a sink for dispersing animals;
- that as a best-case scenario, the expected long-term development scenario in (3) above is realized within the UKA with an associated incidental harvest rate of 6% annually;
- that the acquisition and rehabilitation of land enables at least an 80% increase in carrying capacity within the KCA; and
- that incidental harvest rates within the KCA are kept to a minimum (2% annual) level.

An annual dispersal rate of 17% to reflect displacement from the UKA to the KCA was set with 50% of dispersing animals surviving.

**Output**
Based on the above, PVA modelling indicates a localized extinction of the koala population within the UKA within the next 25 years (Fig. 8). Dispersal of displaced animals and an increase in carrying capacity however, allows establishment and persistence of a population within the KCA which stabilizes at approximately 200 animals.
Fig. 5. The status quo - mean koala population size ± SD for the C-PKHA for each year over 50 years at varying incidental harvest rates.

Fig. 6. Mean koala population size ± SD for the C-PKHA for each year over 50 years at varying incidental harvest rates with initial population size and carrying capacity reduced to reflect development within the IDF. Dotted line indicates MVP of 170 animals.
Fig. 7. Mean koala population size ± SD for the C-PKHA for each year over 50 years at varying incidental harvest rates with habitat loss in the UKA of 75% within 15 years. Dotted line indicates MVP of 170 animals.

Fig. 8. Mean koala population size ± SD for the UKA and KCA meta-populations within C-PKHA for each year over 50 years reflecting habitat loss of 75% in the UKA and rehabilitation of 80% within the KCA. Dotted line indicates MVP of 170 animals.
Conclusions
Because of the relatively large population size estimate of 510 animals, loss of habitat due to the development of the IDF alone does not substantially increase the C-PKHA koala population’s probability of extinction provided that the rate of incidental harvest does not exceed 2 – 3% of the annual population estimate. Unfortunately, EPA and QPWS data from the Moggill Koala Hospital indicate that the rate of annual incidental harvest due to road mortality and dog attack in other developed areas of southeast Queensland approximates six percent of the current population estimate (EPA/QPWS 2006, QPWS 2002). In reality, this estimate of mortality rate is likely understated because an unknown number of motor vehicle strikes and dog attacks are not reported and hence go unrecorded. Regardless, in all modeled cases for the C-PKHA, a harvest rate of six percent or greater resulted in either a decline in population size to below the MPV or a decline to extinction within the 50 year time frames considered by this report. Given the extent of development likely to occur within the UKA we suggest that the rate of harvest experienced by koala populations in the area post-development will gradually increase to eventually match that estimated by the EPA/QPWS data and thus approach the higher harvest rates presented herein as worst case scenarios. Hence a key outcome from our modelling is that the C-PKHA’s koala population will invariably decline towards extinction independently of population size once the incidental harvest approaches or exceeds 6%. Having said this, it must also be recognised that our consistent use of baseline demographic data does not reflect likely changes in age-class distribution and a reduction of reproductive output arising from an increased incidence of disease due to development related impacts; hence the outputs presented herein must be interpreted as optimistic.

On the upside though and consistent with the recommendations detailed later in this report, PVA modelling has also indicated that it is theoretically possible to establish a viable koala population in the KCA by increasing the carrying capacity of this area over time and maintaining a low incidental harvest rate; this is a particularly encouraging outcome that provides an impetus for action.
Conserving the C-PKHA’s koala population: a view to the future

If koalas are to be offered a meaningful chance of long-term population viability within the C-PKHA, the key task ahead is to essentially create a mirror image of the population’s current configuration (see Figure 4). This involves creation of a new source population within an area that is currently serving as a sink with limited carrying capacity, while the existing source population itself becomes a sink over the time frame that development occurs in the UKA. To create this mirror image will not only be a difficult task but one that also requires single-mindedness in the context of an assertive and urgent management response.

Ideally, a conservation strategy for the C-PKHA’s koala population would be undertaken over a time-frame of at least 20 years in order to allow adequate time for proposed habitat restoration works to be implemented. However, given the extent of committed development within the UKA and the timeframe within which habitat clearing will take place, a much tighter timeframe for koala conservation measures is clearly required.

What must be stated from the outset is that the majority of planned future development in the UKA portion of the C-PKHA essentially constitutes development in what is otherwise high quality koala habitat. Ideally, this should have at least invoked the need for environmental offsets in the interests of koala conservation. According to Policy 2 (Offsets for net benefit to koalas and koala habitat) of the Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016, the required value of any offsets package should total at least 1.5 times the value of the Residual Habitat Impact (RHI) for that proportion of an offset package comprising high quality habitat measures. For the purposes of determining the value of proposed offsets, protection of existing habitat is afforded a higher offset value than habitat restoration due to the time lag before restored areas become effective habitat, to the extent that twice the calculated habitat offset area would be required if the offset site is mainly cleared and has to be restored. Application of this approach to the development outcome envisaged for the
UKA results in a requirement for approximately 1200ha of offset habitat to be acquired and effectively managed (see Appendix II).

Notwithstanding the above, our preferred outcome for the C-PKHA is for the KCA component to support at least what we consider to be the MVP for koalas of approximately 170 animals (Phillips unpublished data). The koala MVP figure is complex in its derivation (see Friend, 1987) but otherwise based upon knowledge of koala population dynamics, age-based mortality data, genetics and the interrelated variables of disease and its potential effect on koala fecundity. Thus, based on our knowledge of overall koala densities within the C-PKHA (0.23 koalas/ha) and incorporating a 50% habitat occupancy rate to accommodate stochasticity and associated meta-population expansion and contraction events, a minimum area of at least 1478ha will be required to effectively cater to the MVP determination. The size of this area approximates that of the KCA itself (1492ha), implying that conservation and management effort within this area will need to be intense and widespread. Moreover, this area must also remain relatively undisturbed in terms of road network in order to ensure that any incidental harvest remains sustainable at the population level.

A role for translocation?

The Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016 states that koala translocation should be restricted to exceptional circumstances and operate under strict scientific guidelines. The policy statement rightly indicates that translocation can have significant impacts on the animals being translocated as well as affecting other animals already occupying habitat in the release area and further stipulates that the translocation of koalas will not be approved unless in accordance with a controlled scientific research approval that has the underlying aim of expanding knowledge about wildlife translocation.

In the case of the C-PKHA koalas, translocation seems an essential component of any conservation strategy. We would not normally support translocation as an appropriate measure in situations where conflicts arise
between habitat requirements and development. However, given the extent of habitat clearing expected to occur in the study area over the next few years and the likely number of animals involved, a translocation program appears not only to be essential, but also the appropriate moral and ethical response. Otherwise, the majority of the current source population(s) will be displaced and almost certainly eliminated. Hence we consider it crucial to “rehome” as many of these animals as possible if the population is to be effectively managed for sustainability in the longer term. A review of the literature concerning koala translocation programs is provided in Appendix III, along with a draft set of protocols to assist the process. A source of funding to enable this component of the strategy will need to be identified.

Also necessary will be measures that minimise overall adverse impacts arising from ongoing habitat clearing and the eventual transformation of the existing UKA into what will ultimately become a largely residential area. Inter alia, such measures include the need for an informed (as opposed to ad hoc) and landscape-based approach to the matter of identifying and consolidating habitat areas, and making provision for corridor and/or linkage areas that allow egress of koalas and other wildlife from the area. A more detailed discussion of these and other relevant measures is provided for consideration in Appendix IV.

The Preferred Response
This section outlines our preferred conservation and management response to the issues we have raised in this report and is based on the premise of a long-term objective to establish and sustain a MVP of koalas within the KCA component of the C-PKHA. To this end we have attempted to both categorize and prioritize our recommendations in the form of a three-staged approach which must, by necessity, incorporate a temporal component. Our determination of this latter consideration is based on the underlying assumptions:
1. That koala habitat in the IDF will be lost in the next 12 – 24 months, resulting in an overall reduction in the carrying capacity of the C-PKHA generally, along with the displacement of up to 140 koalas;
2. further development within the UKA will proceed over the following 10 – 15 years, resulting in a further highly significant loss of koala habitat and the ongoing displacement of animals; and
3. that despite the potential for adoption of best practice koala conservation measures within the SDF, its ability to support and/or sustain a viable koala population will be inexorably compromised by an unsustainable incidental harvest.

We have used the term “securing” in the recommendations that follow in deference to the need to be able to guarantee habitat outcomes for koalas in each of the key areas we have identified in Figure 9, the basis for which are in general accord with recently developed guidelines and principals (Appendix V). In an ideal world, we would hope for a supportive and widespread community response to matters such as this, in which case the notion and application of Voluntary Conservation Agreements would appear an ideal solution. Moreover, we believe that it will not be possible to achieve a meaningful outcome within the KCA generally without a significant measure of community support and involvement with habitat embellishment programs, which will otherwise be a key requirement for those engaging the VCA process. Having said this, the task ahead also requires a large central habitat area to be created which for all intents and purposes must be singularly devoted to koala conservation. For this to be realized, we submit that lands comprising the identified primary and secondary habitat areas ideally need to be formally acquired in order to effectively provide for security of tenure and to confidently enact the necessary restoration works.
Recommendations
Stage 1 (Time frame: 2007 – 2009)

Recommendation 1:
Secure primary habitat areas identified in Figure 9.

Recommendation 2:
Commence translocation of koalas from IDF area to vacant and secured habitat areas in KCA and elsewhere in LGA in accord with EPA approvals and the experimental protocols detailed in this report.

Recommendation 3:
Prepare restoration management plan and initiate habitat restoration works in Pimpama Wetlands Conservation Reserve.

Recommendation 4:
Prepare restoration management plan for primary habitat area.

Recommendation 5:
Investigate the potential to transfer development rights from Lot 74W31402 to Lot 1RP55470 and reclassify these landholdings as KCA and UKA respectively; secure Lot 74W31402.

Recommendation 6:
Investigate options to secure the permanent protection of the remainder of Lot 1SP150729 to the west of the existing portion of the KCA adjoining the Coomera Waters Estate.

Recommendation 7:
Ratify and implement koala guidelines for remainder of UKA as detailed in Appendix IV.
Fig.9. Lands to be secured
Recommendation 8:
Initiate discussions with landholders in identified VCA areas, seeking broad agreement to increase vegetation cover through planting of preferred koala food trees and minimizing other perceived threats.

Stage 2 (Time frame: 2009 – 2012)

Recommendation 9:
Secure secondary habitat area(s) identified in Figure 9.

Recommendation 10:
Initiate habitat restoration works within secured primary habitat areas.

Recommendation 11:
Develop restoration management plans and initiate habitat restoration works within secured secondary habitat areas.

Recommendation 12:
Subject to a review of results arising from Recommendation 2, translocate additional animals from within affected areas of UKA to vacant and secured primary and/or secondary koala habitat areas in KCA or elsewhere in LGA as required.

Recommendation 13:
Review efficacy of koala management guidelines for UKA and amend if necessary.

Recommendation 14:
Continue discussions with landholders in identified VCA areas.
Stage 3 (Time frame 2012 – 2016)

Recommendation 15:
Continue liaison and/or discussions with landholders in identified VCA areas.

Recommendation 16:
Continue habitat restoration works in secured primary and secondary habitat areas as required.

Recommendation 17:
Re-assess population size and distribution/extent of koala meta-population cells within the KCA.

Recommendation 18:
Assess suitability of habitat restoration works in secured primary and secondary habitat areas to receive additional koalas.

Recommendation 19:
Translocate additional animals from within affected areas of UKA to vacant and secured primary and/or secondary koala habitat areas in KCA or elsewhere in LGA as required.

A simplified timeline for implementation of the preceding recommendations is presented overleaf. We thus look skywards, cross our fingers and entrust this report, its recommendations and ultimate implementation to Council.

“Hito yori sosenshi kodo suru koto”
Table 1. Approximate timeline(s) for tasks required over the ten year timeframe envisaged as necessary to realise the underlying objective of the C-PKHA Koala Conservation Strategy. Associated recommendation numbers are shown in brackets.

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<td>Clearing of IDF</td>
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<td>Investigate alt land use options (5/6)</td>
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<td>Ratify management guidelines (7)</td>
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<td>Rehab plan for Primary Habitat Area (4)</td>
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<td>Clearing of SDF</td>
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<td>Re-assess KCA popn size and distn (17)</td>
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<td>Translocation of koalas from SDF (12,19)</td>
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<td>Establish VCAs (8,14,15)</td>
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References


Brett, K. 2004. Tree selection and habitat use by koalas translocated to the Pimpama Wetlands Conservation Reserve. 3rd Year Final Project. School of Environmental and Applied Science, Griffith University, Gold Coast.


IUCN 2006. The IUCN Position Statement on Translocation of Living Organisms; Introductions, Reintroductions and Re-Stocking, approved by the 22nd Meeting of the IUCN Council, Gland, Switzerland, 4 September 1987.


McAlpine, C.A., Rhodes, J.R., Callaghan, J., Bowen, M., Lunney, D., Mitchell, D., Pullar, D., Possingham, H.P., 2006c. The importance of forest area and
configuration relative to local habitat factors for conserving forest mammals: A case study of koalas in Queensland, Australia. *Biological Conservation* **132**: 153 -165.


..........................................................
### Appendix I - Baseline PVA parameters

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<th>PVA Parameter</th>
<th>Value</th>
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<td><strong>Scenario settings</strong></td>
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<td>Number of iterations</td>
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<td>Number of years</td>
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<tr>
<td>Extinction definition</td>
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<td>Maximum age for reproduction</td>
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<td>Maximum number progeny per year</td>
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<td>Sex ratio at birth (in % males)</td>
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<td>EV in % breeding</td>
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<tr>
<td>% females producing 1 offspring</td>
<td>Normal</td>
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<td>(of those producing progeny)</td>
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<td><strong>Mortality rates</strong></td>
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<td>Mortality of females aged 0-1 (%)</td>
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<td>Mortality of females after age 2 (%)</td>
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<td>Mortality of males after age 4 (%)</td>
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<td>Frequency (%)</td>
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<td>Reproduction severity</td>
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<td>Survival severity</td>
<td>0.75 (= 25% mortality)</td>
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<td>Stable age distribution</td>
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<td>% of population harvested</td>
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* indicates parameters modified in subsequent scenarios
Appendix II

Estimating offset requirements for the UKA component of the C-PKHA if treated as a KCA for the purposes of determining suitable offsets.

The total area within the UKA is 1035ha, of which 843ha would be considered high suitability habitat (hsh), with the remaining 192ha considered medium suitability habitat (msh). The following offset calculations assume that within the next few years ~ 80% of this habitat will be permanently removed for development. This equates to the loss of ~ 674.4ha of hsh and ~ 153.6ha of msh. The Residual Habitat Impact (RHI) associated with this loss would be: 674.4 x 1.0 (hsh) x 1.0 (permanent loss) = 674.4 habitat units plus 153.6 x 0.7 (msh) x 1.0 (permanent loss) = 107.52 habitat units. Thus, a total RHI of 781.92 habitat units (where habitat units = the area of habitat in hectares x habitat suitability weighting x time lag weighting). Now, given that the required value of an offsets package should total at least 1.5 times the value of the RHI for that proportion comprising high quality habitat measures, the total required offset in this case would be 1.5 x 781.92 = 1172.88 habitat units (in this case hectares). Therefore, the offsets package would need to secure the protection of 1172.88 ha of equivalent hsh within adjoining areas (preferably adjoining Koala Conservation Areas), or part hsh and part habitat restoration (whereby 2 habitat units of habitat restoration would be required for each habitat unit to be offset by this means).

In order to be treated as offsets for the purposes of the Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016, habitat measures require either securing the permanent protection of habitat that may otherwise be cleared, or improving habitat values through restoration of previously cleared but otherwise secure lands. As outlined in the Koala Conservation Plan, permanent protection of offset areas could be achieved by a number of means including: i) protection by Covenant under the Land Act 1994 or Land Title Act 1994; ii) Conservation Agreement under the Nature Conservation Act; iii) declaration under the Vegetation Management Act as high conservation value; iv) gifting the area to the state or local government for inclusion in the protected area or parkland estate. However, in
some cases it may be necessary for high priority conservation areas to be bought for conservation purposes by either voluntary or compulsory acquisition.
Appendix III

Translocation

The IUCN defines translocation as the movement of living organisms from one area with free release in another (IUCN 1987).

Animal translocations have become a popular tool in wildlife management and are increasingly used in an attempt to resolve a number of issues facing managers. In a review of documented translocation projects worldwide, Fischer and Lindenmayer (2000) identify three main categories of reasoning for animal translocations: to solve human-animal conflict, to supplement game populations, and conservation. Their review included international projects involving a variety of taxa of which approximately half were carried out for conservation purposes. They concluded that the success rate of translocations in general is poor, and is particularly low in Australia across all taxonomic groups. Translocations undertaken to resolve human-animal conflict were largely unsuccessful due to a number of factors including predation, post-translocation mortality and homing behaviour. The success of translocations for conservation purposes tended to vary depending on a number of factors including location of the source population, use of supportive measures and the number of animals released (Fischer and Lindenmayer 2000). In general however there is a shortage of documentation following translocation exercises and therefore success is difficult to gauge (Fischer and Lindenmayer 2000). This reflects a lack of standard assessment tools for gauging the success of translocations, which also means that managers lack the comprehensive information needed to inform them of the success or otherwise of translocation projects.

Koalas present a number of challenges for translocation programs; they are a specialised folivore and thus the area selected for translocation must ideally contain identical food tree species to that from which the animals are sourced. Koalas are also highly site philopatric and will exhibit homing behaviour if released close to their original home range areas. The combination of site
philopatry and koala socio-biology also dictates a need to consider whether there is another population already resident within the selected release site; if so then ejection from the release area will be swift. Conversely, it is also important that other koalas occur in the general area.

*Extent of use*

There is a long history of koala translocation in Australia’s south. Much of the widespread distribution of koalas throughout Victoria, South Australia and islands off the south coast of Australia is attributable to translocations (Martin and Handasyde 1990; Phillips 1997). Koala populations on Kangaroo Island off South Australia, French Island, Phillip Island and Sandy Point in Victoria are the result of translocations as early as the late 1800s while translocations from islands to the mainland have been and are carried out with animals sourced from French, Phillip and Quail Islands (Backhouse and Crouch 1990, Martin and Handasyde 1990).

There is little published data on translocation events in Queensland and in most instances only a small number of animals have been involved. Ellis *et al.* (1990) monitored the movements of four rehabilitated koalas released into unfamiliar habitat while other work has focused on similarly small numbers released into the Coombabah Conservation area and other areas of the Gold Coast Hinterland (Dr. Jon Hangar *pers comm.*). Most recently, a small number (n=5) koalas were translocated from a development site at Harbourtown near Biggera Waters, to the Pimpama Wetlands Conservation Reserve. The significance of this latter project is that it included a pre-translocation habitat assessment (Phillips *et al.* 2003) which established the suitability of habitat and the absence of koalas from the selected area, and the use of a soft-release protocol which essentially confined the animals to a selected food tree for several days. Post-release monitoring of these animals using radio tracking established that initial movements of animals following their egress from the soft-release enclosure focused on finding food trees, whereafter additional (non-food) species were increasingly selected (Brett 2004). Monitoring of the habitat into which these animals were released (Phillips and
Pereoglou 2004, 2005) as well as assessments in 2006 have confirmed the continued presence of the study animals within the nominated release area.

**Issues associated with koala translocation**

The current status of koala populations established as a result of past translocation exercises indicate that complex processes regulating koala populations have historically been overlooked or ignored and that the simple movement of animals from one area to another does not guarantee establishment or maintenance of a self-sustaining population. The apparent success of population establishment in some of the aforementioned cases is attributable to repeated translocations to the same location over time. The koala population in the Brisbane Ranges area of mainland Victoria was established after five separate translocation events spanning 33 years (Martin and Handasyde 1990). Similarly, a koala population on Phillip Island was established through at least three separate translocation events in the 1870s, 1923 and 1983 (Backhouse and Crouch 1990, Lee et al. 1990). Additionally, translocation of animals to the mainland from islands has been so common that an issue now faced by managers is the lack of habitat remaining for release of translocated animals (Lee et al. 1990).

Koalas live in polygynous social groups which consist of overlapping home ranges ordered by a male-dominance hierarchy (Lee and Martin 1988, Mitchell 1990). Within each social group, one alpha male is responsible for defending a territory of feed trees and the females it supports (Mitchell 1990, Phillips 1997). Translocation of koalas into an area already supporting koalas has the potential to either disrupt the social structure of the existing group, or conversely, to result in structural breakdown of the source population (Phillips 1997). A local example of such a case was reported from Tucki Tucki in NSW where the rapid decline of a koala population was attributed to translocation of a (small) number of koalas from the area (Phillips 2000).

In many cases, populations established as a result of translocation have been subject to ongoing intensive management to maintain numbers at sustainable levels (Backhouse and Crouch 1990). In the cases of French Island, Sandy
Point and Kangaroo Island koala populations, removal and/or sterilisation of animals is now undertaken in an attempt to maintain population densities at ‘suitable’ levels.

**Individual**

Dispersal from release sites is widespread post-translocation (Prevett 1991, Phillips 1997) and is considered to be a contributing factor in some failures to establish populations after translocation (Lee et al. 1990, Phillips 1997). Forced dispersal of koalas new to an area will be instigated by resident dominant males (Mitchell 1990). This limits the translocated animal’s potential to breed successfully and exacerbates the stress that may otherwise be experienced.

On an individual level, translocation exercises (those whose results are readily available) consistently report deaths of substantial proportions of those koalas involved in the translocation. Lee et al. (1990) and Santamaria (2002) report mortality rates of 13% and 23% respectively of koalas translocated from French Island to the mainland. The death of one animal (from a sample of 5) during a translocation program on the Gold Coast was attributed to the stress of repeated capture and translocation (Phillips and Pereoglou 2004-5). Mortality rates of translocated animals in most cases are greater than that observed in natural populations. Mortality is commonly attributed to the stress associated with capture and translocation, however translocated animals’ risk of predation is also higher due to the need to come to the ground more often whilst familiarising themselves with the release area (Phillips 1997). Unfamiliarity with the release site may exacerbate stress and in some cases may have led to starvation (Lee et al. 1990, Santamaria 2002). High mortality is also observed in dependent young following translocation (Lee et al. 1990, Phillips 1997). There is also an apparent reduction in fecundity of females following translocation (Lee et al. 1990, Santamaria 2002).

It must be noted here that a large proportion of animals involved in translocation projects in the southern states and islands are animals sourced from Chlamydia-negative populations (Phillips 2000). Stress associated with
capture and translocation is likely to manifest itself in the expression of symptoms associated with chlamydial infection and subsequently increase mortality rates when carried out using animals sourced from Chlamydia-positive populations (Phillips 2000).

Mortality rates reported in the literature are likely to be under-estimates as monitoring of animal translocations post-release is usually short-term if carried out at all. Radio-transmitter failure is also cited in most cases (ranging from seven to 42 percent of monitored animals) Decreasing the (Lee et al 1990, Santamaria 2002, Phillips and Pereoglou 2004-5). Reports from post-translocation monitoring indicate that dispersal of animals from release sites out of the range of radio-telemetry is common (Lee et al 1990, Prevett 1991, Phillips 1997), thus increasing the difficulty in ascertaining the fate of some individuals.

**Overall**

Overall, few studies report the outcome of translocations as unequivocal successes, citing the influence of factors such as weather conditions and the presence of back/pouch young in females (Lee et al. 1990) and additional stress associated with large dispersal movements on the subsequent health and survival of koalas after translocation (Prevett 1991). The *ad-hoc* nature of historical translocation exercises has in general not resulted in self-sustaining koala populations but rather created ongoing management problems for managers and the unnecessary stress and death of a large but unknown number of koalas. Though rarely undertaken, intensive radio-tracking exercises are required to provide the monitoring effort necessary to assess the success or otherwise of koala translocation exercises.

As detailed in the dot points below, the IUCN/SSC (2006) advocates a strong policy and associated guidelines relating to translocations in general. They recognise that a large amount of time, money and rigorous scientific grounding is required for translocation projects.
• The availability of suitable habitat needs to be addressed adequately both in terms of the species' requirements but also political constraints to the short- and long-term viability of the habitat.

• Previous causes of decline must be ascertained and eliminated in the release area and any restorative work required must be initiated before reintroduction is carried out.

• Removal of individuals must not endanger the wild source population.

• Design of each translocation must be in the form of a scientific experiment with the collection of adequate pre- and post-release monitoring data to enable testing of the methodology.

• Demographic, ecological and behavioural studies of released stock must be undertaken.

• Study of processes of long-term adaptation by individuals and the population.

• Collection and investigation of mortalities.

• Interventions when necessary.

• Decisions for revision, rescheduling, or discontinuation of programme where necessary.

• Habitat protection or restoration to continue where necessary.

• Continuing public relations activities, including education and mass media coverage.

• Evaluation of cost-effectiveness and success of re-introduction techniques.

• Regular publications in scientific and popular literature.

The Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016 (EPA 2006) states that translocation will not be approved for the removal of animals in areas undergoing development and will be considered only for scientific endeavours. Translocations into other areas must demonstrate that a viable population is able to be sustained in the target
area. Further, the guidelines that translocations must follow reflect those of the IUCN.

As argued elsewhere in this report, we consider the need for a translocation program to be a vital component of any meaningful conservation strategy for the C-PKHA. Moreover, the current level of knowledge regarding both the practice of translocation and the current distribution of resident koala populations within the C-PKHA allows us to move with greater certainty and confidence in terms of predicting likely outcomes. Unfortunately, the extent of remaining habitat within the KCA that is currently capable of supporting koalas is limited to two key areas. The first of these – the Pimpama Wetlands Conservation Reserve – has about 80 hectares of suitable habitat that is currently unoccupied (i.e. outside of redline areas). If we apply our overall C-PKHA koala density estimate of 0.23 koalas/ha, then no more than 20 animals could theoretically be translocated to this location. A further 100ha (approx) of similarly suitable habitat on what are currently freehold lands in the centre of the KCA are also not currently being utilised by koalas, hence an additional 25 could be translocated to this location. Beyond this number of animals, translocations would need to occur outside of the C-PKHA, presumably to other areas west of the M1 Pacific Motorway.

The number of animals potentially available for translocation and the existing knowledge regarding translocation practice and procedures suggest that the basis for a rigorous scientific experimental design could be developed along the following lines:-

1. That the basis of the experiment be a comparison of survivorship, tree selection and movement patterns by koalas translocated using 3 different release protocols (Soft release – vacant; Hard release – vacant and Hard release - random).
2. Koalas selected for translocation will be randomly selected from resident populations within the IDF in the first instance.
3. The minimum number of koalas to be monitored in each instance will be no less than 20 animals comprising 10 males and 10 females.
4. Capture protocols must be in accord with best practice measures requiring the use of experienced koala researchers and ACEC approved capture and transport techniques.

5. All captured animals must be sampled for underlying disease and be subjected to full health assessment by a qualified veterinarian or other suitably experienced researcher prior to translocation.

6. Translocation must take place within 2 - 3 hours of initial capture.

7. Koalas translocated to areas of suitable but vacant habitat within the adjoining KCA must be confined to a temporary holding facility constructed around the selected release tree (that is also a preferred koala food tree) for a minimum of 7 – 10 days (Soft release - vacant).

8. Koalas translocated to areas of suitable habitat outside of the C-PKHA must be released into a preferred koala food tree that is located no less than 15kms from the western boundary of the C-PKHA (Hard release – vacant/Hard release - random).

9. The movements and survivorship of koalas affected by 7 and 8 above must be monitored by radiotracking for a minimum of 12 months following translocation, commencing every 1 – 2 days for the first month following release and thereafter weekly.

10. Upon completion of the radiotracking component, the health and disease status of all remaining animals must be established in accord with 5 above.

11. Results of the study must be submitted for publication in a peer-reviewed scientific journal within a 6 month period following completion of the project.
Appendix IV

Recommended Koala Protection Measures for Future Development Applications in the UKA component of the C-PKHA

This section refers to *Policy 1: Koala sensitive development* of the *Nature Conservation (Koala) Conservation Plan 2006 and Management Program 2006-2016* and outlines measures that we consider appropriate within the UKA portion of the C-PKHA.

1. Pre-planning

If the retention of areas of native forest is possible, such areas should be selected in conjunction with adjoining development areas in order to avoid retention of small, isolated habitat patches but instead to maximize habitat quality and landscape connectivity values. Ideally, habitat protection areas should seek to embellish already designated habitat link-corridor areas and large blocks of protected habitat, particularly those within or adjoining the KCA, and should focus on redline areas so that carrying capacity of the UKA generally is maximised. The permanent protection and ongoing management needs of such consolidated habitat protection areas should ideally be addressed through a Voluntary Conservation Agreement.

Figure 11 illustrates a hypothetical corridor-linkage system for the UKA that, with the inevitable wisdom of hindsight, may have gone some way towards ameliorating the current conservation dilemma now being considered. While the likelihood that some elements of this network might be retrospectively applied within the IDF is no doubt overly optimistic, we respectfully submit that it is not yet too late. Outside of the IDF though, some consideration should be given to implementing the measures as illustrated, assuming a minimum width of 50 – 100m in each instance.

Additional to the above, koala sensitive development and design measures within minimum 50m wide zones (defined by practical boundaries such as streets) could also be implemented wherever residential development adjoins
Fig. 10. Hypothetical corridor network

Habitat linkage
- IDF
- Koala Conservation Area
- Urban Koala Area
the outer edge of consolidated habitat protection areas such as those alluded to above. Development and design measures should include:

- Retention of preferred koala food trees.
- Consideration of larger lot sizes (e.g., 2000 m²).
- Prohibition on the keeping of domestic dogs.
- Incorporation of 300 mm gaps under fences to minimise restrictions to koala movement.
- Restriction of traffic speeds to 40 kph (or less) throughout the 50m wide buffer zone, using vehicle calming devices to mitigate speed wherever practicable.
- Requiring the use of wildlife exclusion fencing and regularly spaced underpasses along arterial roads, particularly where such roads traverse corridors and/or habitat linkage areas.
- Locating all through roads outside the 50m buffer zone.
- Ensuring that swimming pool fencing is designed and positioned to keep both small children and koalas safely out.
- Direction of street lighting downwards and away from the edge of habitat protection areas.
- Ensuring that all bushfire asset protection and other buffering requirements are met outside consolidated habitat protection areas.

Measures may also require the preparation and implementation of vegetation-habitat management and restoration plans for all consolidated habitat protection areas. Options for seeking developer contributions for compensatory habitat protection and/or restoration measures should also be fully explored.

2. Koala management during clearing and construction operations

- The retention of preferred koala food trees should be maximized during the course of initial clearing activities, thus ensuring that essential food resources are retained, if only for the short term.
- koalas spotted during clearing activities should not be disturbed and otherwise afforded a minimum 50m buffer.
- Koalas spotted during clearing activities must be allowed to leave the area of their own volition.
Appendix V
Prioritising habitat areas for protection

The following considerations are based on “Planning Guidelines for Koala Conservation and Recovery - a guide to best planning practice” currently being finalised by the University of Queensland, Australian Koala Foundation and the NSW Department of Environment and Conservation) (McAlpine et al. 2006a). While we have not specifically applied these considerations to the task of developing a conserving strategy for koalas in the C-PKHA, they nonetheless provide justification for the actions we have recommended and are provided here for information purposes.

i) **Habitat Thresholds.** Evidence from research in Noosa Shire has indicated that the probability of koalas being present falls as the percentage of the landscape containing forest communities (including preferred koala habitat) falls below ~ 40% to 60%. These percentages provide useful overall targets for habitat protection and restoration.

ii) **Patch size.** Evidence from fragmented coastal landscapes in Noosa Shire indicated critical patch size requirements, with koalas 50% less likely to be present in patches less than ~ 50 ha in size. There was also some evidence to suggest that the chance of koalas being present starts to decline once patches become smaller than ~ 150 ha. Hence, priority should be given to protecting patches of preferred koala habitat larger than ~ 50 ha in size, unless part of a cluster of highly connected patches.

iii) **Patch shape.** Habitat patches should ideally be more circular than linear in shape in order to minimise edge effects. Edge effects might affect koalas by, for example, increasing the risks of predation by roaming dogs or decreasing the health of preferred food trees. As habitat patches become smaller, the amount of edge, relative to the area of each patch (the perimeter-area ratio) increases. Therefore, small patches are generally more subject to edge
effects than large patches. For a given patch size, the amount of edge is smallest for a circular shape, but largest for a narrow linear shape.

iv) **Connectivity.** If habitat patches are close enough to each other for koalas to move freely between them they may be adequately connected for koalas, providing there are no major barriers such as roads, fences, or significant threats such as wild dogs, roaming domestic dogs or traffic. In general, koalas would be expected to undertake regular home range movements between habitat patches if they are separated by distances no greater than ~ 100 m and provided there are no significant barriers or threats. Although koalas are relatively mobile, isolation of patches can be an important predictor of koala occurrence, with koalas more likely to occur in patches close to other patches than in isolated patches. Programs to maintain or enhance connectivity should aim for a network of larger habitat patches linked by corridors at least 100m wide, but preferably wider to minimise edge effects.

Small populations that are highly isolated tend to suffer much higher extinction risks than populations that are connected to each other via animal movement. Immigration or recruitment into a population can provide a ‘rescue’ effect and can help maintain genetic diversity. The survival of meta-populations (a group of sub-populations connected by dispersal) relies on the ability of animals to recolonise habitat patches where a sub-population has become locally extinct. Whilst habitat patches that are further apart are often considered less connected than patches close together, connectivity also depends upon the nature of the matrix (i.e. the most extensive landscape element, generally cleared areas between vegetated patches in highly fragmented landscapes), and the existence of barriers to movement.

v) Priority should be given to **restoration programs** intended to enlarge the size of remnant koala habitat patches that are close to or smaller than 50 ha, with the aim of increasing their size and improving connectivity. Lower priority should be given to revegetation of areas adjacent to very small (less than 2 ha in size) habitat patches. Restoration programs should consider the shape of the area being revegetated and avoid constructing narrow linear patches.
vi) It is likely that lower quality categories of koala habitat perform important buffering functions, as well as providing supplementary food and shelter resources and habitat connections. Hence the presence of lower quality habitat should not be disregarded when selecting locations for habitat corridors.

vii) Emphasis should be placed on the need to **maintain ecological integrity** of protected habitat areas. Priority should be given to contiguous areas of preferred habitat, particularly those that are known to contain koalas. However, the apparent absence of koalas should not preclude the protection of such areas as koala populations may establish over time and such areas may be a critical resource for the recovery of local populations.