University of Southern Queensland

Faculty of Engineering and Surveying

Prioritising Locations for Investment Based on Threats to Reptiles and Ecosystems within the Condamine Catchment

A dissertation submitted by

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ABSTRACT

The biodiversity of the Condamine Catchment is constantly under threat from various sources and with varying impact. Site and road maintenance, inappropriate grazing and fire regimes, clearing of vegetation, weeds and feral animals present threats to reptiles. In the past 200 years 60% or 13 million hectares of the original vegetation has been cleared.

To ensure no further loss of biodiversity, priority locations for investment need to be identified for identification and abatement of threats. This project aims to locate and quantify such places within the Condamine Catchment, as they relate to threatened reptile colonies. Representing less than 2% of total sightings, reptiles account for 13% of the species identified as threatened.

The methods in this study represented an effective way of taking point data, in this case sightings of threatened reptiles, in a catchment and by applying Boolean logic in a GIS, mapping polygon locations of interest. Available data was in the form of shapefiles in format useable by ArcGIS and Excel tables.

The selected vegetation communities relating to reptile sightings totalled 40,887 hectares in area, of which 27,889 hectares also contained other non-reptile endangered, vulnerable or rare species. These vegetation communities are recommended to be priority locations for future investment in threat abatement.

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ENG4111 Research Project Part 1 &
ENG4112 Research Project Part 2

Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

28 October 2010

Date

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Jayne Thorpe and Lucy Richardson of Condamine Alliance provided the initial impetus for the project, advice concerning the scope, direction and ongoing relevance of the study and access to significant datasets. Their contribution was invaluable.

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ABBREVIATIONS

ASDD	Australian Spatial Data Directory
CA	Condamine Alliance
CCMA	Condamine Catchment Management Association Inc
DCDB	Digital Cadastral Data Base
DEM	Digital Elevation Model
DERM	Queensland Department of Environment and Resource Management
DEWHA	Australian Government Department of the Environment, Water, Heritage and the Arts
DoSS	Degree of Site Suitability
EPBC	*Environment Protection and Biodiversity Conservation (Act 1999)*
ESA	Ecological Society of Australia
GIS	Geographic Information System
IUFRO	International Union of Forest Research Organizations
MDBA	Murray-Darling Basin Authority
MDBMC	Murray-Darling Basin Ministerial Council
NCA	Queensland Nature Conservation Act 1992
NRM	Natural Resource Management
PLS	Partial Least Squares regression
QBB	Queensland Brigalow Belt
RE	Regional Ecosystem
SDI	Spatial Data Infrastructure

SLATS	Statewide Landcover and Trees Study
TRC	Toowoomba Regional Council
USQ	University of Southern Queensland
VMA	Queensland Vegetation Management Act 1999

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CHAPTER 1

INTRODUCTION

1.1 Introduction

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This project seeks to investigate threats to reptile species and ecosystems within the Condamine Catchment, analyse these spatially and prioritise investment locations accordingly using a GIS.

The Condamine Catchment (or NRM region) in south east Queensland is part of the Southern Brigalow Belt Bioregion which extends south to the border of New South Wales. It is known as a "hotspot for reptiles" however in the past 200 years 60% or 13 million hectares of the original vegetation has been cleared (Wilson 2003).

The excesses of land clearing in Queensland particularly since World War ll and the frenzied clearing of 1999 when over 1 million hectares of bushland was cleared by landholders seeking to beat new laws are well documented (The Wilderness Society 2009).

Since the Queensland Government ended broadscale remnant clearing on 31 December 2006 there has been a decrease in annual clearing of woody vegetation. In fact there was 48% decrease in the first year of the new legislation (DERM 2010i, McGrath 2007).

There is now an opportunity to assess the impact of current threats to reptiles and to invest in what remnant vegetation that remains to ensure no further loss of biodiversity. As part of that process it is necessary to quantify the regional ecosystems that support reptilian habitat and find priority locations for investment.

Two of the reptiles studied, the golden-tailed gecko and the brigalow scaly-foot are endemic to the bioregion and therefore important to the Condamine Catchment. Since all five of Australia's lizard families, four of the six snake families and one of the four turtle families (the others are found in marine environments) are found in the Southern Brigalow Belt it is safe to assume that any efforts to remove threats to the reptiles at risk and preserve their habitats will have a flow on positive effect on the total biodiversity of the region (Wilson 2003).

1.2 Statement of the Problem

The biodiversity of the Condamine Catchment is constantly under threat from various sources and with varying impact. Threats identified to reptiles include but are not limited to site maintenance, road maintenance, inappropriate grazing and fire regimes, clearing of vegetation, weeds and feral animals (Condamine Alliance 2010).

With diverse threats to numbers of reptile and other significant species the allocation of resources for abatement becomes important. What are the priority locations for investment and what is their extent within the Condamine Catchment?

The Condamine Catchment Management Association stated in 2009 that “There has been no detailed and systematic survey of fauna or flora within the catchment”. A wide range of birds, frogs, reptiles and mammals have been described by specific studies. It was recognised at that time that there were seven reptiles (e.g. Yakka skink), six birds (e.g. Powerful kite) and one frog species (Red and yellow mountain frog) that were classified as rare in the Catchment (CCMA 2009). The recent “Back on Track” study by Condamine Alliance / DERM identified six threatened reptiles including two that are regarded by the agencies as critical or high priority (the endangered long-legged worm-skink included in this study and the rare border thick-tailed gecko for which no sighting data was available)(DERM 2010b). It is clear that more research into threatened species is warranted. For current threat abatement strategies it is suggested the above document is the best starting point.

1.3 Rationale of the Study

Sightings of threatened species within the study area have been collated by Queensland Herbarium, WildNet and others over the past decade and more. Datasets also exist of land use and remnant vegetation throughout Queensland.

Recent research in the Condamine Catchment has resulted in publication in 2010 of "Actions for Biodiversity" under the Queensland government initiative "Back on Track" (DERM 2010b). Threat abatement actions towards maintaining and enhancing biodiversity are discussed there. In harmony with that work this research introduces the simple but powerful capability of a GIS to analyse current data spatially to try to provide some links between known reptile habitats and regional ecosystems. By applying various filters such as proximity to roads, vulnerability of vegetation communities and potential threats, priority locations for investment may be chosen based on threats to species and ecosystems. Such recommendations are made in Chapter 6.

1.4 Objectives

To identify and recommend priority locations within Condamine Catchment for future investment in threat identification and abatement for species and ecosystems with focus on reptiles.

1.5 Scope and Limitations

Study Area (see chapter 3.3) was limited to the Condamine Catchment. From datasets of species sightings, only those considered endangered, vulnerable or rare were studied. The study was further restricted to reptiles although other species at risk which had been sighted within the same regional ecosystems were noted.

Regional ecosystems were defined by Sattler and Williams (1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil (DERM 2010e).

Under the Queensland Vegetation Management Act 1999 (VMA) regional ecosystems (REs) are classed as of Least Concern, Of Concern or Endangered. Similarly, the Biodiversity Status of an RE is classified as of No Concern at Present, Of Concern or Endangered.

From vegetation mapping of the study area, only those vegetation patches in REs considered remnant and in proximity to reptile sightings were selected. Their VMA Class and Biodiversity Status were recorded.

The GIS used for the project was ESRI ArcGIS 9.3.1. Spatial Analyst extension and Arc Toolbox were available and useful.

Time constraints due to scheduling of phased completion of the project to suit University of Southern Queensland deadlines and minor limitations due to resources available to students dictated the scope and limitations of the study.

The methods used, results obtained and conclusions made relating to threatened reptiles could be transferred to other threatened species within the study area and may be avenues for future research.

1.6 Dissertation Organisation

The first chapter introduces the topic for research, its aims and objectives. The rationale for the study is presented.

A literature survey follows in chapter 2 with sections devoted to clarifying prior work, defining legislative requirements and constraints, an outline of current investment strategies, identifying alternative spatial analysis methods, defining and evaluating threats to species and ecosystems, and miscellaneous literature.

Chapter 3 deals with the research methodology and design. The study area is described. The roles of stakeholders are briefly summarised to provide a context for the project. The methods used from data selection and acquisition to collation of results and validation are detailed here. The use of a GIS as the primary means of visualising, analysing and presenting the data is recognised and described.

Chapter 4 is devoted to the results from the study. The reasons why reptiles were chosen as the focus species is explained. Similarly the choice of vegetation communities near to sightings of threatened reptiles is justified, giving study results which strengthened inclusion of selected ecosystems. Specific threats to reptile species are outlined and the influence of wildlife havens such as reserves and National Parks is presented. The ecotone edge effect is briefly mentioned.

Chapter 5 is a discussion of the results. Results are interpreted in the light of the data available. Some comments are made on the currency and accuracy of the datasets and their adequacy for the task.

The GIS model used for the project is validated, strengths and weaknesses presented and options for future study considered.

The final chapter presents the conclusions and recommendations of this project. Recommendations are made in two categories: recommendations for practical applications and recommendations for future research.

The dissertation concludes with appendices, references and bibliography.

CHAPTER 2

LITERATURE SURVEY

2.1 Introduction

The purpose of this review was to establish the premise for the project, viz. to clarify prior work, to define legislative requirements and constraints, to define and evaluate threats to species and ecosystems, to outline current investment strategies and to identify alternative spatial analysis methods for the project.

Figure 2.1: *Dalrymple Creek, Goomburra State Forest.*

2.2 Clarifying Prior Work

Personal communication with Jayne Thorpe, Condamine Alliance, established the scope and eventual breadth of the project, i.e. which species and ecosystems were selected. This depended on the outcomes as they developed, since a major focus was to prioritise for funding, which became apparent after analysis.

A pre-publication copy of “Back on Track” (DERM 2010b) reveals major threats to priority species and actions to address them. The naming and localising of specific threats, the outlining of current actions and the listing of potential contributors for implementation as well as the document’s currency, make this a valuable resource.

Richardson (2008) describes a reptile recovery plan for the Queensland Brigalow Belt which identifies 16 species under threat and proposes a 24 point management plan. This document lists the many stakeholders who may be involved in the management of threatened reptiles, lists potential benefits to other non-threatened species in the QBB and describes the microhabitat requirements specific to individual reptile species. It is a helpful document for clarifying prior work.

Lower than average rainfall in recent years has seen widespread tree decline in riparian woodlands. Associated with this has been weed infestation *Lippia canescens* (Reardon-Smith, K et al. 2005). This threat appears to be increasing and was considered for the project.

Native rodents have a role in seed dispersal and predation of the Bunya Pine (Smith, IR et al. 2005). This paper was useful; however it is not readily available other than in abstract form. Efforts to obtain this article were unsuccessful.

Prioritising investment locations necessarily assumes known economic and community / social values for existing ecosystems. Maraseni et al. (2005) wrote a thought-provoking paper discussing the valuation of ecosystem services from forests. They argue that total goods and services from forests are undervalued when non- marketed goods are not valued. They report on the development and testing of a method for evaluating the net benefits from forest that

> *incorporates primary data on carbon sequestration rates, and biodiversity and soil conservations values*.

This approach is more inclusive than traditional valuations and is worthy of close consideration.

Introduced weeds are a significant threat to native vegetation and there are a number of papers available, one of which by Readon-Smith et al. (2004) is available from USQ in hardcopy only.

Murray-Darling Basin Ministerial Council (2001), *Basin Salinity Management Strategy 2001-2015* is an example of communities and governments working together to control salinity and key natural resource values within their catchments. Salinity targets are established and an accountability mechanism proposed.

Toowoomba Regional Council's *Mt Kynoch Water Treatment Plant* (brochure) (TRC 2010) outlines water sources and treatment for the 122,000 people dependent on the Toowoomba water supply.

Toowoomba Regional Council's *Wetalla Water Reclamation Facility* brochure (TRC 2010b) provides the history and current practices of Toowoomba's sewerage collection and management. Toowoomba Regional council is cognisant that the use of water resources in the region impacts towns and cities downstream, since Toowoomba is located at the very head of the Murray-Darling catchment area.

The Eastern Darling Downs has seen a 60% overall reduction in native vegetation since 1975. At the same time there has been an increase in pasture land of 50% (Le Brocque, AF et al. 2003). This is of concern and confirms the importance of threat abatement programs.

Remnant vegetation in the Condamine Catchment has been well described over the past decade however Le Brocque et al. (2003) make the salient point that

> *simple, robust and meaningful on-ground indicators of the impacts of human activities in remnants* [are needed].

This appears to be an opportunity for further study and perhaps some field work.

The importance of reptiles is established. Reptile and amphibian populations are declining worldwide with more species at risk than either birds or mammals, moreover

> *Reptiles and amphibians hold vital positions in forest and aquatic food webs …are important for nutrient cycling …are indicators of ecosystem health (and) compose an important portion of the vertebrate biomass* (Hutchens and DePerno 2009).

Datasets received from Condamine Alliance and USQ sources include Condamine Catchment boundaries, cadastral information, DEM data, threatened species sightings, essential habitat for endangered species and ecosystems, Statewide Landcover and Trees Study (SLATS) foliage and more. These were the springboard for this project. They are listed in the Appendix.

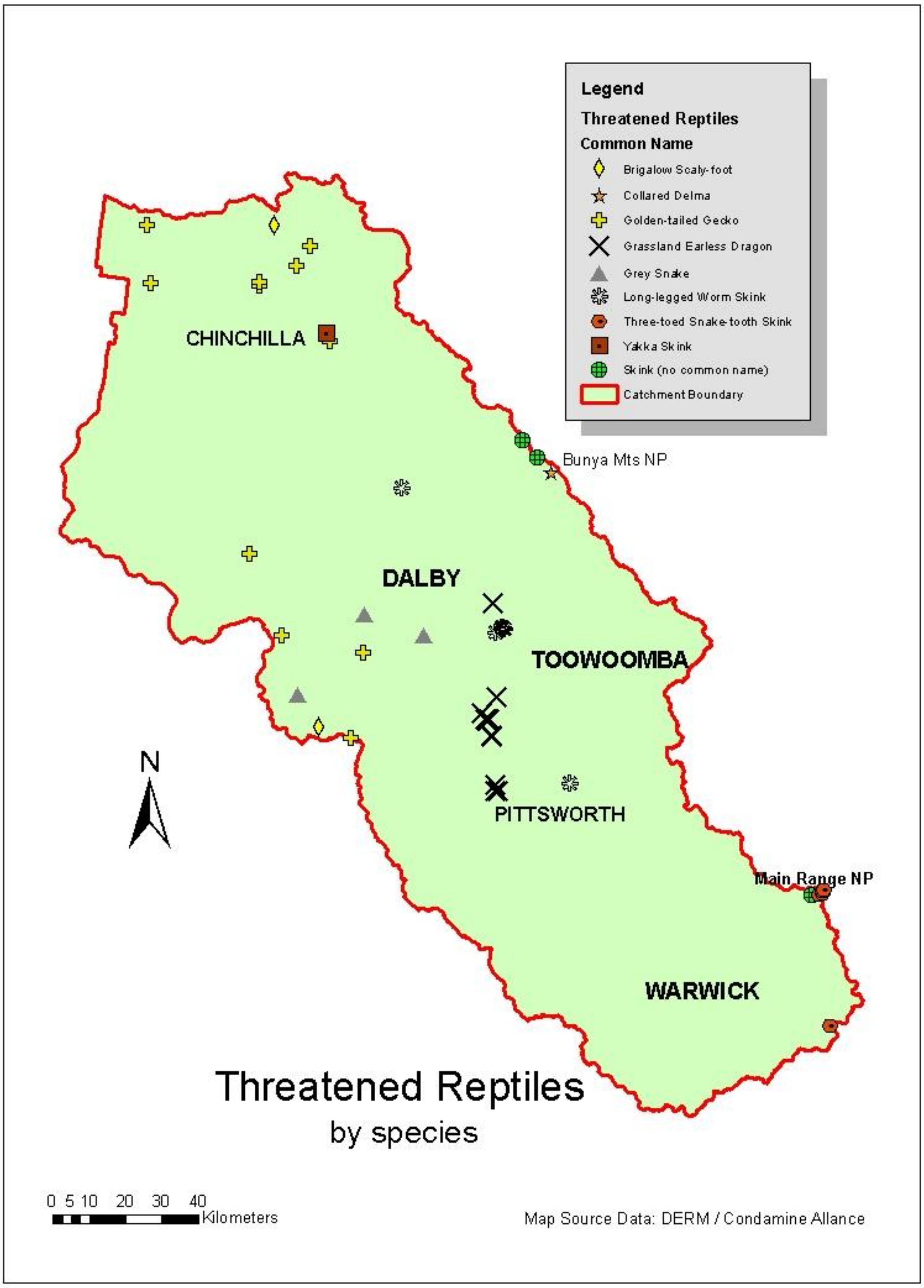

Figure 2.2: *Threatened Reptiles by Species (DERM / CA)*

Table 2.1:*Recognized Threats to Selected Reptiles (DERM 2010).*

THREAT	REPTILE
Road maintenance	Collared delma Yakka skink Long-legged worm skink *
Site maintenance	Yakka skink
Inappropriae grazing regimes	Collared delma Long-legged worm skink
Clearing of vegetation	Collared delma Yakka skink
Fire regime	Long-legged worm skink Collared delma
Linear Infrastructure development	Yakka skink
Mining	Yakka skink
Feral cats	Long-legged worm skink Collared delma Yakka skink
Feral foxes	Long-legged worm skink Collared delma
Feral pigs	Yakka skink Collared delma
Weeds - lantana	Long-legged worm skink
Weeds - *Lippia*	Collared delma Long-legged worm skink
* major threat	

2.3 Defining Legislative Requirements and Constraints

The *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) is the Australian Government's central piece of environmental legislation. It provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places — defined in the Act as matters of national environmental significance (DSEWPC 2010). Nationally threatened native species and ecological communities, native migratory species and marine species are listed. There are developed recovery plans for listed species and ecosystems. A critical habitat register is also being developed. Threats are identified and abatement plans suggested. On the website a protected matters search tool allows reports to be generated for the user's area and field of interest. The website is currently experiencing technical difficulties. This is an area for further study.

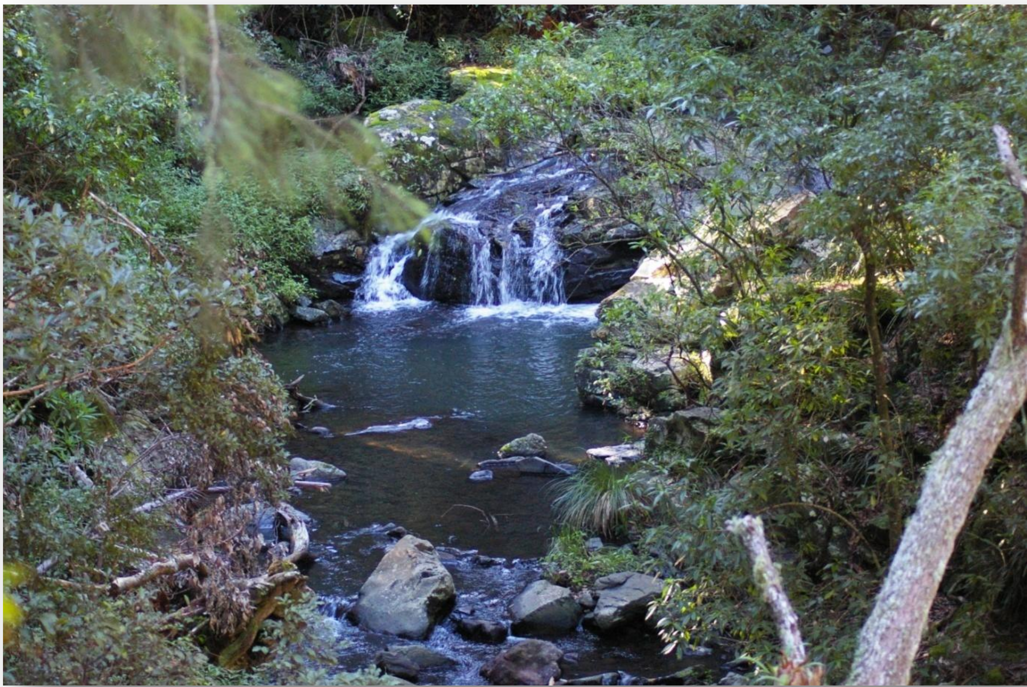

Figure 2.3: *Cascade in Dalrymple Creek.*

In the State jurisdiction the Queensland Nature Conservation Act 1992 (Queensland Parliamentary Counsel 2010) is the legislative framework for the conservation of nature. The Act applies to classes of wildlife described as protected (extinct in the wild, endangered, vulnerable or rare; and near threatened and least concern), international wildlife and prohibited wildlife. The purpose is to ensure that any use of the wildlife is ecologically sustainable.

Another crucial piece of State legislation is the Queensland Vegetation Management Act 1999 (Queensland Parliamentary Counsel 2010b). Vegetation Management is defined as the management of vegetation in a way that achieves the purpose of the Act, including

(a) the retention or maintenance of vegetation to—

(i) avoid land degradation; or

(ii) maintain or increase biodiversity; or

(iii) maintain ecological processes;

(b) the retention of riparian vegetation;

(c) the retention of vegetation clumps or corridors.

These are sound objectives and project recommendations have attempted to enhance these purposes.

Personal communication 19/05/2010 with Jason Chavasse, Senior Vegetation Management Officer, DERM Toowoomba. The place of the Vegetation Management Act within the framework of existing State and Federal legislation was discussed.

The Department of Environment and Resource Management (DERM) has further explanation of the process of determining the class of pre-cleared and remnant vegetation within a regional ecosystem under the *Vegetation Management Act 1999.* The categories of *endangered, of concern* and *of no concern at present* are described (DERM 2010f).

2.4 Defining and Evaluating Threats to Species and Ecosystems

Regional Ecosystems were defined by Sattler and Williams (1999) as vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil (cited in DERM 2010f). The Regional Ecosystem Description Database (DERM 2010j) lists the **Biodiversity Status** of each regional ecosystem. The Biodiversity Status is based on an assessment of biodiversity significance using the classes *endangered, of concern and of no concern at present.*

Biodiversity Significance is a ranking of an area according to specified values to account for rarity, diversity, fragmentation, habitat condition, resilience, threats, and ecosystem processes. Condition of vegetation is often used as a surrogate for the total biodiversity present at a site. In the website it is possible to search for a regional ecosystem description by entering a key identification number (RE ID), for example "1.3.5".

Threatening processes are those that are reducing or will reduce the biodiversity and ecological integrity of a regional ecosystem. For example, clearing, weed invasion, fragmentation, inappropriate fire regime or grazing pressure, or infrastructure development. Threats to wildlife are listed on the DERM website also (DERM 2010h).

The Regional Ecosystem Description Database is a powerful and helpful tool to assist identification of hotspots within the Condamine Catchment to refine the project by narrowing the field of study in progressing towards prioritising investment locations.

The Queensland Herbarium (DERM 2010d) studies, describes and names plants, and records the floristics, structure, distribution and conservation status of Queensland's plant communities. Many of the records in the VMA databases used for this project contain data collected by Queensland Herbarium. Records in the Endangered Species datasets were collected by WildNet (DERM 2010k).

The national press have recently been discussing the drastic fall in numbers of honey bees worldwide, particularly in the US (Courier Mail 2010). In a recent Good Weekend Magazine (*The Australian* newspaper 08/05/2010) the feature writer promoted the idea that should the plague reach Australia and honey bee populations be decimated, then the Australian native bees could "step up' to become our local honey producers. In Queensland, DERM has a responsibility for apiaries within State forests, including Condamine State

Forest (DERM 2010). Although not regarded as threatened or endangered, a study of the native bee populations and their value as honey producers and their essential habitats is warranted.

2.5 Outline of Current Investment Strategies

Caring for our Country is the way the Australian Government funds environmental management of our natural resources. Caring for our Country supports communities, farmers and other land managers protect Australia's natural environment and sustainably produce food and fibre (NRM 2010).

> *Up to $171 million will be available for investment under the 2010-11 Caring for our Country business plan. An additional $138 million is allocated each year as base-level funding to regional natural resource management (NRM) organisations. Caring for our Country provides a sustained, long term commitment to achieve meaningful and targeted results for our environment and sustainable agriculture. The Australian Government has provided over $2 billion for the first five years of Caring for our Country, of which more than $1.3 billion is already approved for investment in single and multi-year projects for environment protection and sustainable agriculture across Australia, including:*

- *more than $450 million in base-level funding for regional NRM organisations*
- *$77.2 million to expand the National Reserve System, including Indigenous Protected Areas*
- *$63.1 million for Landcare grants to improve sustainable agriculture*
- *over $22 million in grants for critical aquatic habitats*
- *over $37 million in grants for biodiversity protection*

The Australian Government has also been working jointly with state governments to implement a number of ongoing activities that contribute to Caring for our Country outcomes and targets (this funding is also included in the $1.3 billion) including

- *over $3 million since 2008-09 for national coordination of the Australian Weeds Strategy, Weeds of National Significance Strategy and the Australian Pest Animal Strategy*
- *over $11 million since 2008-09 to help eradicate Red Imported Fire Ants and Electric Ants and prevent them becoming established pests*
-

Of direct benefit to the Condamine Catchment are allocations within the following:

> *$27.3 million for Environmental Stewardship Program projects to protect endangered ecological communities in New South Wales and Queensland.*
> *Increasing native habitat and reducing the impact of invasive species $6 million*.

The reference to

> *base-level funding to regional natural resource management (NRM) organisations* (NRM 2010)

means funding allocations to Murray-Darling Basin Management, Condamine Alliance and others.

2.6 Identifying Alternative Spatial Analysis Methods

Haining (2003) singles out the map as having an important role in data analysis and examining results of models. The map helps answer questions such as:

> *'where do those extreme cases on the histogram fall on the map?'; 'where do attribute values from this part of the map fall on the scatterplot?'; 'which cases fall in this subregion of the map and meet these specified attribute criteria?'; 'what are the spatial*

patterns and spatial associations in this data set?'; or 'what are the spatial patterns and spatial associations in this geographically defined subset of the data?'

This comment is relevant for the spatial analysis of subcatchments of the Condamine Catchment chosen for study because of spatial associations or patterns.

Spatial information is one of the most critical elements underpinning decision-making for many disciplines and particularly for catchment decisions. The best decisions, arguably, result from consultation and input from all stakeholders. Spatial Data Infrastructure (SDI) is

> *a portal where each stakeholder can access use and exchange spatial data for social, economic and environmental wellbeing.*
> (Paudyal, DR et al. 2009).

The SDI study was undertaken within the Condamine Catchment. It is relevant for the improvement of natural resource management today and in the future. This is a reminder that practical spatial analysis is more than "office work" and that confirmation by field observations and input from other catchment stakeholders is also necessary.

DEM data is an important input for GIS analysis. It needs to be georeferenced and accurate, depending on the purpose for which it is intended. How accurate is current DEM data? A study in 2008 found that the NRW 25m DEM has better than 10m accuracy at 90% confidence level. The SRTM 87m DEM over the same area has proven to be slightly better with a 95% confidence of better than 10m (McDougall et al. 2008).

.

These accuracies are acceptable for vegetation and wildlife under study in this project.

Classification of input data attributes affects the visual and statistical outcome from a GIS. A technique called “Degree of Site Suitability” (DoSS) has been used to aid standardisation of discrete classification methods.

Basnet and Apan (2007) found that

> *the variations in terms of the class number, the class size, and the weight distribution between classes were the major contributing elements towards measurement inconsistencies.*

They concluded that the usefulness of this method of standardisation is limited for obtaining a comparable and repeatable DoSS measurement. For the current project, attention was paid to classification methods to ensure consistent and repeatable results across the range of datasets analysed.

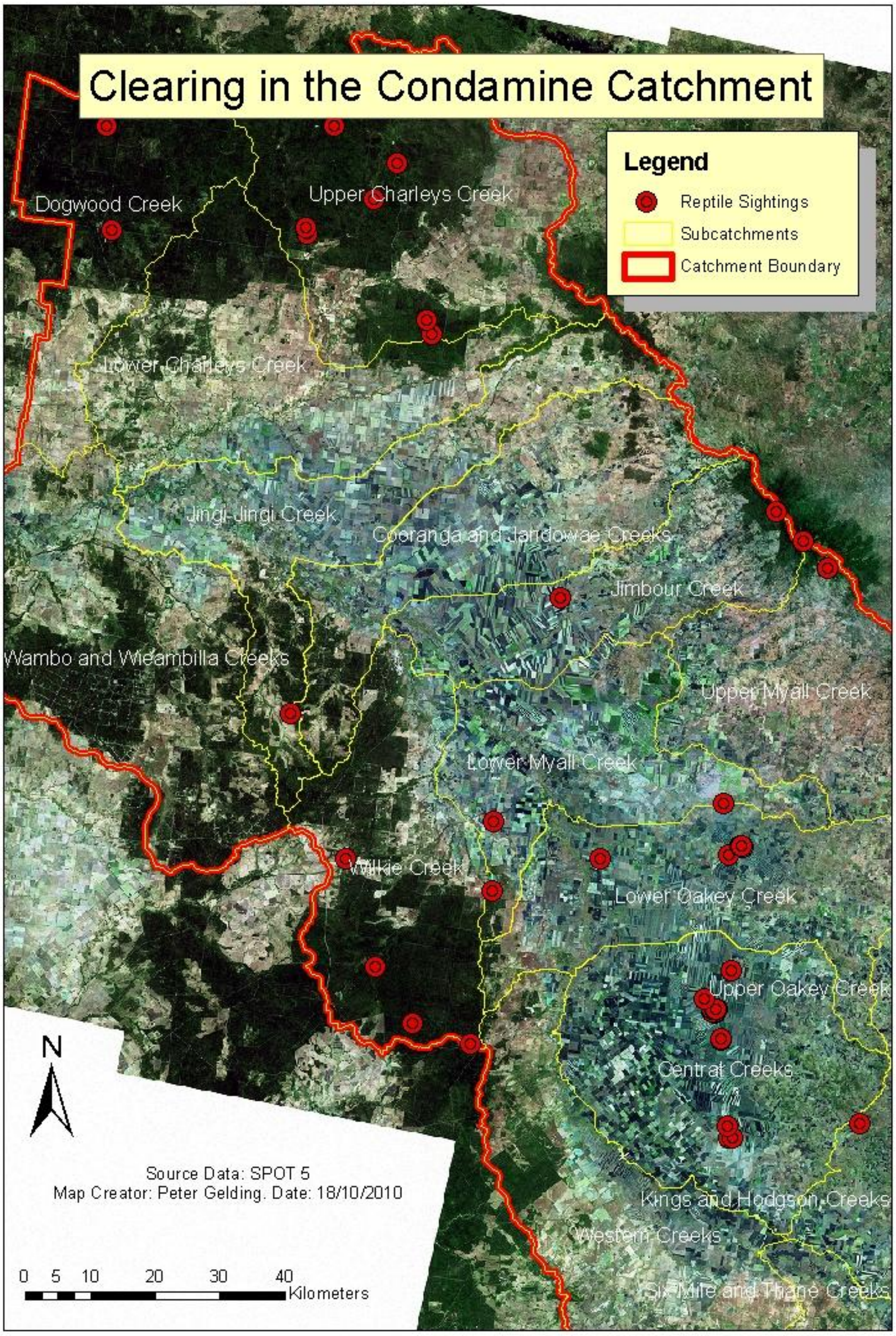

Figure 2.4: *Extent of Clearing in Central Condamine Catchment (Source: SPOT5, CA)*

Lang(1998) has written a textbook relating to natural resource management with GIS. The book and accompanying CD give an introduction to Arcview

GIS 3. Case studies of endangered species and forests and wildfires (sic) are of interest. The software version however is superseded and lacks the power of current versions.

Creating subsets of the spatial data allows constructing of buffer zones around features to facilitate interpolation of the data. Other datasets based on proximity, overlay and attributes can also be created (Schuurman 2004). Kennedy (2006) has written a manual introducing GIS with a more recent version of ArcGIS, version 9.1. This is a helpful reference for spatial analysis tasks contemplated.

Data errors can creep into GIS databases from source data, data entry or data analysis. Korte (2001) explains these errors and introduces terms such as “polygon slivers”. The value of this work is in its perspective that GIS is applicable to a wide range of disciplines and industries.

With the intriguing chapter title “The devil is in the data”, Schuurman (2004b) gives the example of two environmental and forest resource databases developed by different agencies within British Columbia, Canada. Each agency defined the same roads differently and collected separate field data. The two datasets were not temporally contemporaneous and their purposes were also different. They used different classification systems. For reasons of time and money, it was decided to merge the datasets. Not surprisingly the data integration program encountered multiple problems. This case study provides a dire warning - although a GIS can merge datasets successfully, there is no guarantee that the results will be accurate or meaningful.

Hyperspectral imagery from aerial mapping is useful for discriminating selected tree species and regeneration stages that can help improve vegetation mapping and tree stand characterisation (Apan et al. 2009). This is particularly useful in the study of remnant (that is, left behind after clearing) vegetation in the study area. Reasonable accuracies can be achieved. Using partial least squares (PLS) regression Apan et al. (2009) achieved species prediction accuracies ranging from 83-88%.

2.7 Miscellaneous Literature

The Australian Spatial Data Directory provides search interfaces to discover geospatial dataset descriptions (metadata) throughout Australia. This is a very powerful tool which is invaluable for spatial scientists and will greatly assist this project in data collection, identification of prior work and the search for meaningful and relevant spatial analysis methods (ASDD 2010).

Useful contacts (links) provided by Condamine Catchment Management Association – include government, industry, environmental groups, landcare and issues within the catchment (CCMA 2010).

The Bull Oak Jewel Butterfly (Lundie-Jenkins and Payne 2002) provides a celebrated case of near extinction within the Condamine Catchment, with a recovery plan now in operation.

2.8 Conclusion

Funding at national and state government levels is available for protecting endangered ecological communities, for increasing native habitat and reducing the impact of invasive species. Some research is continuing into threat identification and abatement in Australia and overseas. Management and recovery plans are in place or proposed within the study area. Legislation to ensure preservation of biodiversity in Queensland appears to be adequate and functional. GIS are being increasingly used to process and spatially analyse data about wildlife and ecosystems.

This project used GIS methods to identify and quantify priority locations for investment into threats to reptiles that have been identified as endangered, vulnerable or rare.

This chapter has reviewed literature in order to confirm the premise for the project by clarifying prior work, defining legislative requirements and constraints, defining and evaluating threats to species and ecosystems, outlining current government investment strategies and identifying alternative spatial analysis methods.

CHAPTER 3

RESEARCH METHODS

3.1 Introduction

In this Chapter the study area is described together with local environmental issues. Threats to species and ecosystems have arisen due to natural and anthropogenic causes.

The context of the research is mentioned, with reference to various stakeholders within the Condamine Catchment and their roles. A conclusion is made as to the importance of prioritising investment options and targeting locations for investment.

The design of the study is outlined step by step. The most important feature being the datasets – how they were acquired and the processes involved in assimilating and using the data. Methodology as it unfolded during the study is revealed and reasons given for some of the decisions taken and roadblocks encountered.

3.2 Flow Chart

The methods used are supported by a simple flow chart, shown in figure 3.1.

3.3 The Study Area

The Condamine Catchment is the study area for the project. Located in the Darling downs region of southern Queensland, the Condamine Catchment describes an area of 24,434 km^2 of agricultural land west of the Great Dividing Range (see figure 3.2).

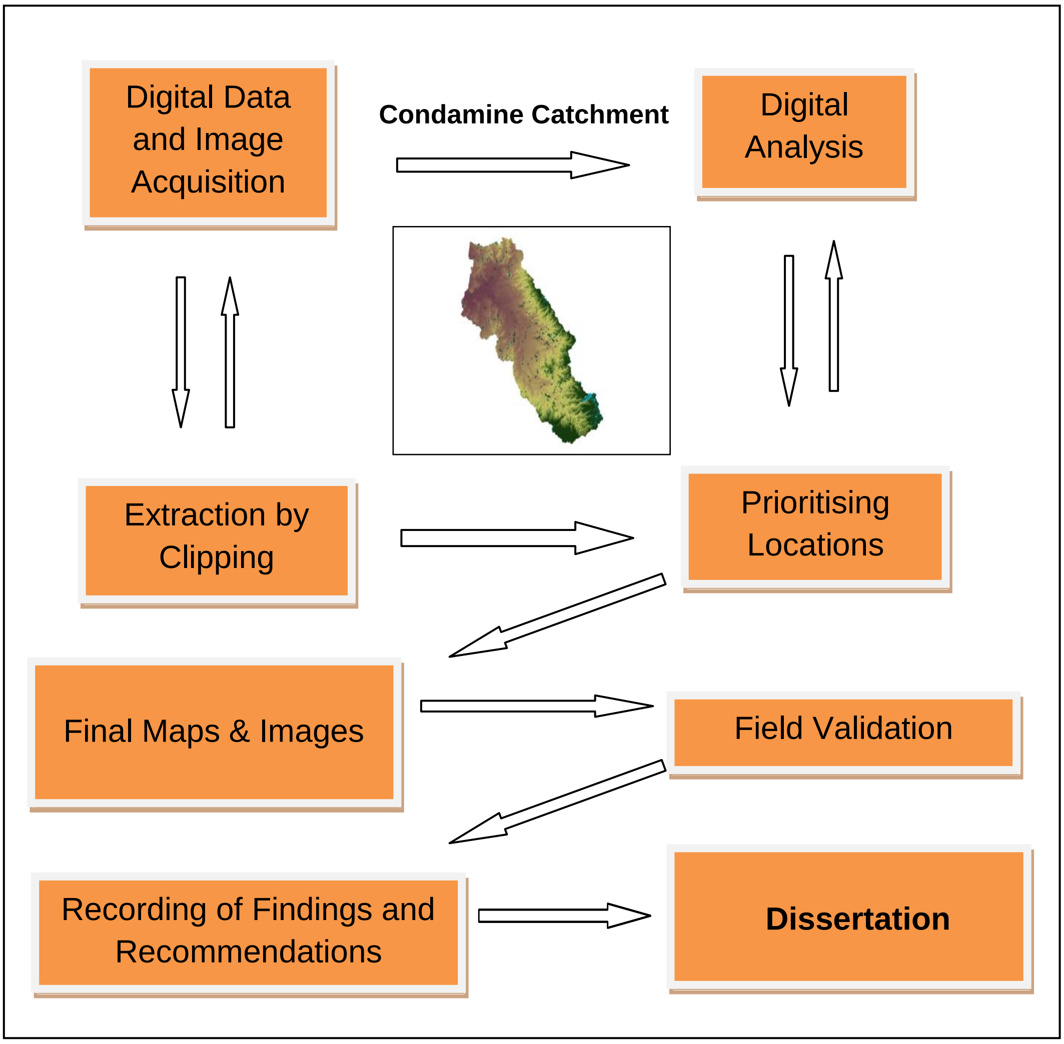

Figure 3.1: *Methodology*

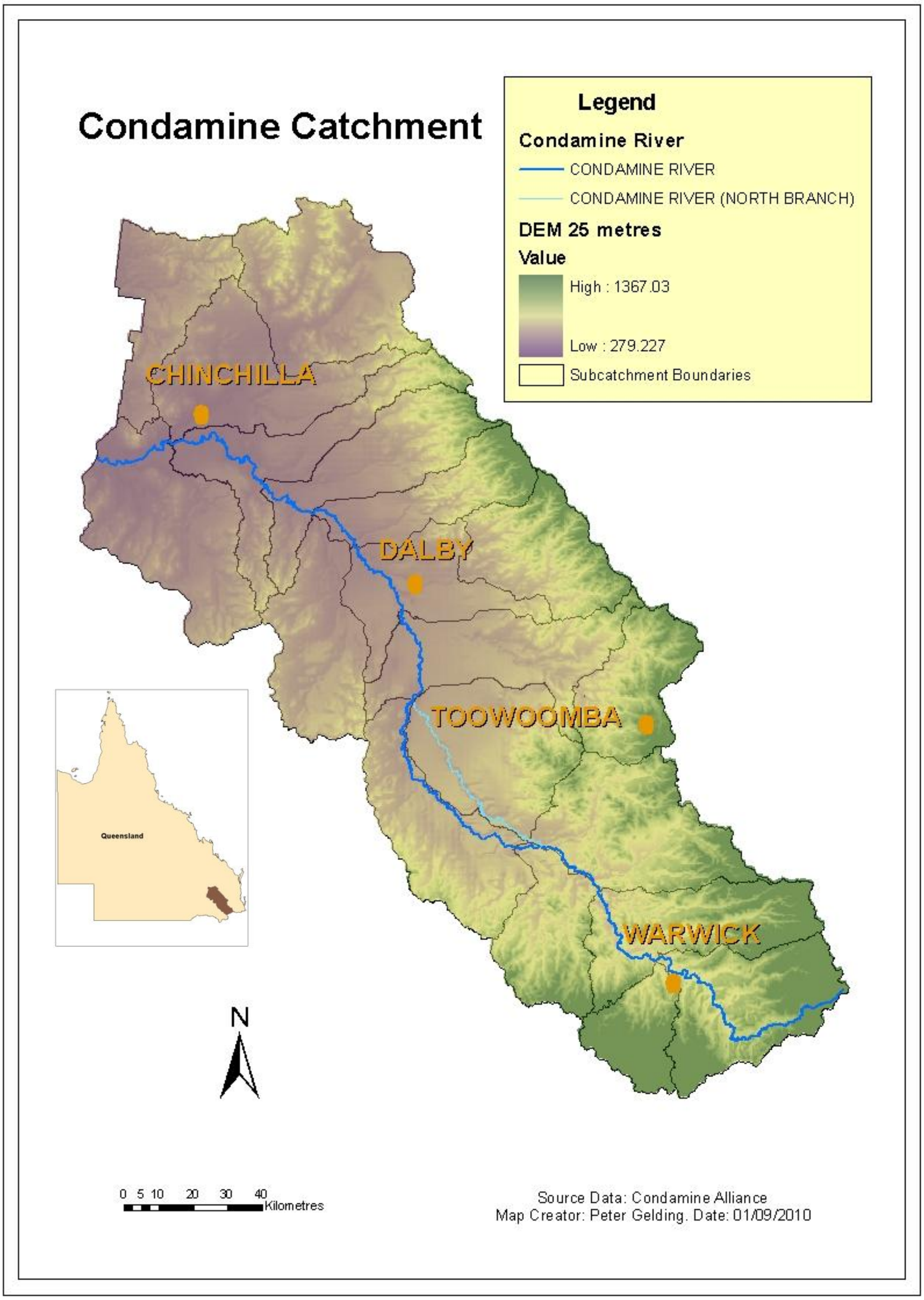

Figure 3.2: *The Condamine Catchment (Source: Condamine Alliance, USQ).*

Creeks mostly flow west away from the Great Dividing range to the Condamine river, which forms a large floodplain extending from Chinchilla in the north to Millmerran / Pittsworth on the south. This is the headwater of

Figure 3.3: *Riparian Forest, Dalrymple Creek*

the Murray-Darling Basin, a vast region extending south through New South Wales, Victoria and South Australia. The importance of the Condamine Catchment to the health of river systems in eastern Australia is therefore evident. Figure 3.4 shows that drainage flows generally from the south and east to the north west of the catchment.

The Dalrymple Creek at Goomburra is one such stream. It is shown pictorially in figures 2.1, 2.3 and 3.3. These photographs were taken by the author on an exploratory site visit in May 2010. Dalrymple Creek starts near

Main Range National Park and flows westerly from the higher elevations in the south east of the catchment area towards the central plains. Riparian forest broken by pasture and open bushland is seen. The creek has a number of cascades and is habitat to Fleay's Barred Frog. The threatened Three-toed Snake-tooth Skink and bird species such as Albert's Lyrebird have been sighted in the vicinity, within the National Park.

Land use in the Catchment includes extensive agriculture – summer and winter crops, vegetables, horticultural crops – some with irrigation. Cattle and sheep are grazed and feedlots, piggeries and poultry farms are found.

Environmental issues in the area include biodiversity (less than 30% of the original vegetation remains after 170 years of agriculture), erosion from poor farming practices last century, salinity problems in small pockets, water quality and the influence of pest plants and animals (Condamine Alliance 2010).

Thus there are a number of threats to species and ecosystems resulting from previous human interventions, current land use and regimes and the presence of feral animals and plant pests. These will be discussed further.

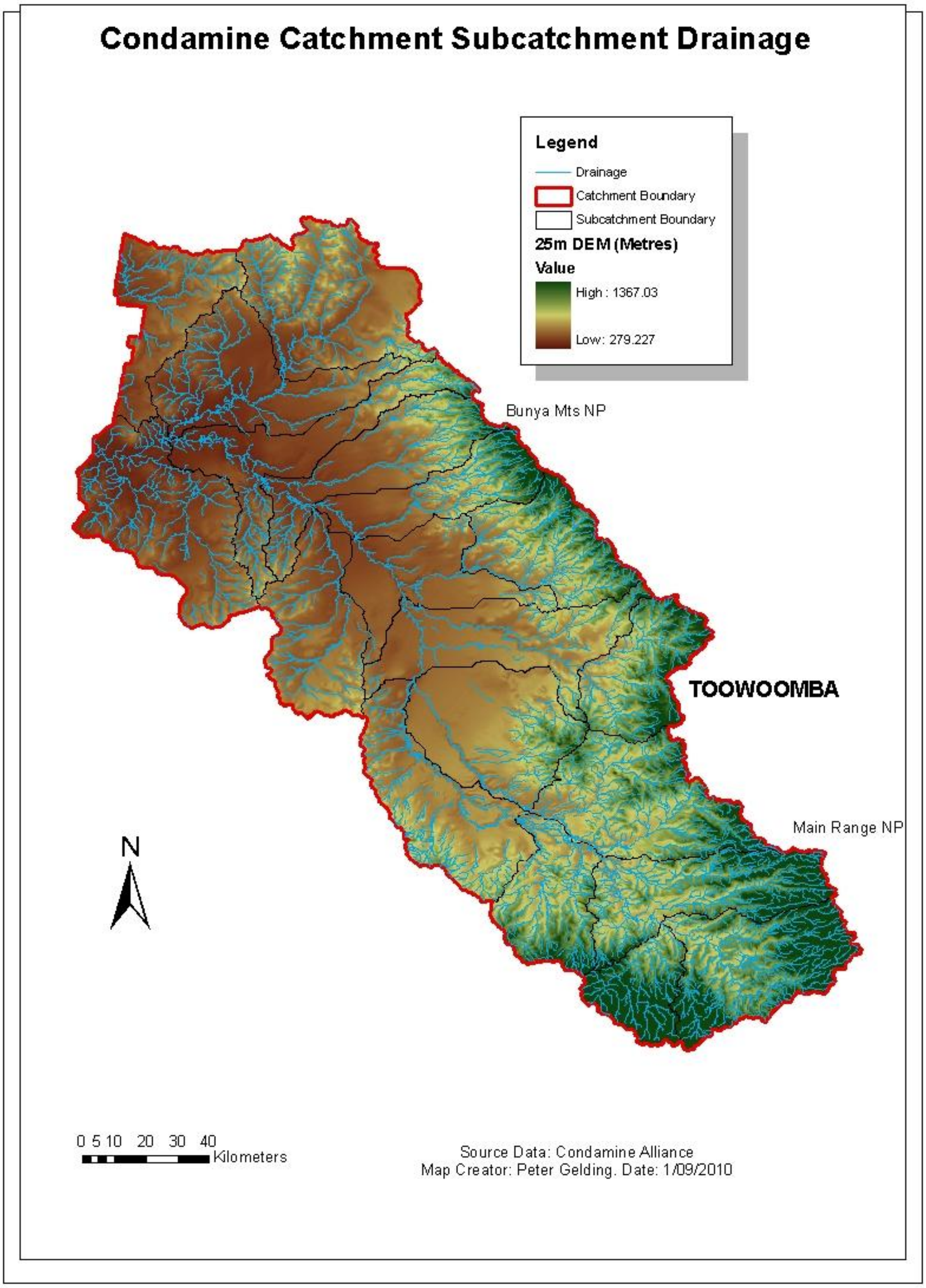

Figure 3.4: *Subcatchment Drainage in the Condamine Catchment (Source: CA)*

3.4 Context to the Study

3.4.1 The Role of Local, State and National Governments.

The Australian community places expectations on its governments at all levels to enhance and protect the environment for current populations and to be custodians for future generations. Accordingly each jurisdiction has a role to play and has set up bodies and departments by acts and regulations of parliament. The literature survey uncovered specific roles and duties of these government bodies, including current legislative requirements, restrictions and restraints due to funding priorities and the proposed framework for future planning.

The Condamine Catchment includes part or all of Toowoomba, Western Downs (formerly Dalby) and Southern Downs Regional Councils. It is located in the State of Queensland in the Commonwealth of Australia.

3.4.2 The Role of Industry.

Responsible industry in Australia is developing a culture of the triple bottom line. This is a phrase coined in the 1980's to emphasize a shift away from mere profitability to profitable sustainability. The "triple' denotes the three major dimensions of sustainability - economic, social and environmental (DEWHA 2010).

The effect of this culture shift is a greater transparency and accountability for economic, environmental and social corporate performance (DEWHA 2010 2). There is great variation in the take up of this new corporate responsibility between industries and even within industries, however it is an emerging and increasing option for Australian business. Bodies such as Condamine Alliance could be the beneficiaries of discretionary funding from industry in the future and should consider planning for this eventuality. Hence the importance of prioritising investment options and targeting locations for investment.

3.4.3 The Role of Community Landcare Groups

There are more than 4000 locally based community landcare groups in Australia. Thousands of volunteers including 40% of farmers are working in farmlands, waterways and coastal areas to plant trees, restore wildlife habitats, minimise erosion and salinity and helping to protect the urban environment (Landcare Australia 2010).

The Condamine Catchment Management Association Inc (CCMA) incorporated in 1996 aims to coordinate the activities of landholders, community groups, industry groups and all spheres of government within a river catchment. It was formed under the Queensland Government Integrated Catchment Management Strategy 1991(CCMA 2010).

The Catchment is divided into seven sub-catchments and Members of CCMA (limited to 21) together with Associates (unlimited) meet regularly to administer activities. CCMA has a representative on the Board of Condamine Alliance, the regional body.

3.4.4 The Role of a GIS.

In a Geographic Information System (GIS) the elements of data, hardware, software and human come together to transform raw data into useable information from which questions can be answered and decisions made (Burrough and McDonnell, 1998). The tool of GIS takes spatial data about endangered habitats and sightings of threatened species and through manipulation and analysis displays trends and identifies locations of interest for further research and study. The power of a GIS is the ability to bring together diverse datasets and synthesise them, making spatial relationships visual (Schuurman 2004). The spatially explicit effects of management decisions and other disturbances on vegetation at large scales can be studied (Larson et al. n.d.). The display options available bring visualisations that inform and communicate.

3.5 Digital Data and Image Acquisition and Input

Building on the literature review and with the supervisor's guidance, a search was made to find relevant datasets to undertake the project.

Datasets supplied by Condamine Alliance and obtained from USQ sources provided the major input for the early stages. Some of these datasets originated from DERM. Later further datasets from Queensland Government Information Service (QGIS) were downloaded and used for the filtering process. This was to strengthen the choices made of regional ecosystems considered significant, relative to sightings of endangered, vulnerable or rare species.

Data was in the form of shapefiles in format useable by ArcGIS and in Excel tables. They included land use data, regional ecosystems, VMA data, SLATS foliage and sightings of species. Later, datasets of roads, protected areas and drainage were also overlaid on the ecosystems and species maps.

Digital thematic maps (DEM and DCDB) and images from SPOT5 and Landsat TM were classified and linked using ArcGIS 9.3.1.

The option to rasterise the vector data was considered and some files were converted. However the study focussed on Boolean methods in vector data structure to produce the results described.

3.6 Preprocessing

Many of the datasets were not projected but were in Geographical Coordinate System GCS_GDA_1994. This meant that their coordinates were latitude - longitude and expressed in degrees. Whilst suitable for surveying purposes they were unsuitable for input into a GIS for spatial analysis. In particular, the study called for areas to be calculated requiring units to be metres. Spatial datasets were therefore georeferenced to a common map projection transverse Mercator GDA_1994_MGA_Zone_56.

The process adopted took advantage of the ability of the software to georeference “on the fly”. A dataset layer already in the required projection (for example the catchment boundary layer) was added to a new map in ArcGIS. Units were selected as metres (or meters). As subsequent layers were added (for example regional ecosystems) the software converted them to MGA projection coordinates, expressed in metres. Reprojected layers were then saved into a new library using the Export Data command and used as base layers for further study. When saving layers in this manner it was important to save in coordinates of the data frame, not in coordinates of the layer source data.

3.7 Digital Analysis

The power of a GIS is to be able to handle large amounts of digital data, storing, manipulating and analysing with tools. This ability to integrate spatial information with statistics and with analytical processes results in spatial patterns that otherwise would not be easily apparent (GIS Lounge 2010).

For example: overlaying of datasets, one of the original tasks of a GIS (GIS Lounge 2010). Using ArcGIS overlay, concentrations of point data (e.g. sightings of threatened species) within the catchment were displayed to bring focus to remnant vegetation, essential habitat for endangered species and other locations of interest.

An important task was to ensure the datasets were in correct format for analysis. In some instances this involved rasterising vector structured datasets. This was achieved using Arc Toolbox conversion tools to produce grid files. As indicated however, vector data was chosen for the final processing.

3.8 Extraction of Data

At times it was necessary to import datasets of larger extent than the study area, for example the whole state of Queensland. For efficiency and ease of handling, data was clipped where necessary using the cookie – cutter method. A subset of the data was created within the shape of the Condamine Catchment. An example is shown in figure 3.2.

3.9 Spatial Analysis of Data Subsets Using a GIS

3.9.1 Boolean Operations

Vector geoprocessing (extraction and clipping) was followed up with spatial analysis using Boolean logic, generally union and/or intersection.

The process of selecting a target species was undertaken by overlay of species sightings with regional ecosystems. The original dataset of the Condamine Catchment contained 60,178 sightings of all species including flora and fauna (angiosperm – multiple families and animalia – amphibia, aves, incertae (indeterminate), insect, mammalia and reptilia). Of these 6% (3626 sightings) were of species endangered, vulnerable or extinct in the study area using codes under the EPBC (*Environment Protection and Biodiversity Conservation) Act 1999.*

A similar dataset with 3689 sightings of fauna and flora using NCA (Queensland Nature Conservation Act) 1992 status endangered, vulnerable or rare was adopted as base data for the study.

The distribution of species by group name is shown in Table 3.1

The chosen dataset contained species sightings from 1960 to 2005. 47.4% of sightings were since 2000, 51% during the 1990s, 1.4% during the 1980s and only 0.2% pre-1980.

Table 3.1: *Species Sightings by Group (Source Dataset: Condamine Alliance)*

GROUP NAME	SIGHTINGS %	SPECIES
Amphibia	84.1	8
Angiosperm	6.0	39
Aves	4.7	11
Gymnosperm	0.1	2
Insecta	0.7	2
Mammalia	2.7	5
Reptilia	1.7	10
TOTAL	100.0	77

Recent data for regional ecosystems (2009) was mapped and overlaid on the species sightings. Boolean overlay in ArcGIS is appropriate for two layers, only (ESRI 2009). When overlaying the polygon data (regional ecosystems) on point data (species sightings), Boolean intersections resulted in layers containing point data. This was a potential barrier to obtaining useful information for areal studies. It was clear that a polygon output was required. A manual approach i.e. manual selection of remnant vegetation polygons adjacent to species sightings overcame this problem.

3.9.2 Selection Process

A major task was to select a focus group of threatened species. This would allow priority locations to be chosen for future investment, whereas a study of all threatened species would by default select almost the entire Condamine Catchment. This was outside the scope of this study due to time and other constraints.

Mapping of the species groups gave a clear visual understanding of their spatial distribution. It was apparent that many sightings had been made adjacent to roads. This was particularly true for reptiles. The reason for this is likely to be because of ease of access, serendipity (happening to "stumble" on species) or because road verges, themselves, often contain grasses and low bushes that are habitable. In instances of land clearing for agriculture where there is an existing road, the road serves as a natural boundary and strips of remnant vegetation can be left as road verges. This is verified by the existing mapping of remnant vegetation. The abundance of fauna inhabiting road verges also contributes to the threat from vehicle strikes (Clevenger, AP et al. 2003).

Reptiles represented less than 2% of total sightings but 13% of the species identified as threatened. Thus the impact of reduction, degradation or removal of reptilian habitat could have a disproportionate effect on biodiversity. Threats to reptiles include road and site maintenance, clearing of vegetation, fire regimes, mining, linear infrastructure development, inappropriate grazing regimes, feral cats, foxes and pigs and weeds (Condamine Alliance 2010). Discussion of threats is made in Chapter 4. With the increase of mining activity and associated linear infrastructure development planned for the next decade, threats to reptilian habitat will increase (MDBC 2010).

It was decided to use reptiles as the focus species group for this research. The area of selected remnant vegetation in regional ecosystems falling in the proximity of reptile sightings was calculated to be 40,887 hectares. Once those vegetation patches were established, overlay in the GIS identified those patches where significant sightings of other species also occurred. It was found that 61% of vegetation patches related to reptile sightings also had sightings of other significant species that are endangered, vulnerable or rare. Full results are discussed in Chapter 4.

3.9.3 Strengthening Selection of Vegetation Communities

The choice of remnant vegetation patches related to reptile sightings was strengthened by analysis of the regional ecosystems represented. To this end a number of other analyses by overlays were performed:

Reserves and National Parks

Two major National Parks, Main Range (Goomburra) NP and Bunya Mountains NP are within the study area. In addition there are a number of small local nature reserves. Datasets of these special areas were clipped to the study area and mapped by Boolean intersection with the reptile species sightings.

Protected Areas

Two State Forests and two Nature Reserves within the study area recorded species sightings. The forests and nature reserves were added to the data from national parks and included as special areas for protection of reptiles. The concept was that these areas had been sequestered historically for pertinent reasons – biodiversity perhaps, slopes that would discourage cultivation and the presence of remnant vegetation (DERM 2010c).

World Heritage.

Gondwana Rainforests stretch into part of the south eastern boundary of the study area. This coincides with Main Range NP at Goomburra and strengthens the claim for that site to be a priority location for this research. The DCDB was overlaid with National Park data to see the potential for landholders adjoining the NP to be encouraged to assist with preservation of the rich biodiversity.

Other Species

As discussed 61% of vegetation patches related to reptile sightings also had sightings of other significant species in various classes. These included birds, small mammals and amphibians as well as endangered angiosperms.

The relationship between threatened reptiles and other significant species was explored spatially.

Koala Habitat – exists largely to the east of the Great Dividing Range and touches the study area only at Main Range NP. Koala habitat was not of special significance to this study other than the coincidental importance of the Main Range NP as habitat to a number of threatened species.

Status of REs – most vulnerable vegetation communities.

The DERM website records descriptions of regional ecosystems together with their vulnerability under the VMA Class and Biodiversity Status. REs selected for their proximity to reptile species were then checked for vulnerability and the result tabulated. Of the 18 ecosystems in 52 patches represented in the study, two are considered endangered and four "of concern" (Table C1).

Biodiversity Status

Tabular data of VMA Class (Vegetation Management Act) and Biodiversity Status was examined to correlate regional ecosystems within the Condamine Catchment with threatened reptiles. It was hoped that some relationship could be found between the ecosystems that are considered endangered or of concern with reptiles in the proximity.

Land Use Category

Queensland Land Use dataset from 1999 was available. This was classified into the categories of “Conservation and natural environments”, “Production from relatively natural environments”, “Dryland agriculture and plantations’, “Irrigated agriculture and plantations” and “Intensive Uses”. Land Use data was clipped to the study area and intersected with the reptile sightings.

Potential Threats – As significant threats to reptiles are anthropogenic, distance from roads, settlements and other infrastructure was important. As previously mentioned, many species sightings occurred on or beside roads. Buffering from roads at intervals of 500 metres, 1000 metres and 5 kilometres was done to assess impact on neighbouring vegetation communities. No data was available to analyse threats from feral mammals.

3.10 Collation of Relevant Statistics

The statistics function included in ArcGIS 9.3.1 was used to calculate areas of remnant vegetation patches. The number of patches, minimum size, maximum size and sum of areas was noted. When using Boolean operations, it is necessary to use the “Calculate Geometry” function on the output files to correctly use the statistics and ensure the summations are correct.

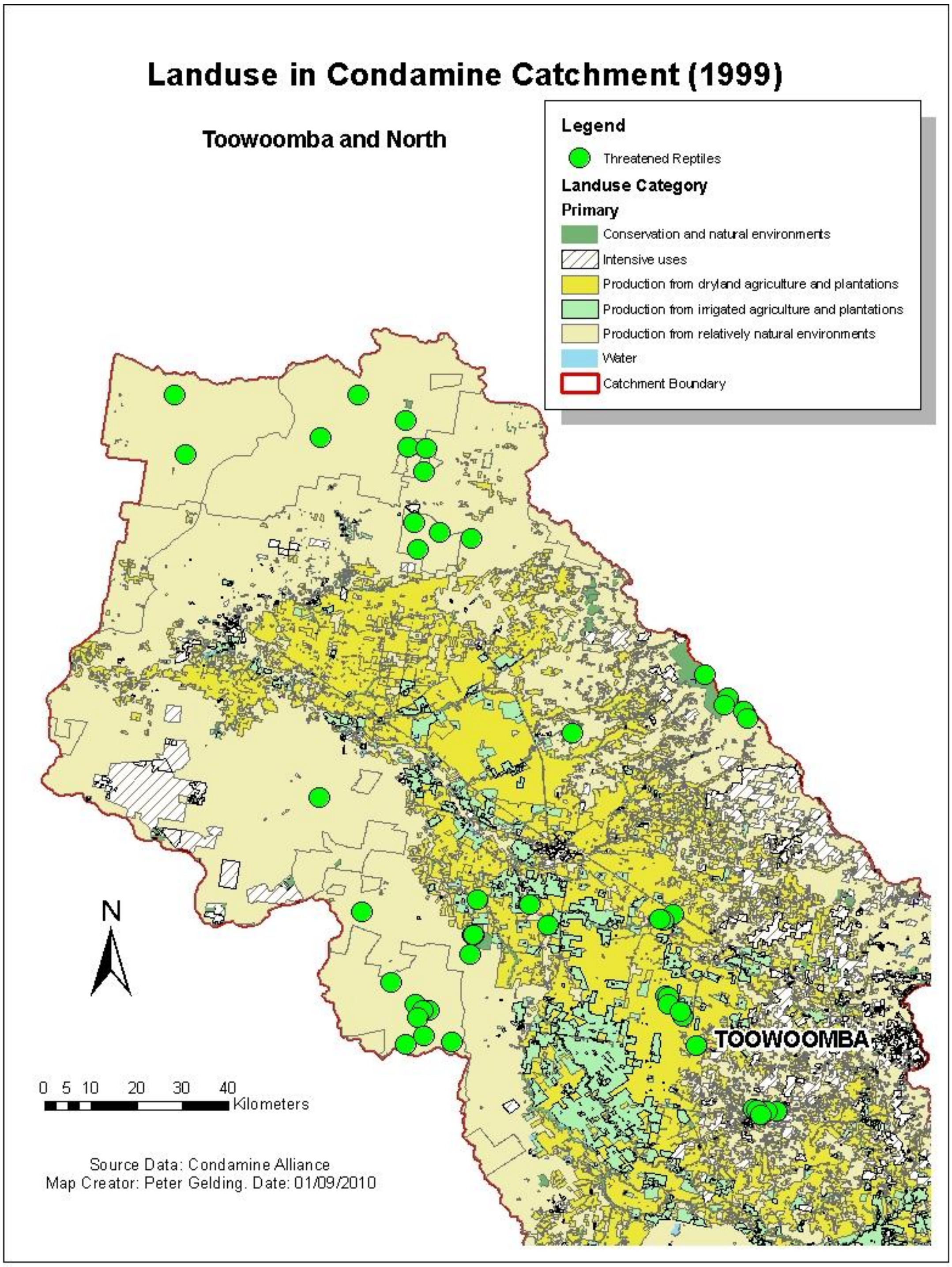

Figure 3.5a: *Landuse in the Condamine Catchment, Toowoomba and North (1999 Data)*

(Source: Condamine Alliance)

3.11 Allocation of Priority Areas

The strategy employed was in five steps:

- Determine priority species from a range of threatened species.
- Select Regional Ecosystems in proximity to sightings of priority species. These became priority locations.
- Rank threatened reptiles with endangered being highest priority.
- Rank the selected REs with endangered being the highest priority.
- 3.11.5 Tabulate results to form conclusions and recommendations.

3.12 Data Cleaning and Checking

The process of intersecting or making a union of subsets sometimes resulted in very small unwanted polygons due to errors in manual selection. Visual inspection of zoomed images was done and these polygons removed. Final datasets were checked for logical consistency to ensure all polygons were closed, had only one label, were topologically related; that nodes were formed at the intersection of lines, there was no overshoot or undershoot and no unintentionally crossed or duplicated lines. A visually check of final images was completed by overlaying.

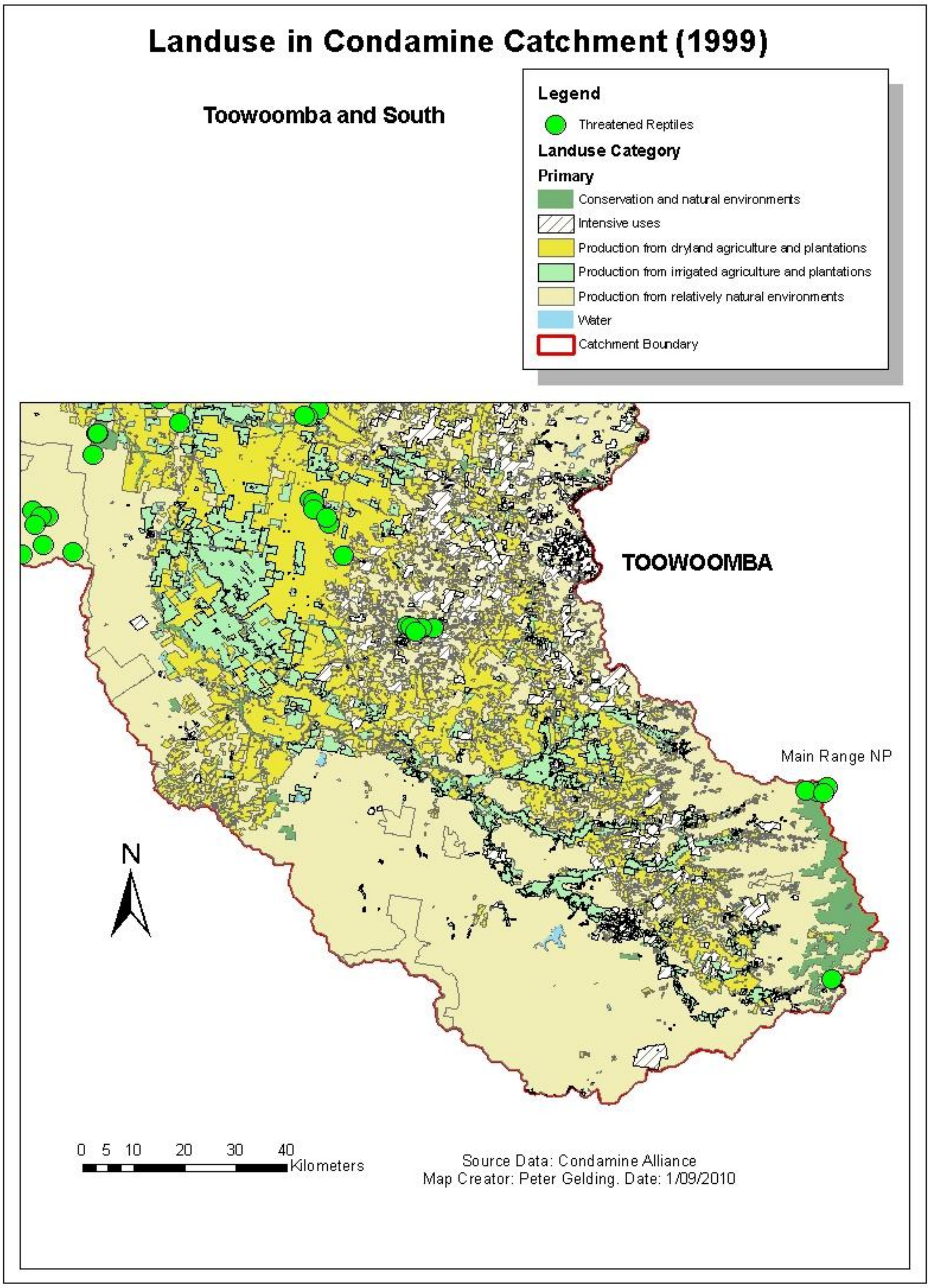

Figure 3.5b: *Landuse in the Condamine Catchment, Toowoomba and South (1999 Data) (Source: Condamine Alliance)*

3.13 Field Validation

Priority locations for investment were the focus of this study. Some of the data relied on reptile sightings up to a decade ago. The latest land use data available was from 1999 and the vegetation data from 2009. It was not known whether there had been small scale infrastructure development such as bores or pipelines adjacent to or inside selected remnant vegetation patches since data collection. Consequently, some form of field validation was required.

An option for validation was to make a site visit to see if vegetation communities were as described and located. A round trip of 321 kilometres was planned which included 40% of the reptile species and 40% of the significant sites in the study area.

Other validation was achieved by visual inspection of SPOT5 imagery and comparison with other coded datasets, with emphasis on vegetation communities. For gross checking only, Google Earth was found to be helpful.

3.14 Summary of Methodology

The area of interest is the Condamine Catchment (also known as the Darling Downs) an area of 24,434 km^2.

- Digital data and image acquisition: Various datasets and digital thematic maps and images were classified and linked using ArcGIS 9.3.1. Spatial datasets were georeferenced to a common map projection GCS_GDA_1994 (pre-processing and image classification stage).

- Digital Analysis: Overlaying of datasets displayed concentrations of point data (e.g. sightings of threatened species) within the catchment to bring focus to remnant vegetation, essential habitat for endangered species and other locations of interest.

- Extraction of data by clipping further refined the locations of interest for spatial analysis. These locations were prioritised based on threats to species and ecosystems. Reptiles were chosen as the focus species.
- Spatial analysis of selected sub datasets using ArcGIS.

- Allocating priority locations for investment using the five step process outlined in 3.10.

- Checking final datasets for logical consistency to ensure all polygons were closed, had only one label, were topologically related; that nodes were formed at the intersection of lines, there was no overshoot or undershoot and no unintentionally crossed or duplicated lines.

- Final images were visually checked by overlaying.

- Confirmation of priority locations by field observation or other means.

- Recording of findings in electronic and hardcopy formats suitable for lodgment.

- Writing and submission of dissertation.

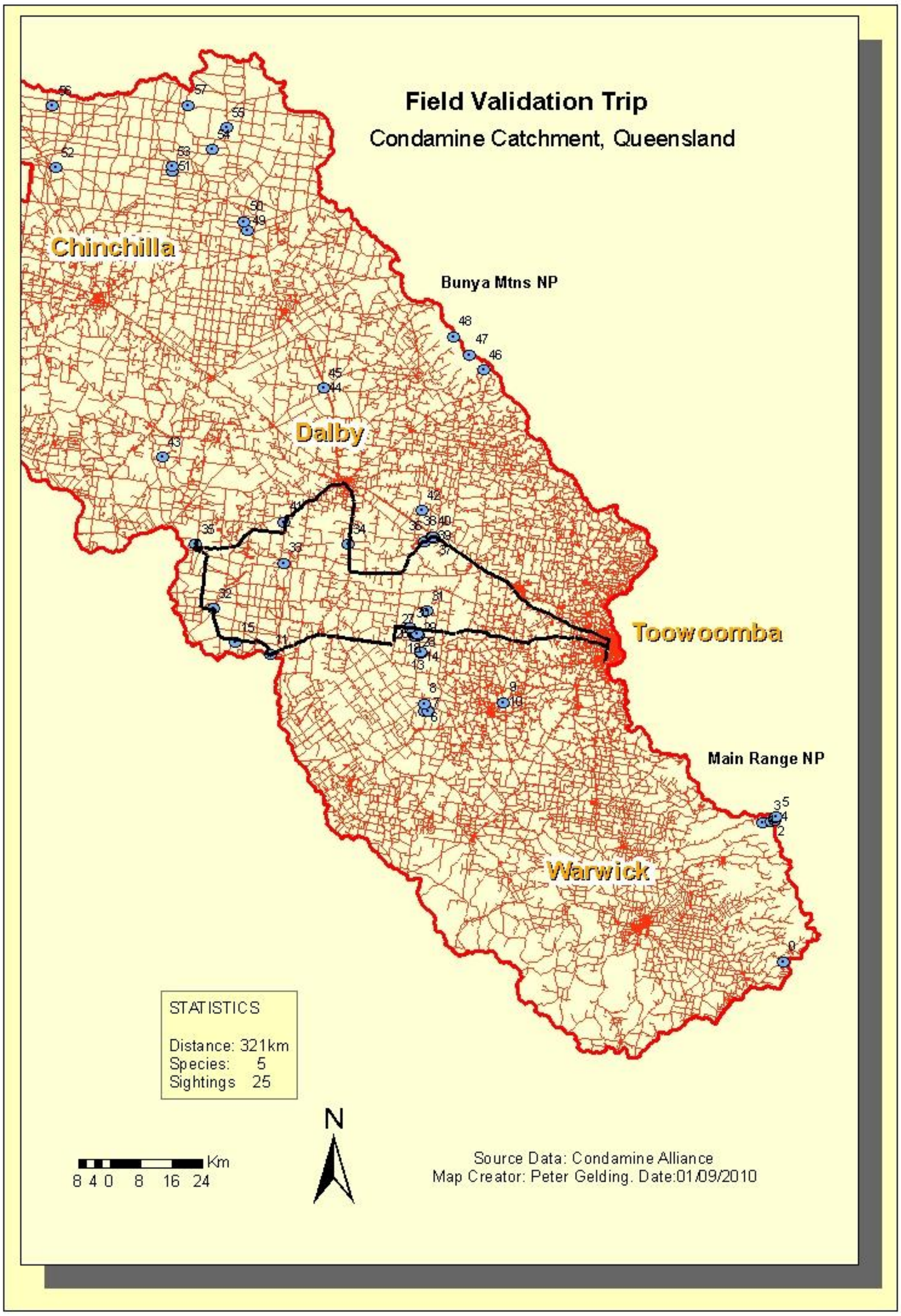

Figure 3.6: *Proposal for Field Validation Site Visit (Source: Condamine Alliance).*

CHAPTER 4

RESULTS

4.1 Introduction

Results from research in the study area are presented. Mention is made of reptiles as the focus species and their spatial relationship to vegetation communities. The reptile species regarded as at risk are listed. The influence of roads and settlement in proximity to the reptilian habitat is seen as a factor in their survival. Some sightings of reptiles have occurred in Nature Reserves, Protected Areas (such as State Forests) and in National Parks. Natural and anthropogenic threats to reptile species are presented in the light of the findings of the study. The edge effect at the ecotone was briefly investigated.

4.2 Results Highlights

- **Possible priority locations for investment for threatened reptiles included vegetation communities related to reptile sightings totalling 40,887 hectares in area, of which 27,889 hectares also contained other non-reptile endangered, vulnerable or rare species.**

- Of the 10 reptile species studied, 100% were found within 100 metres of a road at least once.

- 61% of vegetation patches related to reptile sightings also had sightings of other significant species (in classes such as insecta), so any investment into threat abatement in these areas could have positive impact on other threatened species as well.

- 50% of the threatened reptile species were located in National Parks, State Forests or Reserves.

- 18 regional ecosystems were found to be related to the 58 sightings of 10 reptile species studied.

- 70% of total reptile species occurred in “Conservation and natural environments” and 60% of species also were found in “Production from relatively natural environments”

- The ecotone edge effect could not be determined from the data. Results were inconclusive in this study

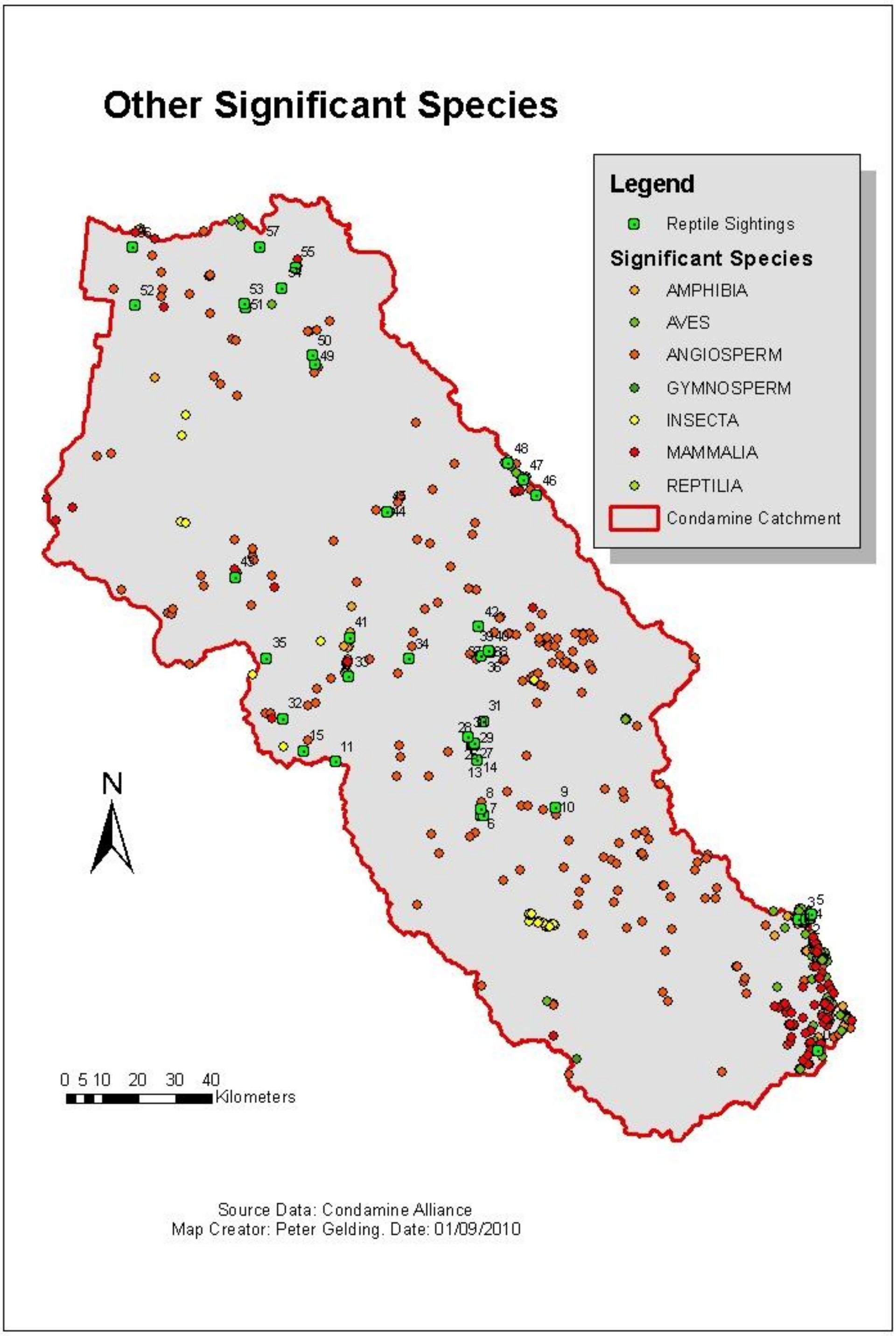

Figure 4.1: *Other Significant Species within Selected REs (Source: Condamine Alliance)*

(Source: Condamine Alliance)

4.3 Reptiles at Risk – the Priority Species

The Condamine Catchment was the chosen study area. It covers an extent of 24,434 km^2 from Chinchilla in the north to Warwick in the south and encompassing Dalby, Toowoomba and other important towns and localities. From a biodiversity dataset containing 60,178 sightings of flora and fauna species, the focus was narrowed to 3689 sightings of species (6%) considered endangered, vulnerable or rare according to NCA status.

The study was further narrowed to include only reptiles. Representing less than 2% of total sightings, reptiles accounted for 13% of the species identified as threatened. Thus the impact of reduction, degradation or removal of reptilian habitat was considered to have a disproportionate effect on biodiversity.

61% of vegetation patches related to reptile sightings also had sightings of other significant species, so any investment into threat abatement in these areas could have positive impact on other species as well.

All the 10 species of threatened reptiles (two were skinks with no common name) are considered important. As previously mentioned, the golden-tailed gecko and brigalow scaly-foot are endemic to the bioregion. The brigalow scaly-foot and the long-legged worm skink are found in endangered regional ecosystems. The collared delma, the yakka skink and the long-legged worm skink are priority reptiles in the “Back on Track” strategy (DERM 2010b).

Accordingly, it is possible to consider these named reptiles as higher priority. The grassland earless dragon is also considered high priority because it has only been found on private land in farming areas (perceived higher threat risk) and is endangered in Queensland and nationally.

National Parks, State Forests and Nature Reserves.

It was found that 60% of the threatened reptile species were located in National Parks, State Forests or Reserves.

Biodiversity Status

While there is a clear correlation between VMA Class and Biodiversity Status (Table C1), one RE was described as of "least concern" VMA class but "of concern' biodiversity status. This was RE 11.3.27a, freshwater wetlands, where a single golden-tailed gecko was sighted in 1993.

4.4 Vegetation Communities – the Priority Ecosystems

Regional ecosystem 11.3.21 is considered endangered (DERM 2010c).

It is described as

> *Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils*

This ecosystem is home to the long-legged worm skink (*Anomalopus* *mackayi*) with five recorded sightings over a two year period.

The other endangered regional ecosystem in the study area is 11.4.3

> *Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains*

in which the Brigalow scaly foot (*Paradelma orientalis*) finds habitat.

A total of 18 regional ecosystems were found to be related to the 58 sightings of 10 reptile species studied. These REs are listed in Table C1: REs and Reptile Sightings, together with their associated reptiles and shown in figures 4.2a – 4.2d. Areas of vegetation patches are listed in Table C2.

The selected vegetation communities related to reptile sightings totalled 40,887 hectares in area, of which 27,889 hectares also contained other non-reptile endangered, vulnerable or rare species.

<u>Land Use</u>

Overlay of Queensland Land Use 1999 revealed that 70% of total reptile species occurred in "Conservation and natural environments" and 60% of species also were found in "Production from relatively natural environments". Although important to the region's biodiversity, only 2 species each were found in "Dryland" and "Irrigated" agriculture and plantations respectively.

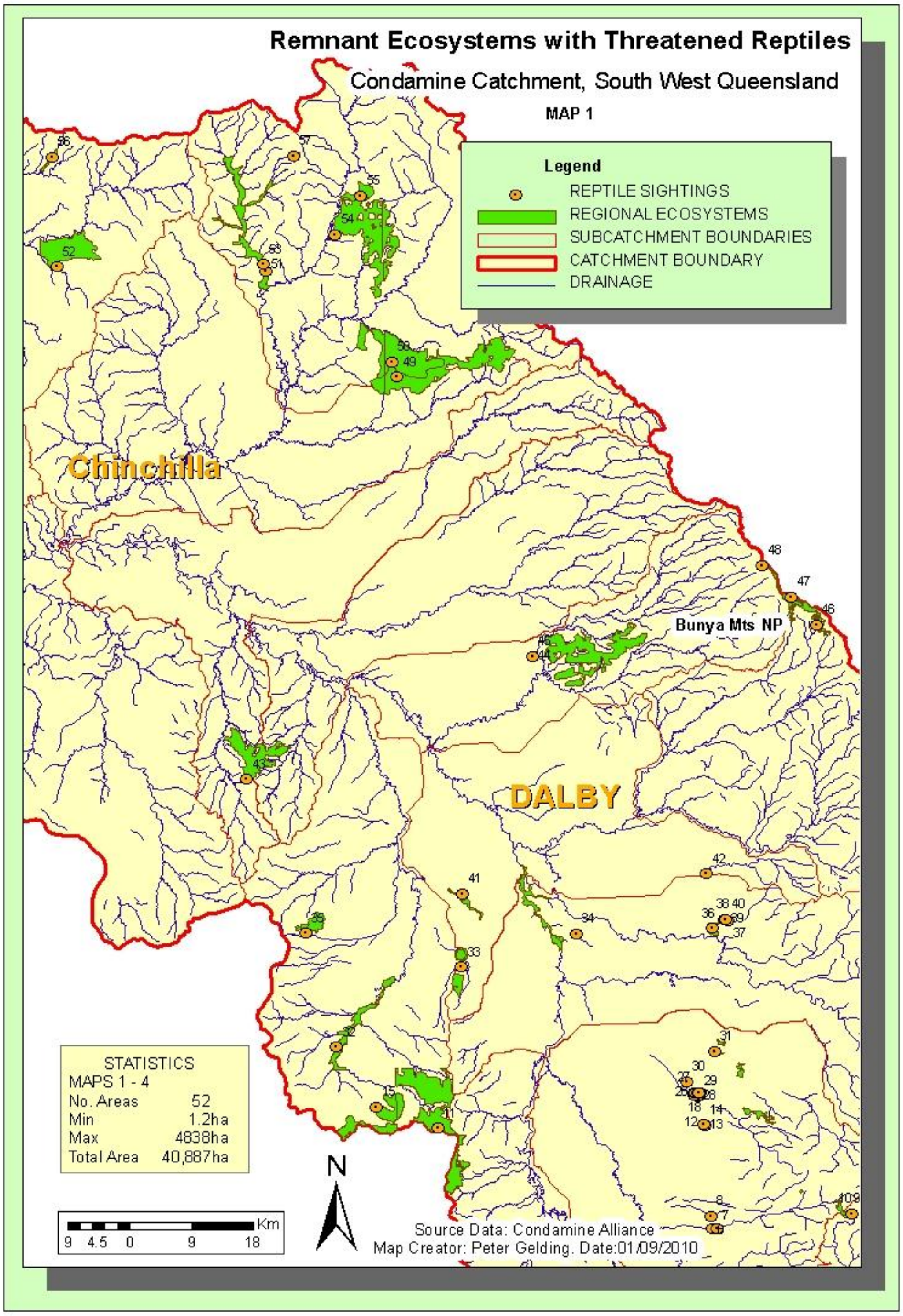

Figure 4.2a: *Remnant Ecosystems with Threatened Reptiles Map 1. Sighting numbers correspond to the numbered list of reptile sightings in Table C1. (Source: Condamine Alliance)*

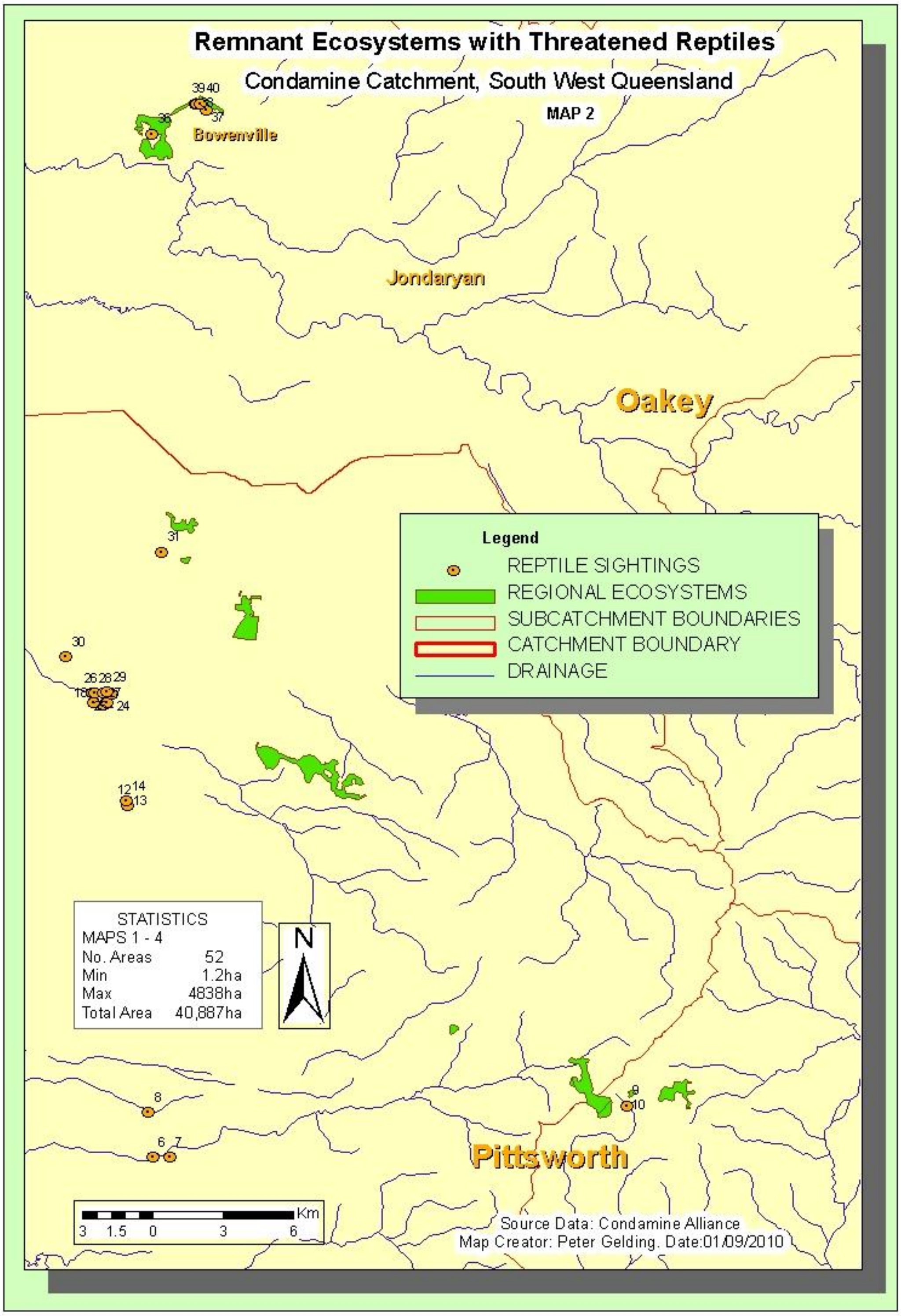

Figure 4.2b: *Remnant Ecosystems with Threatened Reptiles Map 2. Sighting numbers correspond to the numbered list of reptile sightings in Table C1. (Source: Condamine Alliance)*

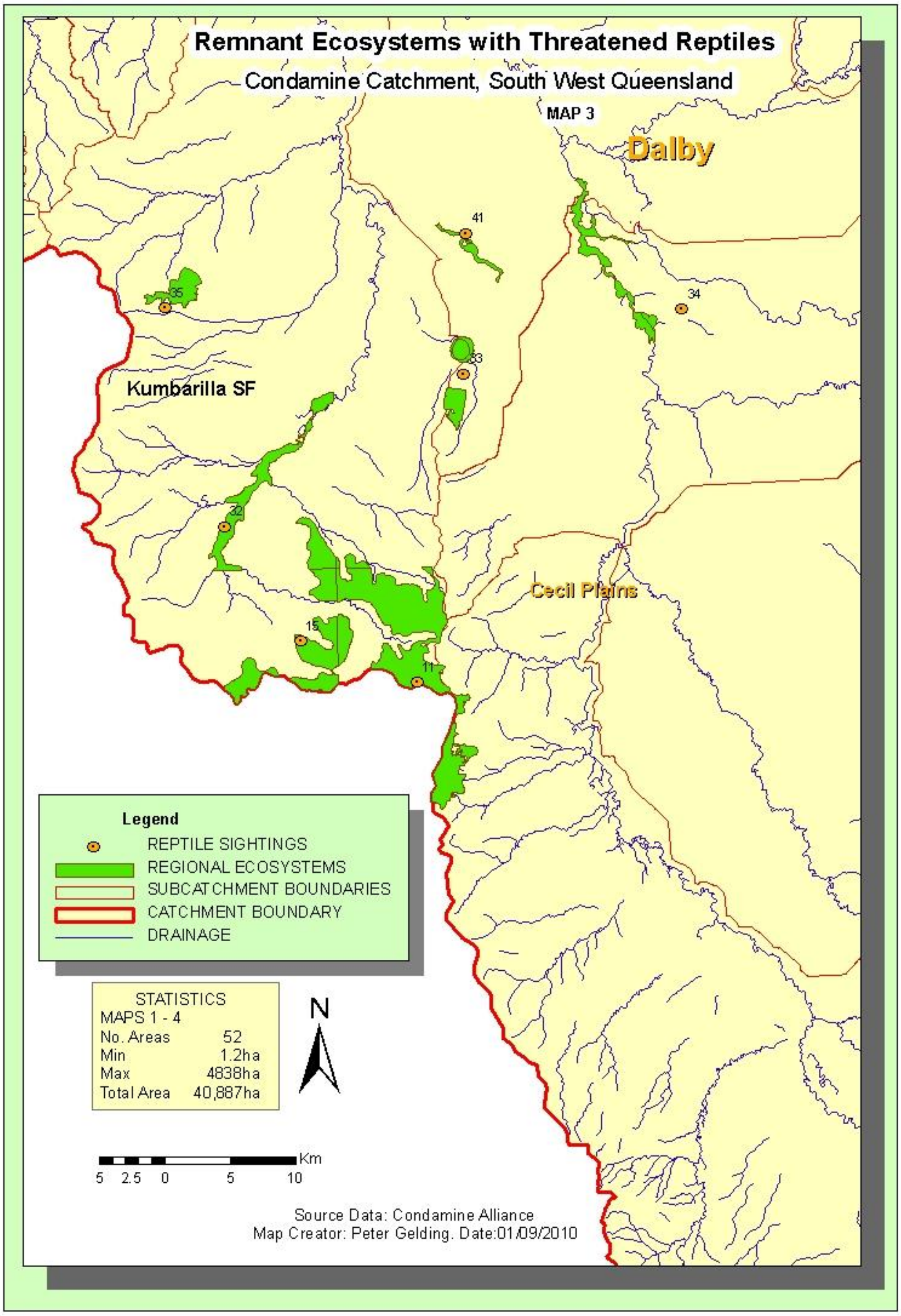

Figure 4.2c: *Remnant Ecosystems with Threatened Reptiles Map 3. Sighting numbers correspond to the numbered list of reptile sightings in Table C1. (Source: Condamine Alliance)*

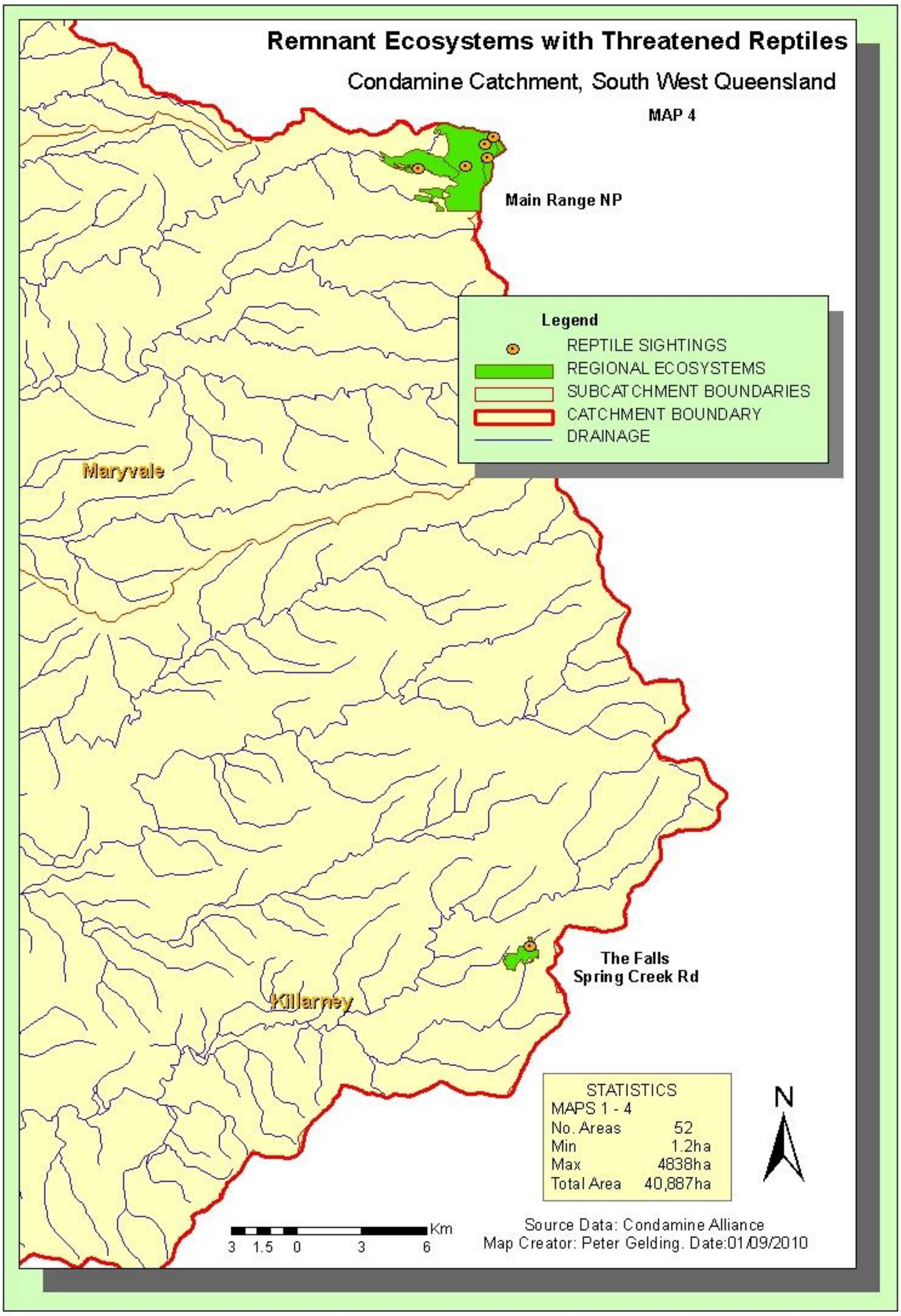

Figure 4.2d: *Remnant Ecosystems with Threatened Reptiles Map 4. Sighting numbers correspond to the numbered list of reptile sightings in Table C1. (Source: Condamine Alliance)*

4.5 Proximity to Roads and Settlement – a Major Influence

The study found that reptiles are most often seen beside roads. Of the total sightings, 64% were either beside or within 100metres of roads. 83% of all sightings were within 500metres of roads.

The grassland earless dragon (T*ympanocryptis pinguicolla*) was significant, representing 43% of all sightings. Just over half of these, 56%, were within 100 metres of a road. However the most important fact was that of the 10 reptile species studied, 100% were found within 100 metres of a road at least once.

4.6 Reserves and National Parks – a potential haven

60% of the threatened reptile species (28% of sightings) were located in National Parks or Reserves, which afford some protection from human intervention. Feral animals are probably discouraged from these areas but it is not known how effective animal management and control has been in Main Range NP or Bunya Mountains NP.

4.7 Threats – natural and anthropogenic

The draft "Back on Track" report (DERM 2010b) described threats specific to reptiles which can be applied to the present study. These are summarised for reptiles common to both studies in Table 2.1

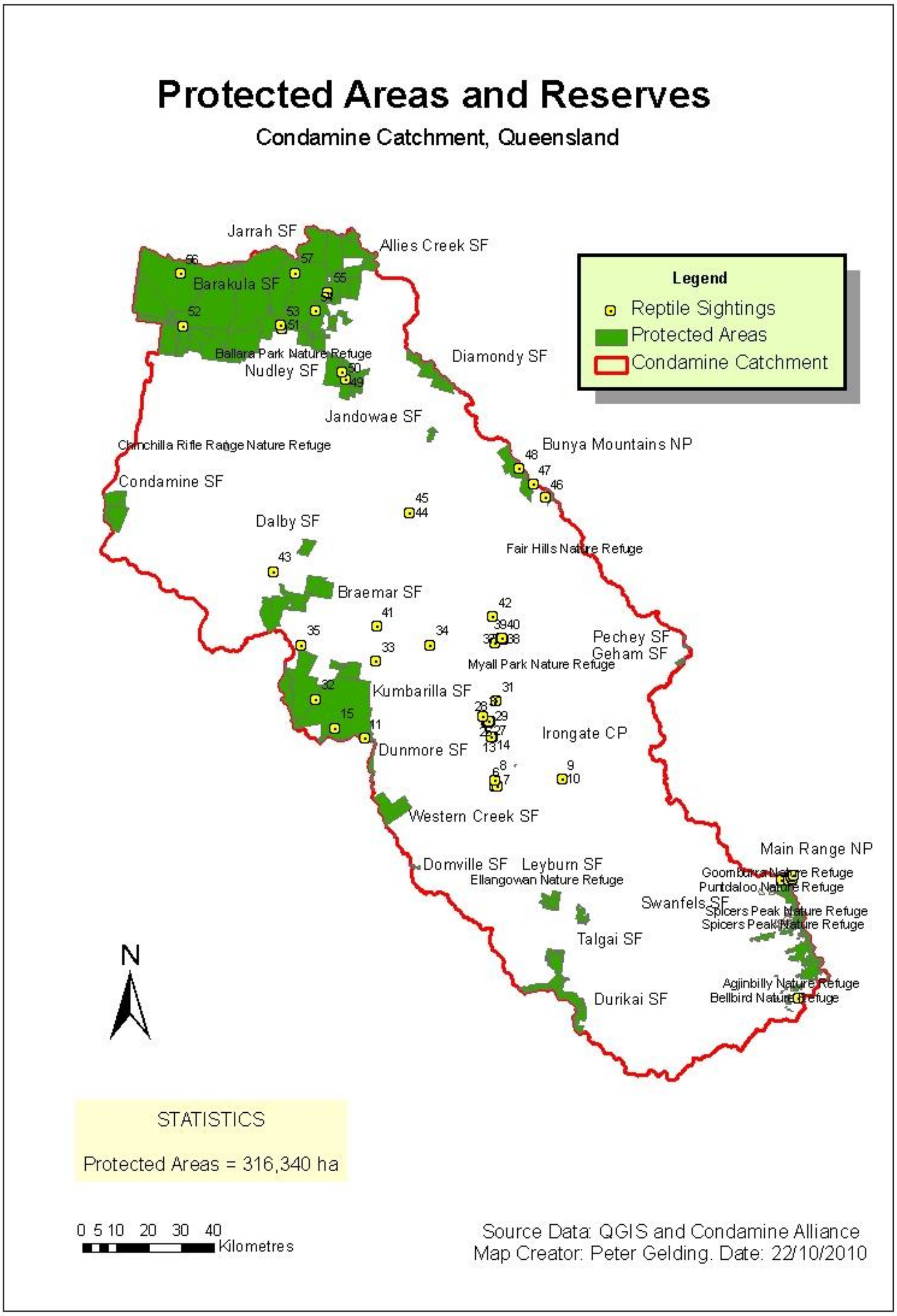

Figure 4.3: *Protected Areas and Reserves (Source: QGIS, Condamine Alliance).*

4.8 The Ecotone Edge Effect – a focus for future study

The ecotone is a transition area of vegetation between two different floral or plant communities, such as forest and grassland (Britannica 2010).

As such, some of the characteristics of both communities are found in the ecotone. Often unique species are also found which are not present in the bordering vegetation systems. It can be a blending of two communities in a portion or fragment or can exist as a band or belt of overlapping vegetation.

The edge effect (the influence of the two bordering communities on each other (Britannica 2010) could not be determined from the data. Results were inconclusive in this study due to the volume of cleared and non remnant vegetation in the catchment and the dispersed nature of the sightings data. However this is a fertile area for further research.

4.9 Conclusion

The study results, as summarised in 4.2 Results - Highlights fulfilled the objectives of the project and are discussed in the next chapter.

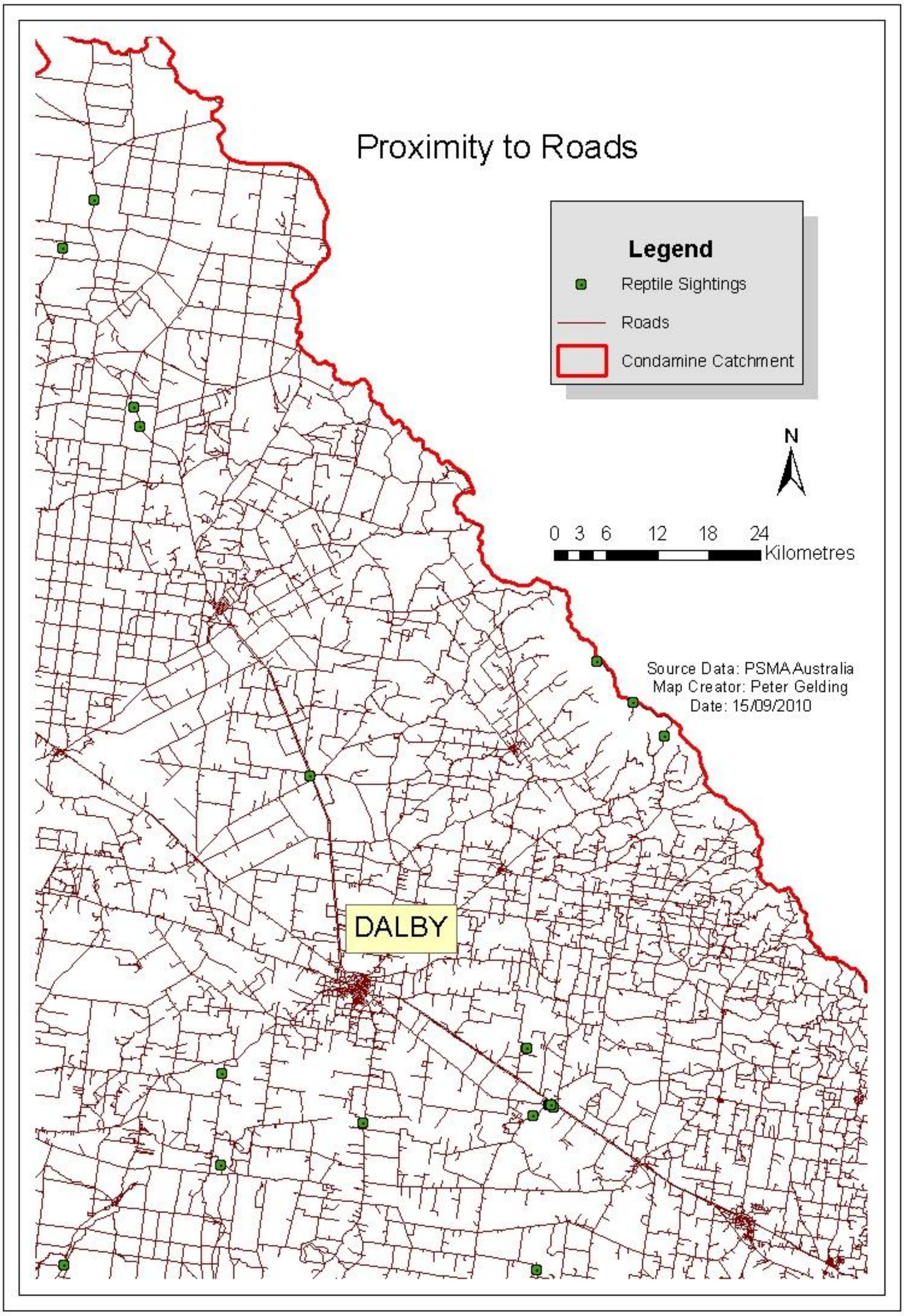

Figure 4.4: *Proximity of Roads to Threatened Reptiles (Source: PSMA Australia).*

CHAPTER 5

DISCUSSION

5.1 Introduction

The intention of this chapter is to present interpretations of the results that are sound, logical and complete. As this unfolds, it is hoped that the author's increasing understanding of the power and yet simplicity of Boolean operations in a GIS to present useful results is communicated.

Figure 5.1: *Collared Delma (Source: Reptiles Down Under 2010)*

The process of narrowing focus from some 60,000 sightings of flora and fauna to the 58 sightings of 10 reptile species studied was a journey. The selection of priority ecosystems depended on the locations of the reptile sightings. The final selection was manual and this is addressed.

The main input for the study was data of various types from different sources. Discussion of the data quality is based on the metadata files and no opinion is expressed on their veracity – it is assumed.

The processes and methods used in the study form a model, albeit an informal one. The model validation is discussed briefly.

Options for further study are canvassed. Clearly this study is only one step towards a better understanding of reptilian occurrence in the Condamine Catchment. For example, the whole subject of roads and the influence of roads and settlements on reptilian survival is complex and interesting and beyond the scope of this research. The topic opens more questions than it answers.

Figure 5.2: *Long-legged Worm Skink (Source: Wilson 2010)*

5.2 Interpretation of the Results

5.2.1 Priority Locations

Reptiles were the focus species group for this research. The area of selected remnant vegetation in regional ecosystems falling in the proximity of reptile sightings was calculated to be 40,887 hectares. This amounts to just 1.67% of the land area of the Condamine Catchment. This result is unexpected since the region is known as a 'hotspot' for reptiles' (Richardson, 2008) and a larger area of vegetation was thought likely. A possible reason for this is that although sightings of threatened reptiles in the data amounted (coincidentally) to one sighting per 42,000 hectares of the entire catchment, a number of sightings were clustered (see figure 2.2). Consequently the remnant vegetation in proximity to those clustered sightings may have been smaller in area than if the sightings had been dispersed.

The regional ecosystems in proximity to threatened reptile sightings are listed in Table C1 in the Appendix. The 58 sightings of 10 reptile species were thus related to 18 regional ecosystems. These included eucalyptus forests and woodland as well as *Dichanthium sericeum* (blue grass) and/or *Astrebla* species grassland on alluvial plains.

A significant number, 87% of sightings of *Tympanocryptis pinguicolla* the grassland earless dragon were in non-remnant vegetation. Whilst most of these sightings (75%) were within 600 metres of a watercourse, others were found more than 3 kilometres from the nearest stream. The significance of this is not known however for future research temporal mapping of sighting data with rainfall records (beyond the scope of this study) may yield information as to the effect of low rainfall periods, or drought, on reptile dispersion. Discussion on the taxonomy of *Tympanocryptis pinguicolla* and its similarity or otherwise to species found in ACT is beyond the scope of this study (Richardson 2008).

Non-remnant vegetation zones were not included in the summation of regional ecosystem areas totalling 40,887 hectares. The sightings in non-remnant patches are significant because decisions regarding species conservation there will differ from threat abatement plans for ecosystems (DERM 2010b). Land clearing has already occurred and the species appears to have to some degree accommodated to changes in habitat. Verification that clearing had in fact occurred at grassland earless dragon observed sites was able to be confirmed from SPOT5 images and from Google Earth (see figure 2.4) as well as from overlay of the DCDB dataset.

Figure 5.3: *Yakka Skink (Source: Redtailboa 2010)*

Analysis of the presence or absence of particular reptile habitat within the regional ecosystems is beyond the scope of this study. General recommendations for maintenance of fauna habitat are found in the literature such as Powerlink Queensland 2007 cited in USQ (2010 p.145). The maintenance of vestiges of cleared vegetation such as fallen trees, hollow logs and leaf litter micro habitats and other reptile-friendly environments is recommended (USQ 2010).

No research studies were discovered which attempted to quantify the hectares of remnant vegetation and/or regional ecosystems linked to reptile sightings. Current emphasis appears to be on quantifying species richness (the number of species detected within an area) or species evenness (the frequency of the individuals detected per species). Species relative abundance is also measured (Hutchens and DePerno 2009). Other models such as the Habitat Suitability Index (1-1ST) developed by the U.S. Fish and Wildlife Service constitute a basic mathematical technique for quantifying the quality of wildlife habitat (Larson et al. n.d.).

5.2.2 Other Significant Species

Once the vegetation patches of interest were established, overlay in the GIS identified those patches where significant sightings of other species also occurred. It was found that 61% of vegetation patches related to reptile sightings also had sightings of other significant non-reptilian species that are endangered, vulnerable or rare (figure 4.1). This is a significant finding. These patches assume the highest priority for investment because the potential return is greater, since there is the implication or possibility that more than one threatened species can be conserved or protected from threats. Conversely, it is important that the presence of other threatened species is recognised so that action towards reptile habitat maintenance does not inadvertently have a negative impact on another faunal or floral species within that ecosystem.

5.2.3 Proximity to Roads

Reptiles were found beside roads. All species studied were seen at least once within 100 metres of a road. This was expected because reptiles are generally too small to be discovered by remote sensing and field data is collected by personnel driving to locations along roads. It is not known if some sightings may have been by serendipity, some of road strike victims. Possible other reasons for roadside sightings include the attraction of bitumen road surface temperature to reptiles seeking warmth. Cold blooded reptiles are known to spend long periods in sedentary behaviour exposed to warmth from the sun (Schmidt-Nielsen 1998). As the day ends, direct sun radiation is reduced however roads and settlements provide residual warmth. It is not known whether species sighting data was collected during daytime or at night, so no conclusions can be made in that regard. A well-known herpetologist claims that dry, moonless nights in summer are the times reptiles are most frequently observed beside or crossing roads (Hoser 1995). Hoser also recorded large numbers of road strikes in the Pilbara region in proportion to observed live specimens.

In the case of *Anomalopus mackayi (long-legged worm-skink) "Back on Track"* agrees that the species is found mainly on roadsides where remnant habitat exists and concludes that road maintenance is a major threat and cause of habitat degradation for the species:

> *“Inappropriate roadside management (e.g. slashing too close to the ground, road widening and encroachment of farming land onto roadsides) is a major threat to this species especially between Toowoomba and Dalby”* (DERM 2010b).

Vegetation along roads verges may also be a haven for reptiles. Typically, this vegetation is maintained by local councils on a rotation basis, allowing grasses and bushes to grow enough to provide shelter for reptiles. This shelter may be attractive especially when the neighbouring land use is cultivation and subject to seasonal ploughing.

Figure 4.4 clearly showed the influence of roads as proximity to reptile sightings in the Dalby area. This factor was found throughout the catchment. Disturbance from incidental human activity such as vehicle or pedestrian traffic may have flushed some individuals into open areas. Other studies, such as Lunney and Barker (1986) have found most species located in forest and woodland and roads were not a factor.

An implication for this study is that roads are easier places to find reptiles but may not be the best indicators of species population density. An unanswered question is “what proportion of the species population is represented by roadside sightings?” In other words, are reptile species over-represented by roadside sightings compared with their occurrence in their natural environment? This presents opportunity for further research.

The assumption made was that any sighting is a sighting and the Boolean logic of reptile sighting AND regional ecosystem (intersection) provided a vegetation patch of interest of known area (hectarage). Reptile sightings near roads which were in non-remnant vegetation areas did not contribute “priority area” in terms of calculated regional ecosystem hectares for the study, which is a perceived weakness. Habitat and soil structure are potentially more important for the maintenance of terrestrial reptile species than floristics (Richardson 2008).

To increase the area for priority locations for investment an arbitrary buffer zone around sightings in non remnant vegetation zones was considered but rejected as not meaningful in the context of maintenance and preservation of regional ecosystems.

Roads are also one of the indicators of the extent of land clearing in the catchment. Obviously without land clearing there would have been reduced economic benefit to the catchment, at least in terms of prevailing agricultural practices in the past century. However, the cited references in the literature survey without exception decry the extent and volume of land clearing in Queensland up until 1999, 60% overall reduction in native vegetation since 1975 in Eastern Darling Downs alone (Le Brocque, AF et al. 2003). Further land clearing, if it were to occur, would require careful management to avoid loss of biodiversity.

Some reptiles thrive near human settlement, increasing the danger from aggressive domestic animals. No data was available regarding threats from feral pigs, foxes or cats, which are known to impact several reptile species adversely (DERM 2010b).

5.2.4 Land Use

Using 1999 as a base year, the Land use dataset for Queensland contained five land categories plus water. Figures 3.5a and 3.5b show their distribution along with the reptile sightings. As expected. A majority of species, 70% were found in "Conservation and natural environments" category and a majority of species, 60% were also found in "Production from relatively natural environments". As a comparison, Lunney and Barker (1986) found that over a five year period 86% of species were found in State Forests, 71% of species were found in coastal National Parks and only 38% in cleared farms, creeks and rivers. Their study is important because after intensive search over successive years, no new species were found and they believed that all species of reptiles and frogs that currently occurred in the study area were found (Lunney and Barker 1986).

Although important to the Condamine Catchment's biodiversity, only 2 species each were found in "Dryland agriculture and plantations" and "Irrigated agriculture and plantations" respectively. This was unexpected since those categories comprise the major land uses, by area, in the catchment. The grassland earless dragon was exclusively sighted in these land use categories (figure 2.2). The implication is that this reptile has a habitat that is more vulnerable to anthropogenic intervention than those afforded the protection of reserves and national parks. DERM confirms the nature of its known habitat in that all specimens are known from highly modified agricultural land which are small holdings devoted to strip-farming of mixed crops (DERM 2010g).

5.2.5 National Parks, State Forests or Reserves

60% of the threatened reptile species were located in National Parks, State Forests or Reserves. This was consistent with the overlay with land use previously described that concluded 70% were found in the “Conservation and natural environments” category. These reptiles are assumed to be at less risk than individual reptiles that comprised the 60% of species which were also found in “Production from relatively natural environments” and at even less risk than those in agriculture and plantations environments. The overlap of species habitats into different land use categories is seen as positive, however an implication is that threat abatement policies that recognise all possible habitats will be the most successful (DERM 2010b).

5.2.6 Ecotone Edge Effect

No pattern was observed that would suggest the presence or absence of ecotone edge effects in this study. Patch shape affects composition and abundance of species at the edge of a patch compared to its interior (APAN et al. n.d.). The variation found in vegetation communities and the disparity in patch sizes in the study area resulted in a number of field / forest, field / stream and forest / stream edges that could be the subjects of further research. Landowners adjacent to National Parks and reserves could be targeted for assistance with reptile management should an ecotone effect be established (DERM 2010b).

5.3 Data Quality

5.3.1 Currency and Consistency

Datasets obtained from Condamine Alliance including catchment boundaries, the Digital Cadastral Database, SLATS foliage (2003), regional ecosystems (2009) and sighting data of species under the VMA classes (2010) were all current at the time of the study.

The dataset of species sightings contained records from 1960 to 2005 gathered by WildNet and Queensland Herbarium. Of these 98.4 % were during the last two decades.

There were no inconsistencies when datasets were overlaid for analysis.

5.3.2 Coverage

There did not appear to be any gaps in the data which covered the complete study area. Georeferencing was necessary for some datasets but this was easily accomplished within the software and the projected data adequately covered the catchment.

5.4 Model Validation

The application of a simple model relying on overlay of vector data structure datasets using Boolean logic to sieve results was appropriate for this study. Locations of interest were found. Subsequently a manual method was used to select regional ecosystems in proximity to reptile sightings. This could have been achieved by allocating variable buffers and intersection, however the number of sightings (58) lent itself to a manual method which also had the benefit of analyst scrutiny to avoid inappropriate patch selection. Polygon slivers were also removed at this time.

Since the input data was highly regarded, the necessity for validation was concentrated on the map output. Selected vegetation community patches were checked one by one with the SPOT5 image mosaic in the visible bandwidth of the catchment area. A correlation was found between cleared and uncleared vegetation in the study results and respective regions in the check image. Similarly, Google Earth images validated the study results. It was beyond the scope of this study to further define the regional ecosystems represented by the uncleared vegetation communities. A field validation site visit of approximately 300 kilometres would cover a sufficiently representative sample of both reptile species and regional ecosystems. A sample proposed field trip is shown in figure 3.6.

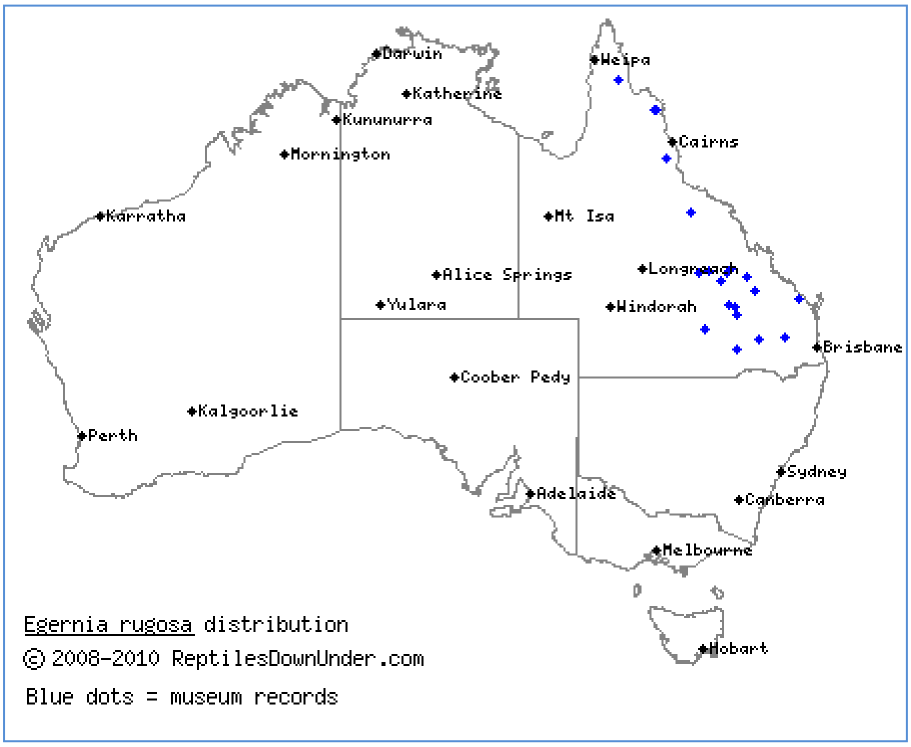

Figure 5.4: *Yakka Skink is Found Only in Queensland (Source: Reptiles Down Under 2010b).*

5.5 Options for Future Study

There are a number of interesting possibilities for further study which have arisen. The nexus between reptiles and threatened amphibians could be explored within the catchment. Also the proximity of other significant species both floral and faunal and their relationship with threatened reptiles could be investigated.

The small number of sightings of threatened reptiles for this study (a total of 58 sightings for 10 species) precluded meaningful statistical analysis beyond basic algorithms. If a larger number of sightings could be documented by a concentrated field effort, other possibilities for spatial analysis could emerge.

The nature of threats has been discussed briefly. These included road and site maintenance, grazing regimes, clearing of vegetation, fire regimes, feral animals and weed infestation (Table 2.1). Linear infrastructure development such as pipelines and bores will increase within the study area as mining projects come on stream in the years ahead. This represents a very important focus area for future research.

Much could be done to study the efficacy of threat abatement methods. The proximity of roads which impact some of the studied reptiles, in particular the grassland eared dragon, puts focus on cultivated land. The education of landholders and the ongoing results of policies and practices in farm management with respect to reptile colonies could be usefully studied. “What is it about roadsides that attracts reptiles?” is another valid question.

Temporal mapping of sighting data together with rainfall records may yield information on reptile dispersion during periods of low rainfall such as experienced in the past ten years.

Temporal studies of regional ecosystems in the decade ahead to compare results with the findings of the present paper would be of value. With clearing of vegetation now regulated, are there natural processes at play which will impact reptile microhabitat in the future?

Other study areas could be selected for comparison with results in the Condamine Catchment.

A more rigorous study of reptiles in the study area may uncover other threatened reptile species or re-establish the rarity of those already documented.

5.6 Summary of Discussion

The study objectives were to identify and recommend priority locations within the Condamine Catchment for future investment in threat identification and abatement for species and ecosystems with focus on reptiles.

Prioritiy locations were identified. Reptiles, the focus species group for this research were in proximity to 18 regional ecosystems of smaller total area than expected. This selected area of 40,887 hectares forms the priority focus for investment in threat abatement.

Non-remnant vegetation regions adjacent to some species sightings have also been identified but not quantified. Threat management in this location will differ from that in regional ecosystems and will depend on the actions of private landowners.

All reptile species studied were seen at least once within 100 metres of a road. One of the questions raised by this phenomenon is “What proportion of the species population is represented by roadside sightings?”

A majority of species were found in protected areas - national parks, state forests and reserves. These are perceived to be at least risk and have the greatest opportunity for continued successful threat abatement.

Data currency, consistency and coverage were considered adequate for the study.

Model validation was achieved by comparing vegetation patches selected for priority with SPOT5 visible bandwidth image and Google Earth. This was restricted to remnant vegetation and cleared areas without correlation of specific regional ecosystems.

Further study would be useful in reptile / amphibian relationship or presence of other significant species within reptile habitats. A similar study could be made in another catchment. Linear infrastructure development may be important as mining projects expand in the future. The effect of road proximity needs better understanding. The success of threat abatement methods could be researched. Some temporal studies could be made.

Figure 5.5: *Grassland (South-Eastern Lined) Earless Dragon Camouflaged (Dollery 2002)*

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the conclusions determined from the conduct of the study with respect to the project's general aims and specific objectives introduced in Chapter 1.It describes the overall success of the application of methods to process and analyse the data and its suitability for identifying priority locations for investment in threat identification and abatement. The chapter concludes on the significance, implications and relevance of this project. Recommendations are made for practical applications of the study and for any future research.

6.2 Conclusions

The methods in this study represent an effective way of taking point data, in this case sightings of threatened reptiles in a catchment and by applying Boolean logic in a GIS, mapping polygon locations of interest. A relationship by proximity was established between reptile sightings and habitat as represented by regional ecosystems.

Vegetation communities as patches within ecosystems were identified as priority locations for investment. This is important because limited resources to be applied towards threat identification and abatement need to be directed towards locations that will yield the best outcomes. The assumptions behind the selection of vegetation communities for priority may be altered through changing circumstances or greater knowledge but the method remains applicable. GIS-based processing together with readily available datasets yielded clear results in achievement of the study objectives. Thematic data layers could be georeferenced, clipped and processed to yield different visual and statistical results in graphical and tabular form. ArcGIS was well suited to this task. In this study once relevant regional ecosystems had been identified, thematic layers of land use, roads, drainage and protected areas were also useful in supporting and strengthening selection criteria.

Improvements to the study can be made by applying more advanced spatial analysis to measure spatial distribution, clustering or dispersion of species and ecosystems. In this project the relatively small number of data points precluded meaningful use of these techniques. Another improvement could be the application of variable buffers to species point data to intersect vegetation patches. A more analyst-intensive method was adopted which gave good results after only a few iterations.

The project methods would be quite suitable for future temporal studies to address issues of change of habitat in threat management. Datasets of linear infrastructure development were not available for this study but would have been useful, since linear infrastructure is a potential major threat to ground dwelling reptiles.

Validation by comparison of final map output with a SPOT5 visible bandwidth mosaic image gave acceptable confidence that study methods were correct. For gross cross-checking a visual comparison with Google Earth gave quite a good correlation with cleared and remnant vegetation. The proposed site visit for field validation would be a useful adjunct to the project.

6.3 Recommendations for Practical Applications

The priority locations identified are appropriate starting points for further investigation. Additional data such as reptile microhabitat within the selected regional ecosystems would serve to concentrate efforts in threat identification and abatement. Those locations outside of currently protected areas could be targeted for special consideration and possible future protective measures, for example, declaration of additional nature reserves. Locations adjacent to parks and reserves could be identified and any private landholders brought into discussions about current and future threats to reptiles and means to minimise impact on their habitat. Roads are a particular hazard for reptiles and studies into engineering controls to minimise vehicle strikes and provision of “pseudo-roads” (warm, sun-exposed platforms attractive to reptiles in safe locations) might be considered.

The study sample size entailed taking the combined data for 10 reptile species of interest. If each species could be analysed separately in a meaningful way, perhaps by a parallel study in a different catchment with substantially higher species density then species-specific threat abatement measures might be developed.

Those vegetation patches with other non-reptile threatened species in addition to reptile sightings should be targeted as high priority because of the probable higher benefit to cost outcomes. However the presence of other significant species should also be established so that inadvertent negative impacts to them from threat abatement directed towards reptiles does not occur.

6.4 Recommendations for Future Research

As discussed in chapter 5, linear infrastructure development such as pipelines and bores will increase within the study area in the years ahead since mining projects are expected to expand. This represents a very important focus area for future research because reptiles are often associated with terrestrial microhabitat (rocky outcrops, loose soil etc.) more than floral species and linear infrastructure development typically disturbs the ground surface.

Temporal mapping of sighting data to record reptile dispersion during periods of low rainfall such as experienced in the past ten years in the study area could yield information for appropriate actions to be taken in future drought conditions.

Similarly, taking the results of the present study as base data, temporal studies of regional ecosystems over the next ten years would be of value. Clearing of vegetation is now regulated in Queensland, however there may be natural and anthropogenic processes which will impact reptile microhabitat in the future.

Other study areas could be selected for comparison with results in the Condamine Catchment. Collaboration in research projects is recommended because information flow in and out of the study area would be beneficial to all concerned.

APPENDIX A

PROJECT SPECIFICATION

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR:	PETER GELDING
TOPIC:	PRIORITISING INVESTMENT LOCATIONS BASED ON THREATS TO SPECIES AND ECOSYSTEMS WITHIN THE CONDAMINE CATCHMENT
SUPERVISORS:	Assoc Prof Armando Apan (USQ) Lucy Richardson (Condamine Alliance) Jayne Thorpe (Condamine Alliance) Michelle Everingham (Condamine Alliance)
ENROLLMENT:	ENG4111 – S1, ONC, 2010; ENG4112 – S2, ONC, 2010
PROJECT AIM:	This project seeks to investigate threats to species and ecosystems within the Condamine Catchment, analyse these spatially and prioritise investment locations accordingly using a GIS.
SPONSORSHIP:	Condamine Alliance
PROGRAM:	(Issue B, 5th May 2010)

1. Conduct literature review to clarify prior work, to define legislative requirements and constraints, to define and evaluate threats to species and ecosystems, to outline current investment strategies and to identify alternative spatial analysis methods for the project.

2. Acquire spatial datasets relevant for GIS analysis.
3. Analyse datasets related to the Condamine Catchment, focusing on threats to species and ecosystems.
4. Explore associations within chosen datasets to highlight priority
   locations for future investment.
5. Record findings in appropriate formats for future studies by others.
6. Recommend priority locations for future investment
7. Submit dissertation by the due date

As time permits:

8. Make recommendations towards construction of enhanced datasets that will be able to be more easily updateable and kept current.

AGREED:

Peter Gelding__Student__________________________ Supervisor

05 /05 /2010 ___ /___ / ___

Examiner / Co-examiner

____

APPENDIX B

DATASETS

B1. Datasets provided by Condamine Alliance

Condamine Catchment: CA_ADM_CABoundary_GG_0405

CA_ADM_Subcatchbdy_GG_21106

Digital Cadastral Database: CA_ADM_DCDB_GGA0906

Essential Habitat: VMA Essential Habitat V2.1

VMA Essential Habitat Points V2.1

SLATS Foliage: CA_VEG_1991_FPC_Zero_6WM0106

CA_VEG_2003_FPC_Zero_GGM0106

Threatened Species:

CA_BIO_FINAL_ALL_COMBINED_SPECIES_DATA_250210

Regional Ecosystem: CA_VEG_RE2009V6_GG_0310

Other: DNRM Tenure Codes: DNRM_tenure_codes.pdf

Draft Condamine NRM Region "Back on Track" Actions for Biodiversity, *Taking action to achieve species conservation in the Condamine NRM region*, February 2010

Technical Documentation Associated with Vegetation Management Act Essential Habitat: vma_ehab_V2_1_tech_doc.pdf

Vegetation Management Act Essential Habitat Map1: qld_ehab_map1_V21

B2. Datasets provided by USQ Faculty of Engineering and Surveying

DEM Data for Condamine Catchment: dem25

Roads: roads_psma_ersis.shp

SPOT 5 Image 10m: sp5col10_CA.img

B3: Datasets downloaded from QGIS (Queensland Government Information Service)

IQATLAS.QLD_KOALAALL_DCDB_A

IQATLAS.QLD_LANDUSE_1999

IQATLAS.QLD_NATUREREFUGES_DCDB_A

IQATLAS.QLD_PROTECTEDAREAS_DCDB_A

IQATLAS.QLD_WORLDHERITAGE_250K_A

APPENDIX C

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

Sighting ID	Species	Common Name	RE	RE2	RE3	RE4	RE Description	RE VMA Class	BDS
0	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	12.8.5				Complex notophyll vine forest on Cainozoic igneous rocks. Altitude usually >600m	LC	NC
1	*Saproscincus rosei*	skink (no common name)	12.8.1	12.8.14	12.8.4		Eucalyptus campanulata tall open forest on Cainozoic igneous rocks	LC	NC
2	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	12.8.1	12.8.14	12.8.4		Eucalyptus campanulata tall open forest on Cainozoic igneous rocks	LC	NC
3	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	12.8.7	12.8.4			Simple microphyll fern thicket with Acmena smithii on Cainozoic igneous rocks	OC	OC
4	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	12.8.7	12.8.4			Simple microphyll fern thicket with Acmena smithii on Cainozoic igneous rocks	OC	OC
5	*Coeranoscincus reticulatus*	Three-toed Snake-tooth Skink	12.8.7	12.8.4			Simple microphyll fern thicket with Acmena smithii on Cainozoic igneous rocks	OC	OC
6	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem, roadside 65m from watercourse		
7	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem, 200m from watercourse		

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

8	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem, roadside 55m from watercourse		
9	*Anomalopus mackayi*	Long-legged Worm Skink	11.8.5			Eucalyptus orgadophila open woodland on Cainozoic igneous rocks	LC	NC
10	*Anomalopus mackayi*	Long-legged Worm Skink	11.8.5			Eucalyptus orgadophila open woodland on Cainozoic igneous rocks	LC	NC
11	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.4a	11.5.4		Eucalyptus crebra, Callitris glaucophylla, C. endlicheri, E. chloroclada, Angophora leiocarpa on Cainozoic sand plains/remnant surfaces. Deep sands	LC	NC
12	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem >3km from watercourse		
13	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem >3km from watercourse		
14	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem >3km from watercourse		
15	*Paradelma orientalis*	Brigalow Scaly-foot	11.7.7	11.5.1	11.7.5	Eucalyptus fibrosa subsp. nubila +/- Corymbia spp. +/- Eucalyptus spp. on Cainozoic lateritic duricrust	LC	NC
16	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem beside watercourse		
17	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem, 160m from watercourse		
18	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem beside watercourse		
19	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem cluster <600m from watercourse		
20	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem cluster <600m from watercourse		
21	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem cluster <600m from watercourse		

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

22	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
23	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
24	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
25	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem, 140m from watercourse		
26	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem, 240m from watercourse		
27	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
28	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
29	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem cluster <600m from watercourse		
30	*Tympanocryptis pinguicolla*	Grassland Earless Dragon					non rem, 1.2km from watercourse		
31	*Tympanocryptis pinguicolla*	Grassland Earless Dragon	11.3.4	11.3.21			Eucalyptus tereticornis and/or Eucalyptus spp. tall woodland on alluvial plains	OC	OC
32	*Tympanocryptis pinguicolla*	Grassland Earless Dragon	11.5.20	11.3.18	11.3.25		Eucalyptus moluccana and/or E. microcarpa/ E. pilligaensis +/- E. crebra woodland on Cainozoic sand plains	LC	NC
33	*Tympanocryptis pinguicolla*	Grassland Earless Dragon	11.3.27a	11.3.27d	11.5.1	11.5.20	Freshwater wetlands	LC	OC
34	*Hemiaspis damelii*	Grey Snake	11.3.2	11.3.25	11.3.4	11.3.27b	Eucalyptus populnea woodland on alluvial plains	OC	OC
35	*Strophurus taenicauda*	Golden-tailed Gecko	11.7.4	11.7.5			Eucalyptus decorticans and/or Eucalyptus spp., Corymbia spp., Acacia spp., Lysicarpus angustifolius on Cainozoic lateritic duricrust	LC	NC

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

36	*Anomalopus mackayi*	Long-legged Worm Skink	11.3.21			Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	**E**	**E**
37	*Anomalopus mackayi*	Long-legged Worm Skink	11.3.21			Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	**E**	**E**
38	*Anomalopus mackayi*	Long-legged Worm Skink	11.3.21			Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	**E**	**E**
39	*Anomalopus mackayi*	Long-legged Worm Skink	11.3.21			Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	**E**	**E**
40	*Anomalopus mackayi*	Long-legged Worm Skink	11.3.21			Dichanthium sericeum and/or Astrebla spp. grassland on alluvial plains. Cracking clay soils	**E**	**E**
41	*Hemiaspis damelii*	Grey Snake	11.3.2			Eucalyptus populnea woodland on alluvial plains	OC	OC
42	*Tympanocryptis pinguicolla*	Grassland Earless Dragon				non rem 300m from watercourse		
43	*Strophurus taenicauda*	Golden-tailed Gecko	11.7.4	11.7.7	11.7.5	Eucalyptus decorticans and/or Eucalyptus spp., Corymbia spp., Acacia spp., Lysicarpus angustifolius on Cainozoic lateritic duricrust	LC	NC
44	*Anomalopus mackayi*	Long-legged Worm Skink	11.8.5			Eucalyptus orgadophila open woodland on Cainozoic igneous rocks	LC	NC

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

45	*Anomalopus mackayi*	Long-legged Worm Skink	11.8.5				Eucalyptus orgadophila open woodland on Cainozoic igneous rocks	LC	NC
46	*Delma torquata*	Collared Delma	12.8.14	12.8.4			Eucalyptus eugenioides, E. biturbinata, E. melliodora open forest on Cainozoic igneous rocks	LC	NC
47	*Lampropholis colossus*	skink (no common name)	12.8.4	12.8.14			Complex notophyll vine forest with Araucaria spp. on Cainozoic igneous rocks	LC	NC
48	*Lampropholis colossus*	skink (no common name)	12.8.14	12.8.4			Eucalyptus eugenioides, E. biturbinata, E. melliodora open forest on Cainozoic igneous rocks	LC	NC
49	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.20	11.10.1			Eucalyptus moluccana and/or E. microcarpa/ E. pilligaensis +/- E. crebra woodland on Cainozoic sand plains	LC	NC
50	*Egernia rugosa*	Yakka Skink	11.5.20	11.10.1			Eucalyptus moluccana and/or E. microcarpa/ E. pilligaensis +/- E. crebra woodland on Cainozoic sand plains	LC	NC
51	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.1	11.5.20	11.3.14	11.5.21	Eucalyptus crebra, Callitris glaucophylla, Angophora leiocarpa, Allocasuarina luehmannii woodland on Cainozoic sand plains/remnant surfaces	LC	NC
52	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.21	11.5.1			Corymbia bloxsomei +/- Callitris glaucophylla +/- Eucalyptus crebra +/- Angophora leiocarpa woodland on Cainozoic sand plains/remnant surfaces	LC	NC

Table C1:REGIONAL ECOSYSTEMS WITH REPTILE SIGHTINGS

53	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.1	11.5.20	11.3.14	11.5.21	Eucalyptus crebra, Callitris glaucophylla, Angophora leiocarpa, Allocasuarina luehmannii woodland on Cainozoic sand plains/remnant surfaces	LC	NC
54	*Strophurus taenicauda*	Golden-tailed Gecko	11.5.1	11.5.20	11.3.14	11.5.21	Eucalyptus crebra, Callitris glaucophylla, Angophora leiocarpa, Allocasuarina luehmannii woodland on Cainozoic sand plains/remnant surfaces	LC	NC
55	*Strophurus taenicauda*	Golden-tailed Gecko	11.7.6	11.5.20			Corymbia citriodora or Eucalyptus crebra woodland on Cainozoic lateritic duricrust	LC	NC
56	*Strophurus taenicauda*	Golden-tailed Gecko	11.3.14	11.3.25	11.5.1		Eucalyptus spp., Angophora spp., Callitris spp. woodland on alluvial plains.	LC	NC
57	*Paradelma orientalis*	Brigalow Scaly-foot	11.4.3				Acacia harpophylla and/or Casuarina cristata shrubby open forest on Cainozoic clay plains	**E**	**E**

Table C2: Areas of Selected Ecosystems

AREAS OF SELECTED ECOSYSTEMS FOR REPTILE SIGHTINGS				
FID	AREA (Ha)		FID	AREA (Ha)
0	535.726215		26	2622.05087
1	118.846333		27	939.245984
2	17.792018		28	3002.173778
3	402.352718		29	4405.688123
4	2313.618087		30	369.600842
5	842.94441		31	463.83423
6	580.362524		32	74.033328
7	66.030972		33	138.585779
8	156.370903		34	97.394414
9	355.245288		35	151.929107
10	1257.646071		36	4473.485912
11	117.112673		37	225.430841
12	4838.549143		38	57.057585
13	320.353886		39	162.047144
14	1634.227458		40	6.14105
15	271.211645		41	111.755602
16	73.850871		42	3.858952
17	730.168245		43	42.295151
18	20.42894		44	7.217921
19	237.45759		45	1.182471
20	38.614438		46	4.094851
21	105.510497		47	5.683763
22	121.980817		48	563.350601
23	80.303013		49	919.973117
24	2216.164768		50	197.927215
25	4234.249685		51	131.383087
			52	22.958075

APPENDIX D

SPONSORS

D1 The role of Condamine Alliance.

Condamine Alliance are the sponsors of this Project, in cooperation with USQ Faculty of Engineering and Surveying and under the supervision of Associate Professor A. Apan.

Co-supervisors at Condamine Alliance are L. Richardson, Science Leader and J. Thorpe, Biodiversity Leader.

Condamine Alliance is a not for profit, predominantly government funded organisation and

> *is the designated regional body responsible for enabling the community to achieve sustainable natural resource management (NRM) in the Condamine River catchment, at the head of the Murray-Darling Basin. The Alliance is accredited by the Australian and Queensland governments to plan, fund and implement NRM programs under the Natural Resource Management Plan for the Condamine River Catchment* (Condamine Alliance 2010 2).

Condamine Alliance has provided access to datasets and documents (listed in Appendix B) subject to a signed non-disclosure agreement with USQ.

These datasets were essential to the conduct of this project. They included spatial information relevant to species, ecosystems and threats, cadastral boundaries and geographic features. Datasets were supported by metadata and suitable for analysis by a GIS. Data integrity, currency and accuracy are discussed in Chapter 5.

Condamine Alliance provides support via personal communication to assist the project's direction and ongoing relevance.

D.2 The roles of USQ and other educational / research institutions.

USQ plays an important role in linking staff and students with industry and not for profit bodies to further research into practical problems and issues which affect our community. USQ was the catalyst for this project which was planned to satisfy the requirements of the course units ENG4111 Parts 1 and 2 Research Project. Resources supplied by USQ included PC workstation, ArcGIS software (see Appendix B) and provision to collect, store, manipulate, analyse and display spatial data.

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