University of Southern Queensland

Faculty of Engineering and Surveying

A Habitat Suitability Index Model For the Trapdoor Spider Species, "*Arbanitis variabilis*"

A dissertation submitted by

Stephen Wade Trent

Bachelor of Science (Zoology)

Honours (Zoology)

In fulfilment of the requirements of

Graduate Diploma of Geomatic Studies (Geographic Information Systems)

October 2005

University of Southern Queensland

Faculty of Engineering and Surveying

ENG4111 & ENG4112 *Research Project*

Limitations of Use

Prof G Baker

Dean

Faculty of Engineering and Surveying

CANDIDATES CERTIFICATION

I certify that the ideas, designs and experimental work, results, analysis and conclusions set out in this dissertation are entirely my own efforts, 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.

Name: Stephen Wade Trent

Student Number: 0050018740

(Signature)

(Date)

ABSTRACT

A habitat suitability model was created for the trapdoor spider species *Arbanitis variabilis,* to delineate the species general distribution within the Maiala National Park, Brisbane, Queensland. Existing literature of trapdoor spider species microhabitats was combined with a pilot study to propose the dominant parameters associated with the focal species preferred niche. Topographic and thematic aspects including elevation, aspect, slope, drainage, vegetation, transport and public access walking tracks were used to rate the habitat suitability of areas.

As information concerning the specific interactions between the species and environmental parameters could not be discerned within the scope of the present study, tree classification ranking, additive map algebra and rule based methods were adopted to calculate the habitat suitability index for each cell. Assessment of the validity of the model by checking the ground truth has not yet been conducted.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

CONTENTS   **Page**

CHAPTER 1 - INTRODUCTION

CHAPTER 2 – LITERATURE REVIEW

CHAPTER 3 – PILOT STUDY

CHAPTER 6 – CONCLUSIONS AND SUMMARY

LIST OF FIGURES

LIST OF TABLES

Number Title   **Page**

LIST OF APPENDICES

ABBREVIATIONS

The following abbreviations have been used throughout the text and bibliography:

AHD   Australian Height Datum

DEM   Digital Elevation Model

Filename.tab   MapInfo Table

GIS   Geographic Information System

HSM   Habitat Suitability Model

HSI   Habitat Suitability Index

MI   MapInfo Version 7

PF   Permutation Factor

SQL   Structured Query Language

TIN   Triangulate Irregular Network

VM   Vertical Mapper (Contour and Display Modelling) version 2.6

CHAPTER 1 – INTRODUCTION

The Niche Concept:

If I knew what it meant I'd be rich.

Its dimensions are N,

And a knowledge of Zen

Is essential to fathom the bitch.

(Cottam and Parkhurst 1969 (from McCune2004 p3))

1.1 OUTLINE OF THE STUDY

The study aims to establish a GIS habitat suitability model (HSM) across a selected section of the trapdoor spider species, *Arbanitis variabilis*'s greater distribution. The purpose of the model was to delineate, identify and rate areas based upon available topographic and thematic information with respect to the preferred habitat of the species. The purpose and scope of this study is detailed in section 1.4 Research Objectives.

Known literature of the focal and other trapdoor spider species (discussed in Chapter 2) was combined with an initial pilot study (discussed in Chapter 3) to define and propose the species general microhabitat characteristics and the associated relationships to topographic parameters. Chapter 4 details the methods by which large scale topographic and thematic information was compiled, manipulated and rated with respect to the species habitat preference and finally, integrated into a geographic information system (GIS). The analysis and results of the preceding section are described in Chapter 5. Lastly, Chapter 6 discusses the validity of extrapolating microhabitat characteristics to large-scale topographic and thematic information.

1.2 INTRODUCTION

Rainbow and Pulleine (Main 2005) first recorded the species from the Tamborine Mountains in Queensland in 1918. *Arbanitis variabilis*'s occurs predominantly within the MacPherson Ranges, though its known range extends from Southeast New South Wales to Northeast Queensland (see Figure 1 below) (Main 2005, Williams 2002). The area selected for study was the Maiala National Park situated in the suburb of Mount Glorius, Brisbane, Queensland.
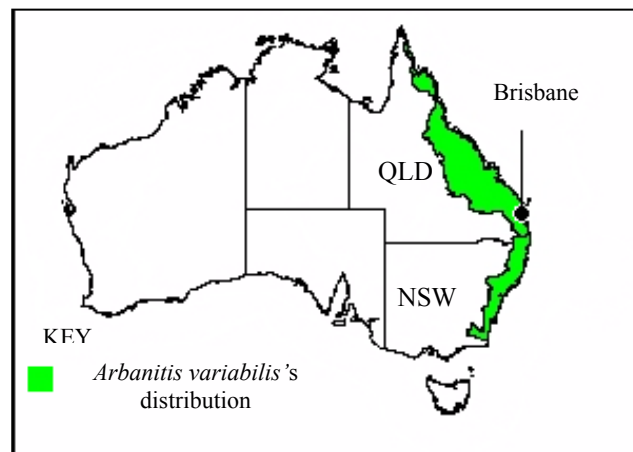
Figure 1.1: The geographical distribution of *Arbanitis variabilis* (*modified from:* Main 2005, p 1).

Although *Arbanitis variabilis*'s distribution has presumably undergone some reduction since European settlement, preliminary observations at the site suggest a healthy population of individuals. Also, as the majority of land clearing and habitation since settlement has been focussed upon areas of lower topography, and the species is presumed to occur predominantly in range formations, it is probable that much of the species original habitat may still be intact. However, as is the case with the majority of invertebrates, there is very little literature concerning the distribution, ecology and demographic status of this particular species. Nor could any literature be found with respect to habitat modelling and trapdoor spider species in general.

In recent years, many trapdoor spider species have been granted significant conservation status. For example, in the West Australian Wheatbelt, a number of species appear to be declining in remnant areas from land-use practices, secondary salinity, the

invasion of exotic fauna and weed species, fire and other processes that affect species' specific habitat requirements (Main 1987, 1999 and Main 2001.).

The acquisition of knowledge concerning the habitat requirements of a species and integration of such factors into a modelling environment may help delimit species occupied and/or suitable habitat, thus its possible range; the extent of fragmentation of its distribution; key areas of resource use; immigration and emigration routes between sub-populations; and estimates of its current and future demographic status.

Thus, habitat modelling can provide ecologists with a method of gaining insight into a specie's specific requirements and demographic status, which may not be easily achieved due to cost and time limitations associated with comprehensive field observations. In many cases concerning endangered or threatened species, the resources and time required to obtain the necessary field data to produce an effective management strategy are simply not available.

Assessing the accuracy by which microhabitat preference for trapdoor spider species, such as *Arbanitis variabilis*, can be extrapolated to large-scale topographic and thematic information through a habitat suitability model, may provide insight to the capability of such models in helping achieve conservation and management objectives. This would be especially useful for species of more threatened or endangered status. The identification and distribution of suitable habitat through models and field research would be useful to delineate the distribution and identify key areas of concern.

1.3 THE PROBLEM

The fundamental requirement for any model is adequate and accurate data. With respect to the formation of habitat models, three other models are necessary, the ecological model, the statistical model and the GIS visual/spatial model. Each of these models in turn require specific data, ecological information detailing the particulars of the focal species, the statistical model representing the relationships between the focal

species and the environment, and the integration of these statistical relationships with topographic and thematic information pertaining to the model area.

The accuracy of a habitat model is thus limited to the accuracy of all three of the previous inputs. Furthermore, the variables and formulas must also adequately (with respect to the predictive accuracy of the intended product) represent the relationships between the species and the topographic/thematic information. Reduced data quality and quantity must be realised and the intended accuracy of the model adjusted to account for inadequacies.

1.4 RESEARCH OBJECTIVES

The previous section addressed the fundamental requirements necessary to produce a habitat suitability index model for *Arbanitis variablilis*. With respect to these requirements, a number of specific steps were initially determined:

(a) Identification of the microhabitat requirements of *Abanitis variabilis;*
(b) Determine where such microhabitats are likely to occur with respect to the different types of available large scale environmental strata (i.e. vegetation type, landform, soil, slope) within the study area;
(c) Extrapolate the results in a geographic information system (GIS) to compare areas with respect to habitat suitability across the entire study site;
(d) Assess the accuracy of the model, by comparing the results with the ground truth.

1.5 CONCLUSIONS: CHAPTER 1

This dissertation aims to assess the validity of extrapolating the microhabitat characteristics of the trapdoor spider, *Arbanitis variabilis*, to large scale topographic and thematic information, by means of a habitat suitability model. Literature concerning

the ecology of trapdoor spider species is discussed in the following chapter to establish the need and methodology. This information plus field research was used to form a full set of parameters of the focal species habitat, which were then extrapolated to the larger study site. The formation procedure and findings of this model may be applicable in assessing suitable habitat for other trapdoor spider species, especially for those of rare or endangered species.

CHAPTER 2 - Background

2.1 INTRODUCTION

Sections 2.2 and 2.3 address the general characteristics associated with trapdoor spider species ecology and the specific literature associated with the *Arbanitis variabilis*. The outcome of these sections was to introduce common ecological traits of trapdoor spiders, how these traits relate to their overall habitat choice and to identify and determine common habitat parameters by which to assess the focal species niche requirements. Section 2.4 discusses the various types of habitat models, the associated pros and cons and the key elements in selecting which model to use.

2.2 COMMON ECOLOGICAL TRAITS OF TRAPDOOR SPIDER SPECIES

The common name, trapdoor spider, encompasses a diverse range of species. Although little information concerning *Arbanitis variabilis*'s ecology and niche characteristics could be found, there exists a large body of literature concerning the ecology and morphology of numerous other trapdoor spider species. A number of general biological characteristics appear common to the majority.

Trapdoor spiders are opportunistic 'sit and wait predators' that feed predominately on small invertebrates. Individuals reside within silk-lined burrows, which are covered by a silk/soil/litter 'trapdoor'. From the few long-term studies that have been conducted, it appears that mygalomorph species (trapdoor and funnel web spiders) are potentially long-lived (Decae. *et al.* 1982; Main 1957, 1987; Vincent 1993). An ongoing demographic study by Main (2001) has monitored two female of the species *Giaus villosus*, for over thirty years.

Although a few species utilise wind currents to airily disperse young by 'ballooning', for the majority, dispersal is comparatively low with juveniles believed to begin burrow excavation relatively short distances from the maternal nest (Main 1987). This restricted dispersion can result in the formation of small aggregations around a number of adults within an area. Such aggregations may decrease problems associated with mate availability and chance extinction from demographic stochasticity. Upon leaving the matriarch's nest and finding a suitable area, young begin construction of their own burrows, which they alone inhabit for the remainder of their life (Vincent 1993; Main, 2001).

Once reaching maturity males emerge from their burrow to mate, probably with a number of females before dying (Main 1957), whilst females may continue to reproduce over a number of seasons throughout their life (Main 1987). The prospect of reproducing a number of times throughout their life may help buffer against unfavourable seasonal conditions unsuitable for reproduction or that result in high rates of mortality in juveniles.

For many trapdoor species whose microhabitats occur in small and often isolated areas, the characteristics of a lengthy longevity, a sedentary life style and low dispersion are partially attributable to their success in persisting in these patches (Main 1987). However, they also make them vulnerable to large-scale changes in the landscape. Their inability to re-locate and colonise distant new areas over a short time span means that rapid degradation of their habitat may possibly result in extinction of a local population (Main 1999). Thus, for many trapdoor spider species, the microenvironments that they inhabit are relatively stable, not subject to constant changing environmental conditions over short time periods.

2.3 DESCRIBING TRAPDOOR SPIDER SPECIES MICROHABITATS

The taxonomic diversity of trapdoor spider species is reflected by the diversity of habitats that they occupy. Species have been found to occupy areas from coastal dunes to

rainforests. Within each of these landform types they occur in specific microhabitats to which they are adapted.

Main (1957) characterised four-microhabitat types for species of the genus *Aganippe* in Western Australia: *Spatulate litter* occurs in forest or woodland areas with a stable, dense and matted eucalypt litter cover present; *Linear litter* is characterised as long, thin vegetation debris produced by plants such as Allocasuarina, Casuarina and Acacia species. These habitats predominantly occur in well-drained poor soils; *Clay flats and claypans* are small to large areas and depressions where bare patches of clay/soil often covered by a crust of algae and lichen are present. Scattered litter and litter banks may or may not be present. Alluvial material is deposited in these areas through erosion processes; *Riparian areas* are the stable banks of small creeks, roadside gutters, gullies and other vertical to semi-vertical areas. These same characteristics are applicable to many other trapdoor species.

Other studies have characterised species of trapdoor spiders preferred habitat by soil type and associated characteristics, litter profiles, vegetation, topographical relief and available invertebrate prey. (Bond and Coyle 1995, Fairweather 1993, Main 1957, 1996, 1999). Often these characteristics are not independent, but rather a reflection of the particular combinations of one another.

The soil and geology type impact on burrow construction (i.e. burrow stability, excavation) and partially determine the soil moisture retaining capacity which affects the microenvironment within a burrow. Vegetation type and structure is also partially a reflection of the soil and geology of a region. The extent and type of vegetation can effect the local microclimate (i.e. shade, wind exposure, humidity), litter, and thus soil profiles and invertebrate abundance.

The presence of litter structure and type plays an important role in determining species habitat. Particular species utilise litter by joining small debris to the door and outside rim of the burrow to increase the effective feeding area (i.e. by funnelling small invertebrates towards the burrow opening) and camouflage the entrance (Main 1957). Litter

profiles may also affect soil moisture content. In comparison, other species occur only in areas of scattered litter or bare ground.

Topographical relief, as stated in Mains study (1957), also affects habitat preference (e.g. banks, flat depressions). The shape and lie of the surrounding topography partially determines the erosion/deposition of soil and litter banks, water courses, aspect and thus, the distribution of the various microenvironments required by trapdoor species.

2.3.1 The Focal Species *Arbanitis variablis*

From the little literature available, the species appears to occur predominately in areas of fluctuating topography, such as range and hill formations. Within such topographic formations, the species microhabitat consists of small bare patches of soil free of heavy leaf litter on semi-vertical, to vertical banks and slopes in closed to tall open forest ecosystems (Main 2005). Such microhabitats are common along the hills, gullies and drainage lines (and cut walking tracks and road banks) of the Mount Glorius area. The continuity and linked networks that gullies and drainage lines provide may have partially facilitated the expansion of the species geographic range. Burrows doors are usually flush with the face of the bank or slope upon which they occur and are covered by a trapdoor constructed from a combination of mud and silk.

The stability of banks presumably impacts on the occurrence of the species. As mygalomorphs are relatively long lived and take a number of years to reach maturity, banks that are consistently changing shape over short periods of time may be unsuitable for habitation. Soil, vegetation, surrounding slope, catchment area and rainfall may all contribute to bank stability. Soil characteristics by the way in which bonds form between soil particles, vegetation by providing cover from rain, erosion and by stabilisation of banks through extensive root networks, whilst slope, rainfall and catchment area affect water flow capacity and movement along drainage lines.

2.4 HABITAT MODELLING

Habitat models utilise a range of characteristics and relationships pertaining to the species in question, its ecology and environment, to predict potential habitat and/or a species chance of occupying an area. Identification of how and which ecological parameters are likely to influence a species preferred habitat, such as discussed in section 2.3.2, form the basis upon which an ecological model is formed. However, identification of theses parameters, can be time extremely time consuming and difficult to define due to the large number of environmental variables often present. The verse by Cottam and Parkhurst 1969 (from McCune2004 p3)) at the start of this chapter summarises this point.

However, identification of such parameters is the initial step in producing a habitat model. These characteristics and relationships may include both the direct and indirect associations of a species to the biotic and/or abiotic components that compose its environment, as long as a spatial element can be linked to each. The relationships and parameters must then be converted into a statistical format, which is later integrated into a GIS environment.

The majority of habitat models utilise both topographic and biological parameters to estimate species occurrence with respect to suitable habitat. Some of the more common topographic characteristics used in habitat modelling include patch area, aspect, slope, gradient, landform position, curvature, elevation, rainfall and temperature. Whilst examples of biological characteristics include the proximity to vegetation type and cover, anthropogenic land uses, the occurrence/absence of other species, and population/metapopulation connectivity and proximity. Which characteristics should be utilised is solely dependent upon the species being studied.

The formation of GIS and its associated spatial analytical capabilities have contributed greatly to the effectiveness, accuracy and ease by which to produce such models. They provide a useful tool, by way of presentation, storing and handling data, facilitating the analysis of such spatial and environmental characteristics and permitting the extrapolation of any determined characteristics and/or relationships. However, in spite

of advances in technology and modelling techniques, a number of dangers are still inherent in theoretical modelling, and should always be kept in mind and addressed throughout the formation of a model.

2.4.1 The Deficiencies and Dangers Associated with Habitat Modelling

One of the main problems researchers face when attempting to both characterise and predict a species habitat, is the availability and accuracy of data (see section 1.3) (Odom et. al. 2001, NPWRC 2001). Often the data required may not have been compiled, whilst manually collecting all the data necessary to produce a model can be extremely expensive, time consuming and thus, often, simply not feasible. Furthermore, pre-existing data may be hard to locate, be stored in different formats or have been collected at an inappropriate scale and/or accuracy. For any model to be successful, the need for relevant data is critical. In some cases, comprehensive field observations may provide a more feasible option than trying to collect the necessary data to produce such a model.

The scale and accuracy at which data has been collected places limitations upon the accuracy of any predicted outcomes. Large-scale accurate data may not be accessible and researches must utilise existing data collected at a smaller scale. When interpreting and publishing the outcomes of a particular model, the researcher must be careful to ensure that he/she adequately comprehends the limitations imposed by the original scale and accuracy.

Furthermore, the different characteristics that define a species niche, may be represented at a number of scales. For example, the microhabitat that the species immediately occupies, the landscape type in which such microhabitats are likely to occur and the regions where such landscape types are found. Thus any sampling strategies to determine the species microhabitat must be carefully designed so that it can be related to the intended landscape data for extrapolation.

Finally, it is important that a model's accuracy is checked before management strategies are produced and applied based on the results of the model. Management strategies formed from inaccurate models may have a detrimental, rather than positive effect on a species conservation status. If a model is to be used over time for management and monitoring strategies, then it should be updated and subject to periodic checks to assess its accuracy temporally.

2.4.2 A Comparison of Habitat Models

As data availability and accuracy impose limitations on the predictive accuracy and capabilities of a model, they also affect the type of model to employ. Different models are more appropriate than others depending upon the circumstances and the intended outcome.

The simplest models, such as HSI models attempt to predict species occurrence by rating potential habitat based on a set of parameters and/or rules. More complex habitat models, as well as habitat suitability parameters, incorporate variables which affect demographic and metapopulation factors. These variables may represent demographic rates with respect to the patch characteristics, connectivity between patches and the rates of immigration/emigration between different sub-populations. (Akcakaya 2001)

The outcome is a more detailed and spatially realistic model (Akcakaya 2001). For example, even if significant suitable habitat is present, there may be no occupation if an external factor is applied such as dispersal barriers or intensive hunting, thus, affecting demographic rates or limiting migration processes. These models incorporate more precise statistical relationships and their interactions to predict the chance of present or future occupancy and demographic status.

As such, they also require extensive data and information detailing the relevant relationships and their interactions. As stated in the preceding section 2.4.2, often data

may not be available, nor the necessary time and resource allocations to acquire the information. In comparison, HSI models are more flexible, so that if only generalisations and assumptions can be formed or are available, a simple model can still be produced (Berry 2004). These models can still be useful if the proposed assumptions and parameters are accurate, however the intended product is likely to be significantly less detailed than more complex models which include a greater range of variables.

A range of approaches and associated statistical methods are employed in habitat modelling, some of which include: linear, logistic and multiple regression analyses (the most commonly used), tree-based models, additive analysis, nonparametric analyses and rule based methods. Once again, which method should be incorporated is dependent upon the data and information available, and also, the way a species responds to a particular parameter. (McCune 2004)

For example, linear and regression methods rely on the assumption that the response (or the rate of change in a response) of a species to an environmental gradient is uniform throughout. This assumption is often violated with respect to species-environmental relationships, which may be, unimodal, bimodal, skewed, sigmoid, step wise or a combination of the above (McCune 2004).

Tree-based models are often used in habitat models where binary response data (e.g. presence/absence data), ranked data or generalised assumptions are available or assumed (McCune 2004). Weighting and ranking functions of the proposed parameters, if known, can still be applied to consecutive variables, whilst interactions can also be integrated. One of the main problems with these models, is that they become extremely complicated with increasing factors, so as to be unmanageable, especially if numerous interaction terms are present (Christensen 2000).

CHAPTER 3 – PILOT STUDY

3.1 INTRODUCTION

As discussed earlier, habitat models require ecological, statistical and topographic/thematic elements. Generally, the relevant ecological aspects of a species must first be determined before the later two elements can be discerned. As such, a pilot study was necessary to identify and collate data on *Arbanitis's variabilis* preferred habitat, so as to validate and add to the existing microhabitat information discussed in section 2.3.

3.2 METHODS

As the sampling time necessary to acquire a data set large enough to test for statistical significance between occupancy and environmental variables was not possible in the current study, an inference and observational approach was adopted to identify general trends with respect to the species habitat requirements. For this reason the intended predictive scope of the model has been somewhat limited. However, even general observations can provide significant insight into a specie's distribution if the proposed assumptions are correct.

Observations were conducted over a period of five days within Brisbane Forest Park. Notes concerning litter profiles, soil type, vegetation type/structure and topographical features associated with the species habitat were recorded. This information plus existing literature was used to form a full set of parameters of the focal species preferred habitat and then extrapolated to the larger study site.

A tree diagram ecological model was constructed from the proposed habitat characteristics. Macro to micro topographic and biological parameters were added left to

right to represent an increase in habitat specificity and a bottom to top approach depicting increasing microhabitat availability (i.e. the greatest density of occupiable habitat is located at the top of the tree diagram).

3.3 THE ASSUMED HABITAT PARAMETERS OF *ARBANITIS VARIABILIS*

As stated in section 2.3.1, *Arbanitis variabilis* occupies areas in both open and closed canopy woodland Main (2005). Within the Mount Glorius area, individuals were observed in dry sclerophyll vegetation (open canopy), moist sclerophyll vegetation, wet sclerophyll vegetation and rainforest (semi-closed to closed canopy). Areas of low heath, (i.e. dominated by shrub and low canopy species), are suggested to be unsuitable for habitation of the focal species. These areas usually represent areas of shallow soils and underlying geological formations close to the surface. No individuals were observed in these areas. No particular or individual species of flora were repeatedly noted that could be utilised as an accurate predictor of spider occupancy. However a number of vegetation structures appear at least to provide suitable habitat, such as micro-vegetation (mosses and algae) and large buttress-tree species and will be discussed later.

Within these general vegetation systems the species appears to fall into a combination of the later two classes depicted by Main's (1957) classification system for Aganippe (see section 2.3), that is, the preferred habitat has similar characteristics to the classes of riparian and clay flat areas. The species was observed to occupy both riparian bank structures and small to large scattered bare patches of clay/soil of lesser gradient.

Leaf litter was noted to considerably limit the distribution of the species. Despite numerous efforts to locate the species under significant cover, individuals, with few exceptions, were observed in bare areas or amongst scattered litter devoid of a dense mulch stratum. These bare to semi-bare areas were often covered by a hard surface crust or extensive micro vegetation such as moss, algae and lichen. The presence of such characteristics suggests a stable microenvironment, which has been exposed for some period (Main 2001).

Soil type, where individuals were found, always consisted of light to moderate clay soils, often with small too large weathered rock debris present throughout. Although this may be a product of the sample area, most species of trapdoor spiders are thought to have certain tolerance ranges to variations in sand, silt, clay and gravel soil compositions. It's likely that *Arbanitis variabilis* is restricted to soils of at least a light clay composition. Such fine-grained soils provide greater soil moisture content than larger soil particles such as sand and gravel. As stated in section 2.3, increased soil moisture content buffers against outside temperature fluctuations, providing a more stable microenvironment for burrowing organisms. The general habitat parameters observed within the study site for *Arbanitis variabilis,* are displayed in Figure 3.1.

Litter Profile: *bare areas devoid of litter, or amongst scattered litter. Very few individuals were found under a dense mulch layer.*

Vegetation structure: *open to closed canopy woodland. Individuals were observed in rainforest through to dry schlerophylic, vegetation. Heath areas, usually representing shallow soils not suitable for burrowing, are assumed to be the least favorable for occupation.*

Soil type: *Small to large patches of stable light to moderate clay soils, small to large gravel may be present and scattered throughout. Heavy sands, gravels and possibly clays may be important in limiting the species greater distribution.*

The Microhabitat of

Arbanitis variabilis

Individuals of the species reside in a silk lined burrow, the entrance sealed with a mud/silk concave door (2≈25mm in diameter), which fits snugly and effectively 'plugs' the burrow entrance.

Interactions

Between

Parameters

Topography: *horizontal to vertical slopes. Individuals were observed on the tops, sides, ridges, and valleys of hills and rises. The densest aggregations were observed on bank formations, whilst more distributed patches of individuals were observed in areas of more continuous undulating micro topography amongst litter mosaics, or sheltered areas under/near roots, logs and trees.*

Other Factors: *may include the proximity and distribution of other 'good' areas, i.e. an area may be suitable, but not occupiable due to low dispersion characteristics. Invertebrate prey abundance may also effect demographic rates i.e. reproduction, age-specific mortality.*
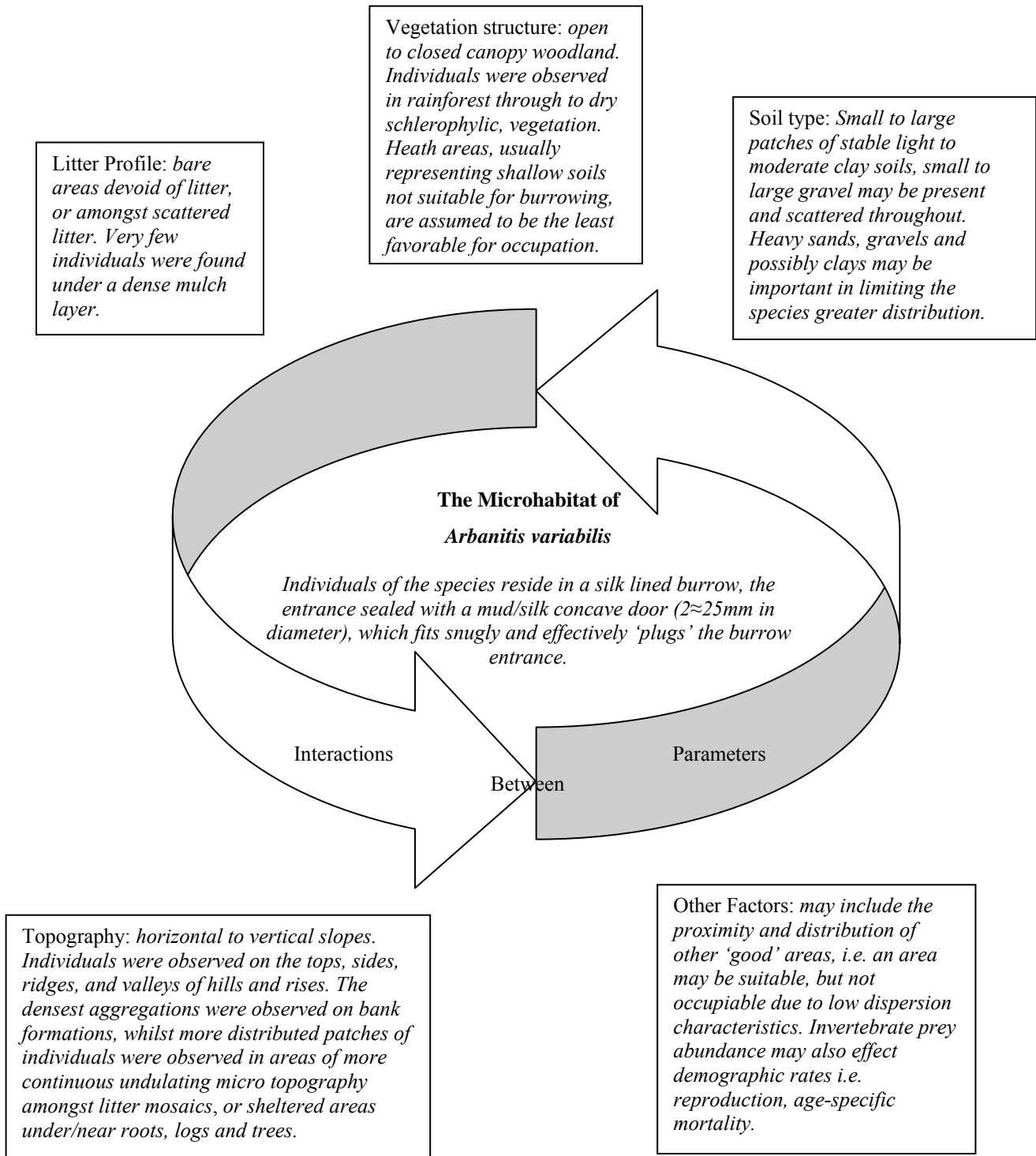
Figure 3.1: The presumed parameters affecting microhabitat preference of *Arbanitis variabilis*.

The occurrence of such microhabitats within the study site were divided into two general topographic landforms, riparian/anthropogenic banks and areas of more continuous undulating slope (i.e. the sides, ridges and flats of hills and topographic rises).

3.3.1 Riparian/Anthropogenic Banks

Whilst conducting the fieldwork, the densest aggregations of the species were observed on semi-vertical to vertical banks. For the purpose of the study, a bank was defined as: An obvious delineation in the general slope caused by weathering, water erosion or anthropogenic processes that have resulted in an independent steep incline.

Bank structures, due to their slope, limit the formation of litter banks. Periods of flooding and rain further limit litter bank formation at the toe of the bank (i.e. so that even small steep banks are often largely devoid of litter). In the Mount Glorious area well-defined banks were predominantly located along drainage lines, walking tracks or roads.

The size, area, continuity and slope of a bank presumably affect the extent of microhabitat available for occupation. The size and area of a bank directly affects patch size, whilst slope and continuity probably play a further role in determining patch suitability by affecting litter cover and the proximity to other aggregations of individuals respectively. Thus, this study proposes that topographic areas that contribute to the formation or contain larger, more continuous and stable bank structures are likely to provide more suitable habitat for occupation of *Arbanitis variabilis*.

Drainage lines/riparian banks

Stream channel erosion is the dominant influence in the formation of banks along drainage lines (Hillel et. al. 2005) and occurs as water passes and removes soil particles from the side and beds of streams and channels. The geology, topography, vegetation

cover, land use, rainfall, and climate of an area (Hillel et. al. 2005) affect the extent of erosion.

Within well-vegetated uncleared areas, such as the Maiala National Park, watercourses and riparian banks can remain stable subject to slow change over relatively long periods of time. Vegetation reduces erosion by firstly providing foliage and litter cover which reduces rainfall impact and secondly, through root networks which help bind and catch soil particles, absorb water and increase soil porosity, thus, decreasing water velocity and surface runoff (Price and Lovett 2002)

Flow velocity and discharge (the volume of water passing a point per unit of time in a stream) affect bank scouring and hence, erosion that occurs in stream channels, i.e. the greater and more concentrated the volume and velocity of water, the greater the soil erosion (Hillel et. al. 2005). Flow velocity increases positively with gradient and negatively with resistance ((rocks, boulders, trees etc). In upper headwater streams flow velocity and discharge generally increase with stream order (Nelson 2003). Although 1st order streams (i.e. no other tributaries above) and gullies may contain a greater drainage gradient, flow increases velocity downstream due to an increase in water volume from joining tributaries and a decrease in the average resistance encountered.

To cope with the increased flow volume the stream morphology also undergoes change with increasing stream order. In well-vegetated areas, initial tributaries are usually shallow V shaped gullies, whilst further downstream the stream channel widens and deepens to account for the increase in discharge (Nelson 2003). Whilst conducting field observations within the study area, generally the frequency of large bank formations were observed to increase in lower headwater drainage tributaries.

However, as stream order increases, occupation of the species may follow a unimodal relationship. For example, sixth and seventh stream orders usually take the form of permanently flowing river systems along areas of lower topography and may be unsuitable due to problems associated with periodic or seasonal flooding. For solitary individuals that remain within their burrow, prolonged periods of flooding may 'drown' a

local population. Both intermittent (flow occasionally or for wet the period of the year) and perennial streams (flow continuously) were present within the study site. However, due to the average stream gradient within the area, and thus rapid drainage, it's likely that even the perennial stream systems have a minimal discharge for most of the year, although water may be present in small pools all year round. Thus, the relationship between bank occurrence and stream order within the site was considered to be positively correlated.

The angle and position of bends and meanders also influence stream bank erosion. Water velocity and channel depth is usually greatest on the outside of meanders and bends and therefore stream bank erosion increases as water is directed into the outside bank, whilst sediment deposited on the inside (Nelson 2003).

The present study therefore suggests an increase in the extent of habitat within the study site with firstly increasing stream order, secondly in channels with greater meandering and lastly, increasing local gradient.

Anthropogenic formed banks (roads and walking tracks)

On average, in comparison to riparian areas, extensive and more continuous banks were noted along such tracks/roads and provide significant microhabitat for the species. As the effects of water flow and erosion are presumably less than that on riparian bank systems, anthropogenic banks may provide an extremely stable environment. Dense micro-vegetation cover was present on many of these banks supporting this statement.

As construction of walking tracks and roads occur, banks are formed on the upper slope due to the removal of soil or cutting down of the slope to produce an approximately horizontal surface perpendicular to the direction of travel. In some cases banks were observed on the lower side also, due to a process of cutting and filling. The extent and scale of bank formation is largely dependent upon the width and orientation of the track/road and the aspect and slope of the topography. For example, a road built on a

steep slope and running perpendicular to the topographical aspect requires more extensive cutting to produce a horizontal surface perpendicular to the direction of travel.

Generally in areas containing steep slopes, such as the Maiala National Park, soil walking tracks are orientated more perpendicular to the topographical aspect (i.e. to avoid problems associated with steep gradients – erosion, travel and construction effort). Roads, as is the case in mountainous regions, were observed to follow the ridgelines.

3.2.2 Topographic Areas of more Continuous Undulating Slope

The second general type of habitat in which the species was observed was on more continuous undulating slopes, although generally more distributed and in lower densities. Within this landform type, available occupiable patches appeared to be more distributed. Furthermore, for a species which presumably has limited dispersion (refer to section 2.2), many suitable patches may effectively be geographically isolated by extensive litter profiles, dense ground cover and/or geological formations. Thus, this paper suggests that such areas likely result in lower densities of individuals and a more dispersed distribution when compared to areas with more continuous bank structures.

Although bank structures are more scattered than within the category riparian and anthropogenic bank formations, small and sometimes large bank structures were still observed. Fallen trees especially on topographic gradients can lead to soil deposition occurring on the upper side, and after decomposition, leave small banks. Surface roots and logs can also provide suitable microhabitat by providing shelter and small bare patches of soil on the underside. To a lesser extent, the species was also observed on horizontal soil surfaces, which may occur as patches amongst a mosaic of dense litter cover.

On steeper slopes, especially where litter cover was dense, individuals were often noted to shelter at the base of tree species on the lower side. This was especially evident with respect to buttress tree species in rainforest and wet/moist sclerophyll vegetation.

The large buttress roots appear to provide shelter and limit litter bank formation, especially at the buttress vertex. Water runoff down the trunk and then down slope may help these small areas remain relatively free of litter, whilst the significant longevity of such flora provides a stable microenvironment.

The present paper therefore assumes that suitable habitat increases with respect to increases in topographic slope. Examples of the different microhabitats described in the sections above are displayed in Figure 3.2.

Bank formation where the species were located.

Burrow entrance.

Sheltered areas and small banks found on slopes of more continuous undulating meso topograpy.

Figure 3.2: Examples of microhabitat environments in which *Arbanitis variabilis* occurs.

3.4 The proposed topographic parameters for assessing habitat suitability for *Arbanitis variabilis*

Based upon the preceding sections, a set of habitat parameters were proposed ranging from a macro to meso scale and are displayed in Figure 3.3. Although the diagram shows an increase in the available microhabitat with meso topographic factors, macro topographic factors play the most significant influence in limiting the species greater distribution.
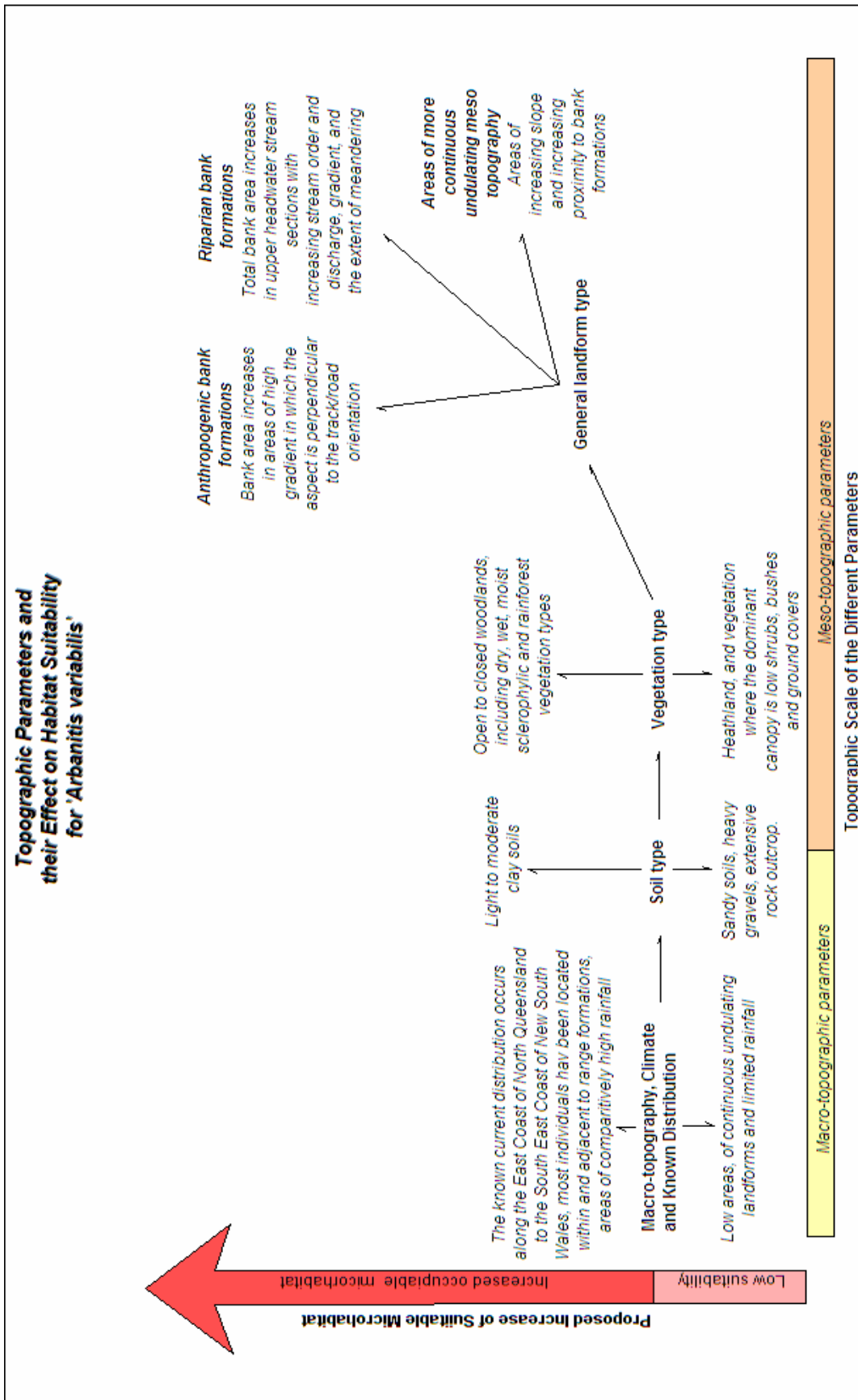
Figure 3.3: Macro and meso topographic parameters and their effect on habitat suitability.

CHAPTER 4 - METHODS

4.1 INTRODUCTION

The following sections in this chapter, detail the type and way by which topographic and thematic information was compiled, transformed and then related to the species habitat preference. From the preceding sections a number of key topographic and thematic elements were identified. These included soil, vegetation, topographic relief, drainage, transport and public access walking track elements.

Two other dominant layers were necessary for the formation of the current HSM. The first of these was a layer displaying the boundary of Maiala National Park in order to define the study area. The second, was a base grid layer, which was used to extract the derived values of selected attributes from the various topographic/thematic layers and to then calculate the Habitat Suitability Index for each cell in the grid. Mapped topographic and thematic information was obtained from various departments including the Queensland Department of Natural Resources and Mines, Brisbane Forest Park Authority and the Brisbane Street Directory (UBD 2004).

The computer system used was a Laptop Dell Inspiron 1100. The desktop geographic information system, MapInfo Version 7 (MapInfo Corporation. 2002), was selected principally due to availability. Other software included the MapInfo add-on Vertical Mapper, Contour and Display Modelling, version 2.6 (Northwood Technologies 2000). The projections of any compiled map themes that were not based upon the Map Grid of Australia (1994) Zone 56 (the Geocentric Datum of Australia (1994)), were transformed accordingly.

Available metadata concerning the base topographic and thematic information is listed in Appendix B. Due to the size of the files used in the current study, a digital copy of all MI tables used, was attached as Appendix C.

4.2 THE COMPILATION AND PRELIMINARY MODIFICATION OF BASE THEMATIC LAYERS

Co-ordinates of the cadastral boundary of Maiala National Park were obtained from the Brisbane Street Directory (UBD 2004) by manual scaling. A MapInfo table was created titled cadatsre (cadastre.tab) and the scaled co-ordinates input as point objects. A region object was then constructed based upon the initial points, which were deleted once the region was created.

A 100m buffer zone was created around the region object in the table cadastre and saved as a MapInfo table (cutter.tab) to act as a cutter for later tables. This was to ensure that spatial entities that were located adjacent too, but outside the National Park and yet which may influence habitat suitability within the cadastre, would still be included in the formation of the HSI model.

Topographic relief (contour interval: 25 meters (5 meters in selected areas)), drainage, and transport themes were obtained from the topographic map series Sammsonvale 1:25 000 (MGA (94), Zone 56 (GDA94)) through the DNR in vector format as MapInfo tables. Coverage included the map sheets 9442-24 and 9442-31 (i.e. the National Park was positioned across the adjoining border of the two map sheets), thus making a total of six tables (i.e. two for each of the above themes). The two associated tables were opened for each theme, and then cut against the region object in the MapInfo table cutter, so that only information located within the cutter region object remained. The tables were then saved as ReliefFin.tab, Drainage.tab and Transport.tab respectively.

Information concerning walking tracks within the national park was obtained from the Brisbane Forest Park Headquarters in hardcopy format (no metadata was available for this information and the accuracy is presumed to be low). This information was then scanned, imported as a raster image in TIFF format and geo-referenced in MapInfo. Walking tracks were manually digitised and the vector file appended to the MapInfo table (Transport.tab).

Vegetation data (mapped at a scale of 1:25 000) was obtained from the Brisbane Forest Park Authority in ESRI shape file format covering all of Brisbane Forest Park. Region objects represented vegetation communities, with attribute columns (*VEGTYPE* and *FIREASSOC*) attached regarding the identification, structure and types of vegetation of each region. This was imported and transformed through the MapInfo tool, "Universal Translator" and saved as a MapInfo table (BFP_veg.tab). The region object in the table cutter.tab was then used to erase all map objects (and associated attribute information) outside the selected region and the new file saved as BFP_vegFin.tab.

4.3 TOPOGRAPHIC HEIGHT, SLOPE AND ASPECT (BASE GRID)

A grid layer with a cell resolution of 30 by 30 meters was created covering the area as defined by the cutter object discussed in section 4.2. The cell size of 30m by 30m was selected based on the trade off between processing time and maximising cell resolution. To each grid cell, values for the attributes, Height, Slope and Aspect were assigned. Each cell represented a base unit, by which habitat suitability was to be later assessed for all topographic and thematic layers.

Point objects were created based on contour nodes in the file ReliefFin.tab by the VM tool 'Poly to Point" and the new file saved as ReliefFin_ptp,tab. A DEM was formed using an existing attribute column *Label*, which contained height values (Australian Height Datum (AHD), expressed in meters). The interpolation method, "Triangulation with Smoothing" was selected. The specifications used, with regards to the triangulated irregular network (TIN) interpolation method, are listed in Table 4.1.

Table 4.1: Specifications with respect to TIN interpolation method.

Specification	Selected value/option and Reason
Maximum Triangle Side Length	250 meters
Coincident Point Distance	0.0079 meters (default value)
Aggregation method	Average
Cell Size	30 meters
Weighting Factor	2
Exponent factor	1

Upon completion of the DEM (saved as LABEL.tab), the VM toolbar "*Grid Manager*" was opened and the option "*Create Slope and Aspect*" from the new table, selected. The files LABEL_Slope.tab (with the option, *values expressed as the angular difference from the horizontal*, selected) and LABEL_Aspect.tab (with the option, *Calculate Aspect Relative to Y-axis,* selected) were created.

VM was then used to export and convert the continuous grid, Label.tab, as a MapInfo Point File and saved as Terrain.tab. This file was then opened and the "Point Inspection" procedure (VM) used in conjunction with the files LABEL_Aspect.tab and LABEL_Slope.tab. This procedure added two columns to the MI browser of Terrain.tab (*LABEL_aspect* and *LABEL_slope*). To each row of the respective columns (i.e. for each point in the table Terrain .tab), the value of the aspect (0-360 degrees, with Map North = 0) and the value of the slope (expressed as the positive angular difference between the slope and the horizontal) were assigned. The result of the above procedures, was a series of points spaced at 30m intervals in a grid formation, with their respective calculated height, aspect and slope of the topography assigned as attribute values.

A grid file was then created (MI - Grid Maker (Version 1.3)) and spaced so that each point in the table Terrain.tab coincided with the centroids of each cell in the created grid. The MI specifications used in creating the grid (Grid30m.tab) are listed in Table 4.2.

Table 4.2: Grid specifications.

Specification	Selected value/option
Projection	MGA Zone 56 (GDA94)
Object Types	Closed Regions
Spacing Between Lines	30 meters
Smoothness	4 extra nodes per edge
Extents	North: 6981130 South: 6975990 East: 481320 West: 474510
Round Extents	No
New Table	Grid30m.tab

A geographic join was then used to select all grid cells that fell within the cutter region (cutter,tab), the selection was then inverted and the new selected cells deleted. This table was to act as the base grid table (BaseGrid30m.tab).

Three new columns were created for this table, *Slope*, *Aspect* and *AHD*. The "Update Column" command was then used to transfer the values from the columns *LABEL_slope*, *LABEL_aspect* and *LABEL_height* in the point file (Terrain.tab) to the columns *Slope*, *Aspect* and *AHD* respectively in the table, BaseGrid30m.tab. A geographic join, 'where BaseGrid30m object contains Terrain object", was used to assign the values of each point to the respective grid cell, in which each point fell.

4.4 DRAINAGE LINES/RIPARIAN BANKS

Three key elements were suggested in determining the extent and distribution of banks along drainage lines (see section 3.3.1), catchment area, the extent of meandering and the gradient of individual sections of drainage line.

An index of the total upstream length of a stream network was used to produce an estimate of the catchment area at any given point. The ratio of the straight-line distance, between the start and end points of a drainage line and the length of the drainage line, was used as a measure of sinuosity, or the extent of meandering. Lastly, rearrangement of the formula,

$$[\text{Tan}(\iota) = \text{opposite} / \text{adjacent}] \text{ to } [\iota = \text{ArcTan(opposite} / \text{adjacent)}]$$

(where "ι" is the slope in degrees from the horizontal, "opposite" the height difference between the start and end points of a drainage segment and "adjacent" the length of the segment) was used to calculate the average slope of each drainage section in degrees from the horizontal.

4.4.1 The Calculation of Catchment Area

A new attribute column was added to the table BaseGrid30m.tab and titled "*Catchment*". A geographic join was used to select grid cell objects (BaseGrid30m.tab) that intersected with drainage polylines (Drainage.tab). Each cell that intersected with a drainage polyline was assigned the value of the accumulated number of cells in which upstream drainage lines had passed through by manual editing (see Figure 4.1). In the case where two or more drainage lines intersected within a cell, the total number of cells that each drainage line had passed through previously, plus 1, was used to derive the catchment value. When more than one drainage line passed through a single cell, but did not intersect, the drainage line with the largest catchment value was used. Cells, that did not intersect any drainage lines, were assigned a value of zero.
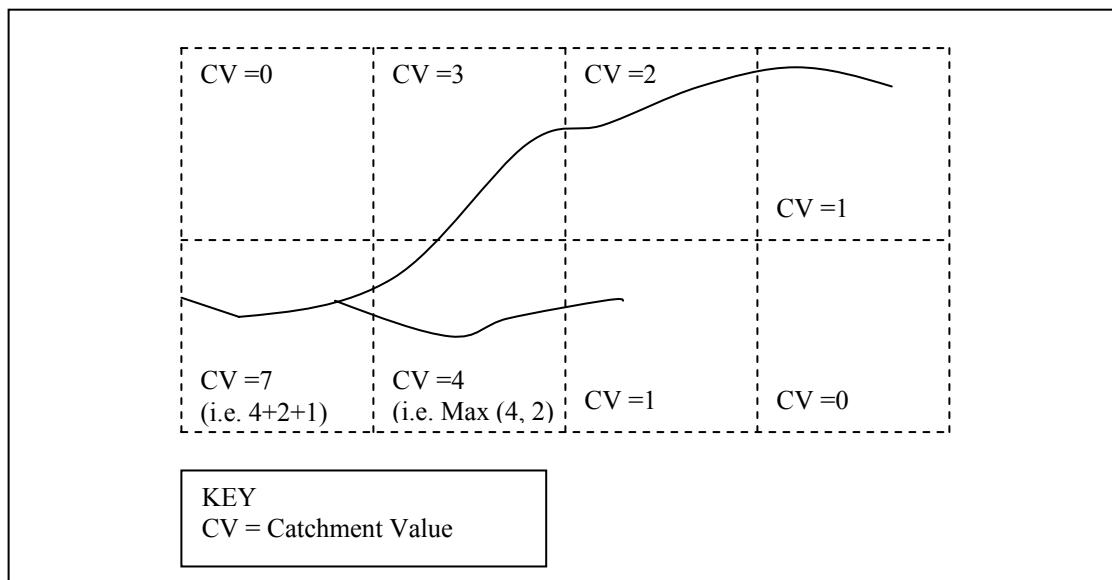

Figure 4.1: The catchment value with respect to cell objects.

4.4.2 The Calculation of Sinuosity and Drainage Line Slope

In order to produce an estimate of the sinuosity and gradient of each drainage line segment, three key elements were required. Drainage line segments had to be defined, the co-ordinates and associated height value of the start and end point of each segment calculated and lastly, the length of each drainage segment known.

Drainage polylines in the table Drainage.tab were manually digitised in MapInfo, so that each drainage section between intersecting streams, or from the start or end points of a stream to the first intersecting point, formed an individual polyline object (see Figure 4.2). The new polyline objects were saved in the table DrainageFin.tab.
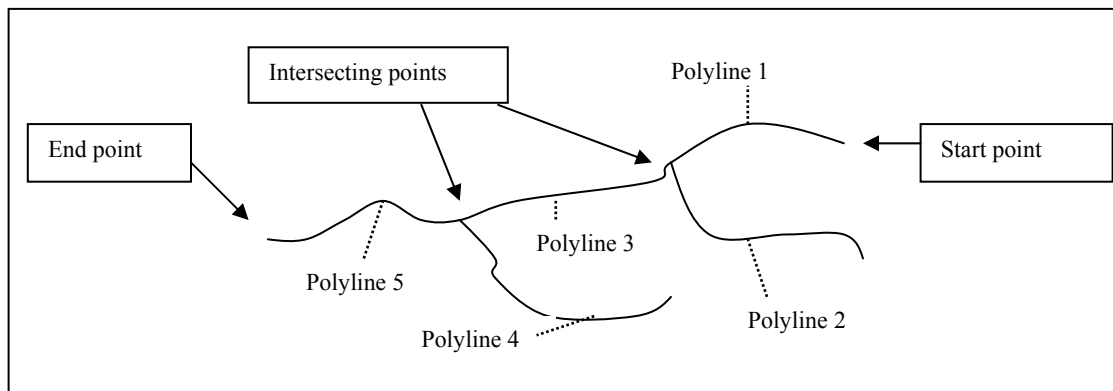

Figure 4.2: Digitising drainage lines.

The MI tool "Overlay Nodes", was used to create new nodes at points along drainage polylines which intersected with grid cells in the table "BaseGrid30m". Next, the VM procedures, 'Poly-to-Point' and 'Point Inspection' were respectively used to create a point object at each node along drainage polylines and to assign height vales interpreted from the table, LABEL.tab. This new file was saved as DrainageFin_ptp.tab and the interpreted height values for each point stored in a created column titled, "*Label_1*". The MI tool, "Coordinate Extractor" was then used to assign the respective Easting and Northing for each row (i.e. for each point) in two new attribute columns titled, "*Easting*" and "*Northing*".

Polylines in the drainage table were then "split" into smaller polylines by cell regions in the table, gird_30.
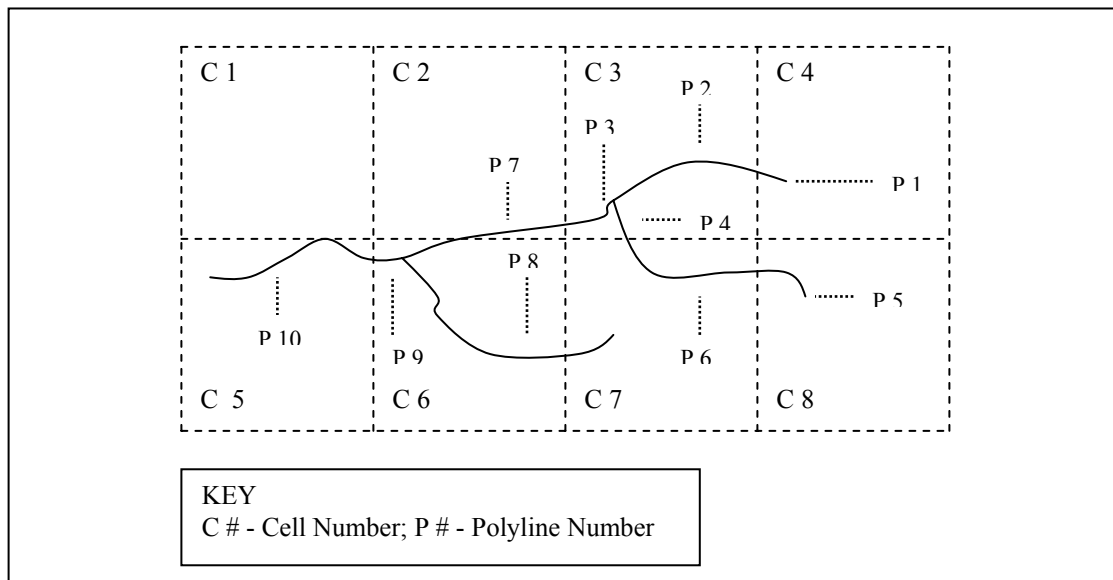
Figure 4.3: The base polyline unit with respect to drainage.

A copy of the table, BaseGrid30m.tab, was saved as PolyGrid_30.tab. All individual cell regions in this file were transformed into polylines and afterwards, combined to form a single polyline object. MI Structured Query Language (SQL) was used to select all point objects from the file DrainageFin_ptp.tab that intersected with the polyline object in table PolyGrid_30.tab. This was to ensure that in later steps, only points that intersected at the start and/or end of an individual drainage polyline, would be selected. This file was then saved as DrainageFinSelected_ptp.tab. As some drainage line's start or end points (i.e. where streams intersected or started within a cell object) did not intersect with the polyline object in PolyGrid_30.tab, these points were manually selected from the table DrainageFin_ptp.tab and appended as rows to the table DrainageFinSelected_ptp.tab.

Drainage polyline objects (DrainageFin.tab) were overlayed with the combined selected point objects. The MI "Update Column" command was performed on two new columns, "*HeightMax*" and "*HeightMin*", in the table DrainageFin.tab. A geographic join command was used "where object from table DrainageFinSelected_ptp.tab intersects object from table DrainFin.tab". The value for each row in the column *HeightMax* was calculated as the maximum value from the column, Label_1 (DrainageFinSelected_ptp.tab) (i.e. selected the maximum height from the start or end

point of a drainage line and assigned this value to the attribute column *HeightMax*). This was then repeated on the column *HeightMin* (DrainageFin.tab) except with the minimum value from the column *Label_1* calculated. Thus, the above process assigned the height values of the start and end points of each polyline object (drainage segment) to the table, DrainageFin.tab (*HeightMax* and *HeightMin*).

The MI "Update Column" command was then performed on a new column *PolylineDist* in the table DrainageFin.tab. The function, "CartesianObjectLength" in meters, was used to assign the distance of each drainage polyline to its associated row in the attribute column.

Assessing Drainage Line Slope

An attribute column, *DrainageSlope*, was added to the table DrainageFin.tab. A value was assigned to this column through the MI "Update Column" command, based on the formula for determining drainage line slope (discussed at the beginning of section 4.4):

(1)   [ι = ArcTan(opposite / adjacent)].

To comply with MI SQL language and the defined column names, the following substitutions were used in the formula: ι = *DrainageSlope*; ArcTan = Atn; "Opposite" = *HeightMax – HeightMin* and "adjacent" = *PolylineDist*. As MI uses radians with respect to calculating the Arctan of an angle, the conversion term (* (180 / 3.1459)) was included to convert to degrees. Thus,

(2)   [DrainageSlope = Atn ((HeightMax - HeightMin) / PolylineDist) *
        (180 / 3.1459)]

Finally, to calculate the straight-line distance between start and finish points of a drainage polyline, the respective co-ordinates had to be calculated. Four new columns to hold the calculated co-ordinates were created and titled *HMaxEasting*, *HmaxNorthing*, *HMinEasting* and *HMinNorthing.*

The MI "Update Column" command was performed on the column *HMaxEasting* in the table DrainageFin.tab. An attribute join was used, so that where *HeightMax* (DainageFin.tab) was equal to Label_1 (DrainageFinSelected.tab), the value for the new column was assigned the value of the column, *Easting* from DrainFinSelected.tab. This procedure was then performed for the column *HmaxNorthing* (DainageFin.tab), but with the new value assigned the value of the column *Northing* in the table DrainageFinSelected.tab. Similarly, the new columns *HMinEasting* and *HMinNorthing* were calculated based on the join, where *HeightMin* from the file DainageFin.tab was equal to *Label_1* from the file DrainageFinSelected_ptp.tab.

Thus, the start point of a drainage line was the highest end point and the finish point, the lowest and the columns *HeightMaxEast*, *HeightMaxNorth* and *HeightMinEast*, *HeightMinNorth* contained the associated co-ordinates, respectively. The MI "Update Column" command was then performed on a new column *StraightLineDist* (created in the table DrainageFin.tab). The value for each row in the column *StraightLineDist* was calculated by Pythagorus's theorem:

(1) $[c = \sqrt{(a^2 + b^2)}]$

(where c is equal to the distance of the hypotenuse of a right angle triangle, and a and b the distances of the remaining two sides).
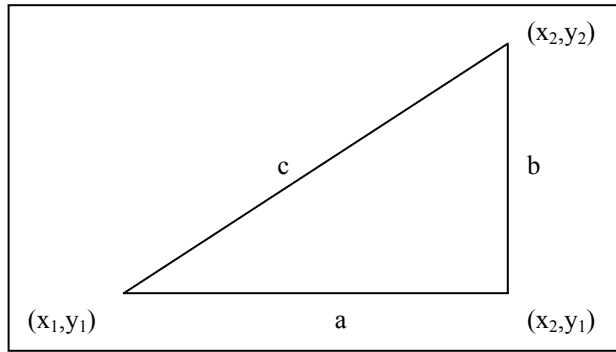
Figure 4.4: Right angle triangle.

In Figure 4.4 above, the distance of the two sides, a and b, of a right angle triangle, is equal to the absolute difference between the x co-ordinates ($x_1 - x_2$) and the absolute difference between the y co-ordinates ($y_1 - y_2$) respectively. Substituting into (1) gives:

(2) $[c = \sqrt{((x_1 - x_2)^2 + (y_1 - y_2)^2)}]$.

With respect to the current study and substituting the column headings and MI SQL terminology into the formula gives:

(3)   [*StraightLineDist* = Sqr(Abs(*HMaxEasting – HMinEasting*) * Abs(*HMaxEasting – HMinEasting*) + Abs(*HMaxNorthing – HMinNorthing*) * Abs(*HMaxNorthing – HMinNorthing*))].

(where c = the straight line distance (*StraightLineDist*), $x_1 - x_2$ = the Easting co-ordinate associated with the highest end point of a drainage line (*HMaxEasting*) minus the Easting co-ordinate of the lowest end point of a drainage line segment (*HMinEasting*); ($y_1 - y_2$) = the Northing co-ordinate associated with the highest end point of a drainage line (*HMaxNorthing*) minus the Northing co-ordinate of the lowest end point co-ordinate of a drainage line segment (*HMinNorthing*); and Abs = the absolute value of a pre-defined function).

Lastly, the straight-line distance (StraightLineDist) divided by the horizontal drainage line distance (PolylineDist) was used to calculate an index of the sinuosity of each drainage line segment. the MI "Update Column" command, was performed on the column *Sinuosity*. The value for each row in this column was calculated by the expression:

[*Sinuosity = PolylineDist / StraightLineDist*]

4.5 ANTHROPOGENIC FORMED BANKS

As described in section 3.3.1, areas which provide more continuous and larger bank structures and thus, larger bank areas, are assumed to provide greater microhabitat for the species. An index of bank area was calculated for each segment of road/track by multiplying an estimated average bank height by the horizontal distance of a road/track segment.

To estimate the bank height along a road/track segment, rearrangement of the formula:

(1)   [Tan($\imath$) = opposite / adjacent] to [opposite = Tan($\imath$) * adjacent]

was used. If the following substitutions, $\imath$ = the topographic slope (S), adjacent = the horizontal distance cut directly into the slope face (HD), and opposite = bank height (BH), then:

(2)   [BH = Tan(S) * HD].

To calculate the horizontal distance cut directly into the slope face, rearrangement of the formula:

(3)   [Cos($\forall$) = Adjacent / Hypotenuse] to [Adjacent = Cos($\forall$) * Hypotenuse]
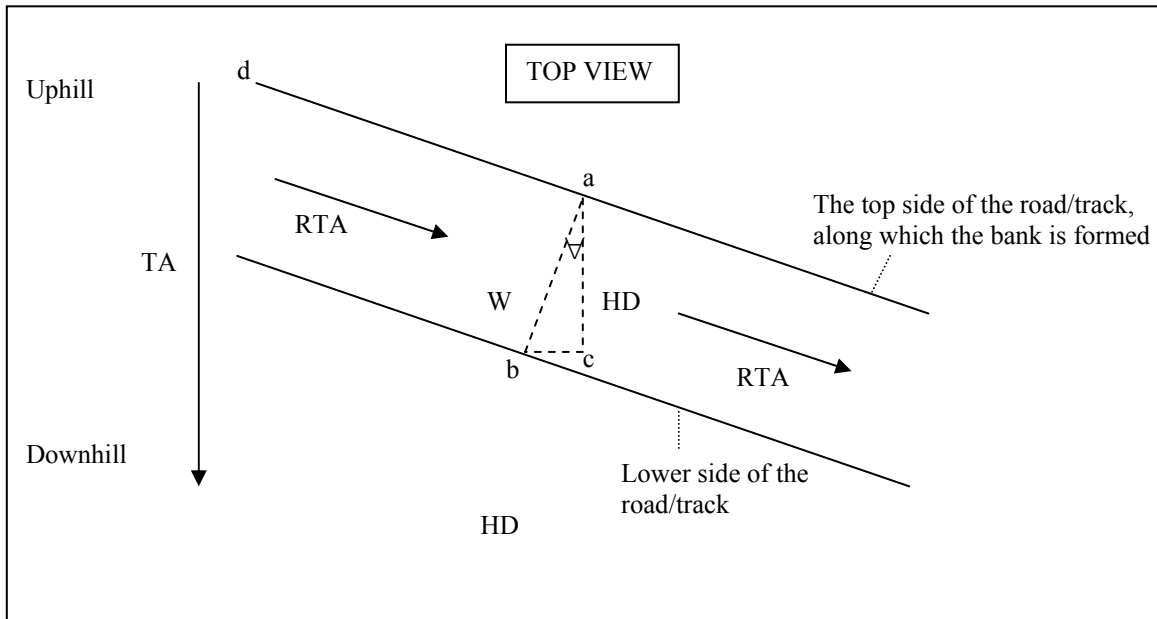
was adopted.

Figure 4.5: Calculating the horizontal distance cut into a slope.

In reference to Figure 4.5 above, if the bearing from points a to b is perpendicular to the road/track aspect (thus ∡(b,a,d) = 90 degrees) and likewise the bearing from points b to c perpendicular to the topographic aspect (thus ∡(b,c,a) = 90 degrees), then ∀ is equal to 90 degrees minus the positive angular difference between the road track aspect and the topographic aspect. With respect to the current study the following substitutions were used, Adjacent = the horizontal distance cut directly into the slope face (HD), Hypotenuse = the width of the road /track (W) and ∀ = 90 degrees minus the angular difference between the aspect of the road/track (RTA) and the topographic aspect (TA). Substituting these terms into (3), the horizontal distance can then be calculated by:

(4) $[HD = Cos(90^o - ∡\{RTA, TA\}) * W]$

(where ∡{RTA, TA} is the positive angular difference between the two aspect bearings). Combining (2) and (4) to produce an estimate of bank height gives:

(5) $[BH = Tan(S) * Cos (90^o - ∡\{RTA, TA\}) * W]$

The average bank height multiplied by the horizontal distance along a homogenous track section (D), provides the associated bank area (BA). Substituting (5) into this equation, gives:

(6)   [BA = (Tan(S) * Cos (90° – $\not\subset$ {RTA, TA}) * W) * D].

However, the formula above relies on a number of assumptions, which are may be violated for a number of reasons:

a) that all road/tracks are produced only by cutting into the slope {however, in general, road tracks are constructed by a process of cutting and filling and the ratio of cutting and filling may vary with respect to changes in topographic slope and/or underlying geology};

b) the face of the newly formed bank along any road/track section is vertical {larger sized banks may be graded to produce a more stable slope};

c) the topographic slope and aspect are homogenous along a road/track section, {as the road/track segment increases in length, topographic slope and aspect are more likely to differ along a segment}; and

d) the slope of a line drawn directly across the width of a track (i.e. from the outside to the inside edge, from points b to a in Figure ..) at any point is horizontal {however, roads/tracks are often sloped to allow for water runoff to prevent pooling}.

Therefore, with regard to the current study, the formula above is intended to provide a comparative index of bank area only. Before an estimate of the bank area of each road/track segment could be produced, the road/track aspect of each segment had to be determined.

4.5.1 The Calculation of Road/Track Aspect

To calculate the road/track aspect, it was first necessary to define each transport segment and the co-ordinates and associated height value of the start and end point of each transport segment had to be calculated.

The MI tool, "Overlay Nodes", was used to create nodes along transport polylines (i.e. polyline objects representing road/tracks in the table Transport.tab) where they intersected with cell objects (BaseGrid30m.tab). The VM options "Poly to Points" and "Point Inspection" were used to create point objects at the nodes along transport polylines and assign a height value to each point. This table was saved as TransportFin_ptp.tab, and the height value stored in a new column, *LABEL_2*. The MI tool "Coordinate Extractor" was used to assign Easting and Northing co-ordinates to each point object in two new columns *Easting* and *Northing* respectively.

Transport polyline objects (Transport.tab) were converted to line objects through manual digitising and the new line objects saved as a new table, TransportFin.tab. Thus, a new line object was formed between each consecutive node along a transport polyline. Figure 4.6 displays the process by which transport polylines (Transport.tab) were digitised to produce a series of single line objects in the table TransportFin.tab.
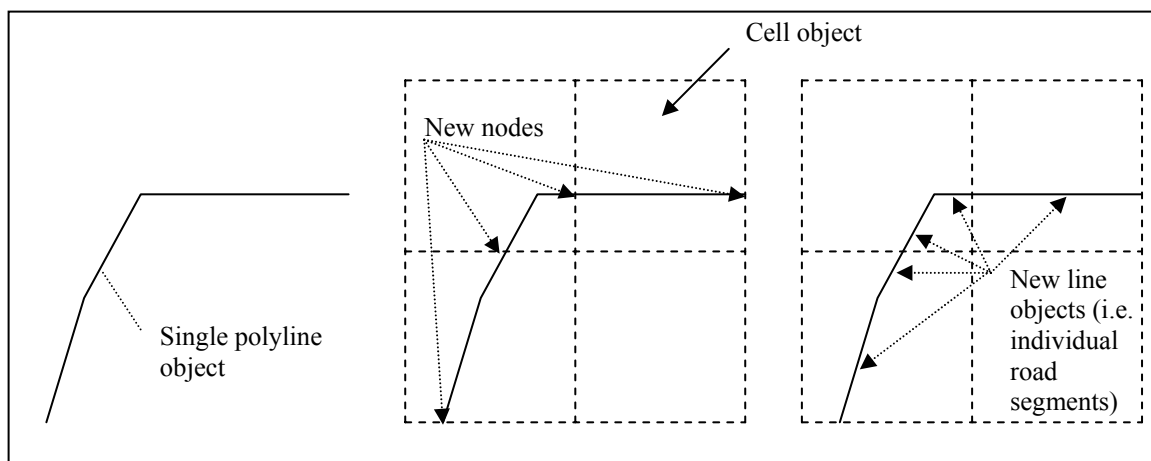

Figure 4.6: The overlaying of nodes along road/track polylines.

Six new columns were then created in the table TransprtFin.tab, titled *MaxHeight*, *MinHeight*, *MaxHeightEast*, *MaxHeightNorth*, *MinHeightEast* and *MinHeightNorth*. Values for these columns were calculated in the same way values in the table DrainageFin.tab were calculated for *HeightMax*, *HeightMin*, *HMaxEast*, *HMaxNorth*, *HminEast* and *HMinNorth* respectively, except, using the tables TransportFin.tab and TransportFin_ptp.tab (instead of DrainageFin.tab and DraiangeFinSelected_ptp.tab). Thus, the co-ordinates of the start and end point of a line segment (i.e. road segment) and associated height value were assigned to the table TransportFin.tab.

To determine the aspect for each section of road, the acute angular difference between the road aspect and a line parallel to the East – West axis (ι) was first calculated by rearrangement of the formula:

(1)   [Tan(ι) = opposite / adjacent] to [ι = ArcTan(opposite / adjacent]

With respect to the fomula above and the current study, two new columns were formed titled *NorthingDiff* and *EastingDiff* in the table TransportFin.tab. The value of the term "opposite" was calculated as the difference between the Northing coordinate at the highest end point of a track *(MaxHeightNorth)*, minus the difference between the Northing coordinate at the lower end point of a track *(MinHeightNorth)*. This value was assigned to the column *NorthingDiff*. "Adjacent" was calculated as the difference between the Easting coordinate at the highest end point of a track *(MaxHeightEast)*, minus the difference between the Easting coordinate at the lowest end point of a track *(MinHeightEast)*. This value was then assigned to the column *EastingDiff*.

Next, a new column was created titled *RoadTrackAspect*. This column was initially assigned the value of ι in equation (1) above. Also, as stated previously, MI when calculating the ArcTan of an angle works with radians, so the conversion factor, (* (180 / 3.1459)) was included. Using MI terminology and substituting column headings into (1) gives:

[*RoadTrackAspect* = Atn (*NorthingDiff* /*EastingDiff*) * (180 / 3.1459)]

In Figure 4.7, ΔN and ΔE represent the difference between the Northing values from the start to end point of a line (*NorthingDiff*) and the difference between the Easting values from the start to end point of a line (*EastingDiff*). The magnitudes of ΔE and Δ N can be used to calculate the bearing of each line with respect to North.

When ΔN and ΔE are both negative, the bearing of the line is equal to 90 degrees minus ι; When ΔN is positive and ΔE negative, the true bearing can be calculated by 90 degrees plus ι; When ΔN and ΔE are both positive the true bearing can be calculated by 270 - ι; and when ΔN is negative and ΔE positive the true bearing is equal to 270 + ι.
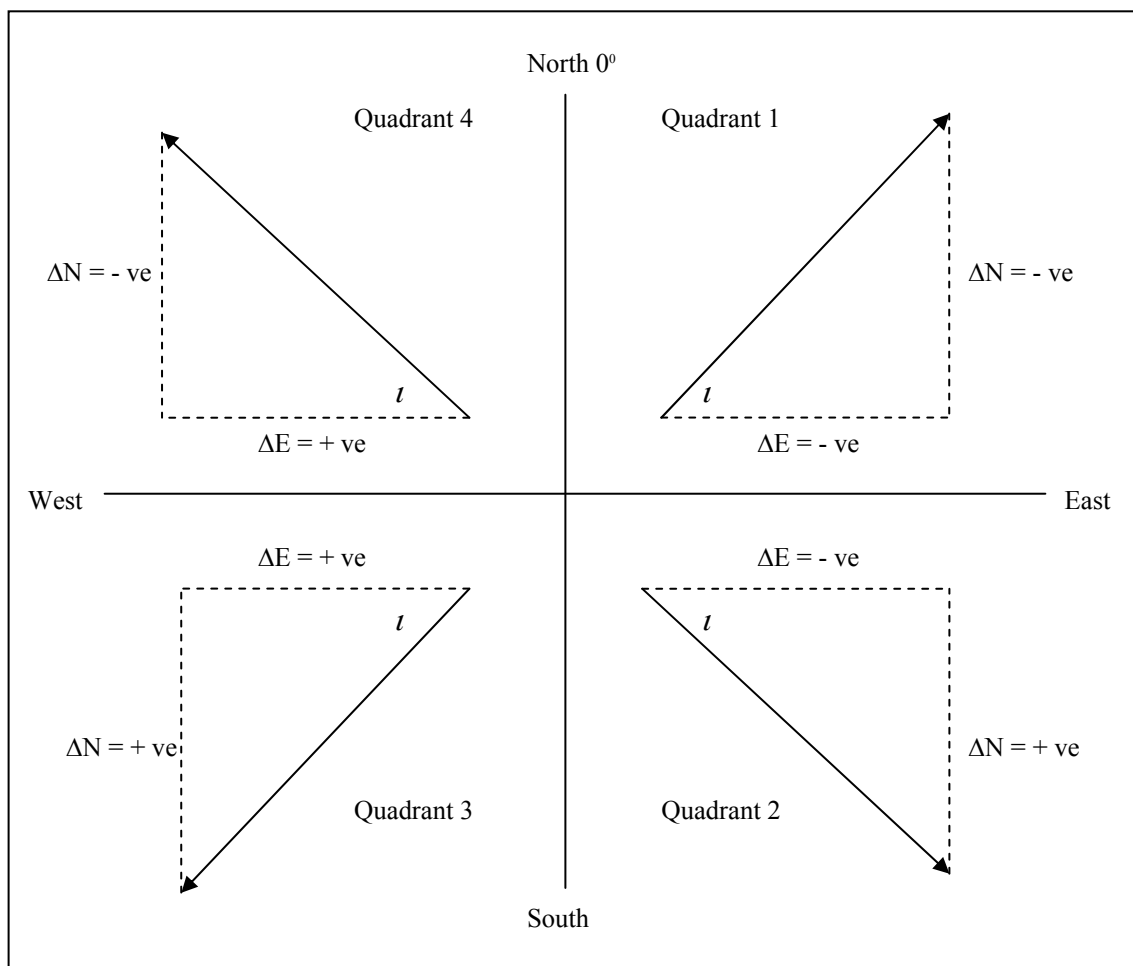

Figure 4.7: Calculating the true aspect.

Thus, to calculate the true value of the aspect of each road segment, the positive or negative magnitudes of the calculated values in the columns *NorthingDiff* and

EastingDiff were used. MI SQL was used to select rows (thus, transport line objects) in which different combinations of the magnitude of the values in the columns *NorthingDiff* and *EastingDiff* were present. The "Update Column" command was used to modify the value in the column *RoadTrackAspect* ($\imath$) appropriately. Table 4.3 below displays the appropriate MI expression used to modify selected values in the column *Road_TrackAspect*.

Table 4.3: The MI expressions used to assign true aspect.

Magnitude of the column *NorthingDiff*	Magnitude of the column *EastingDiff*	The MI expression used to modified the column *Road_TrackAspect*:
- ve	- ve	$90 - Road\_TrackAspect$
+ ve	- ve	$Road\_TrackAspect + 90$
+ ve	+ ve	$270 - Road\_TrackAspect$
- ve	+ ve	$Road\_TrackAspect + 270$

The "Update Column" command and the geographic join, "where TransportFin object (i.e. a line object) is within BaseGrid30m object (i.e. cell region)" was used to transfer values from the columns *Aspect* and *Slope* in the table BaseGrid30m.tab to the columns *TopoAspect* and *TopoSlope* in the table TransportFin.tab.

A new column was then created in the table TransportFin.tab named *TopoAsp_RoadTrackAsp*. The value assigned to each row in this column was the absolute difference between the topographic aspect of the slope and the aspect associated with the road/track. The MI expression used was:

$$[TopoAsp\_RoadTrackAsp = \text{Abs}(TopoAspect - RoadTrackAspect)].$$

As the angular difference between the topological slope and road/track aspect (*TopoAsp_RoadTrackAsp)* should be less than 90 degrees, a number of values in the column required editing. For example, if the road track aspect was 350 and the topographic slope aspect 10 degrees, the angular difference is 20 degrees, however, the calculated value based upon the formula above, would be 340 degrees.

MI SQL was then used to select values that were greater than 90 degrees. The "Update Column" command was performed on the selected values and the following expression applied:

[*TopoAsp_RoadTrackAsp* = Abs((Maximum(*TopoAspect, RoadTrackAspect*) − 180) − (Minimum(*TopoAspect, RoadTrackAspect*) +180))].

The above expression subtracted 180 degrees from the maximum value of either the topographic aspect or the road/track aspect and added 180 degrees to the smaller value. The two values were subtracted and the absolute value of the product reassigned to the column *TopoAsp_RoadTrackAsp.*

However, a number of values (77 out of 668) were still found to be slightly greater than 90 degrees. This is likely a result of the selected cell resolution in the table BaseGrid30m.tab (i.e. the value of the topographic aspect at the center of a cell object being applied to the entire cell). The aspect for the remaining values that were greater than 90 degrees were then manually edited by reversing the road/track aspect and calculating the angular difference between the topographic slope and the reversed road/track aspect. Although this is erroneous, as most of the remaining values that were greater than 90 degrees were only slightly so, reversing the aspect, and then recalculating produced a value only slightly less than 90 degrees.

4.5.2 Calculation of Bank Area

Two new columns, *RoadTrackWidth* and *RoadTrackDist* were added to the table TransportFin.tab. The value of the first column was based on the collection of a number of measurements along different sections of roads and walking tracks. The average value noted within Maiala National Park for roads was approximately 4m. With respect to walking tracks, the average value observed was 1.2 meters.

Each row (thus line object) in the second column, *RoadTrackDist*, was assigned a value through the MI "Update Column" command, calculated by the expression "CartesianObjectLength" in meters.

A new column was added to the table TransportFin.tab titled, *BankIndex*. The formula for bank area (6) discussed at the beginning of section 4.5 was used to assign a value to each row in this column:

(6)   [BA = (Tan(S) * Cos ($90^o - \not\subset$ {RTA, TA}) * W) * D].

With respect to MI terminology and column headings, the following substitutions were used, BA= *BankAreaIndex*, S = *TopoSlope* * (3.1459 / 180), Cos ($90^o - \not\subset$ {RTA, TA}) = Cos((90 -*TopoAsp_RoadTrackAsp*) * (3.1459 / 180), W = *RoadTrackWidth* and D = *RoadTrackDist*. (Nt. as MI works in radians when calculating Tan or Cos of an angle, the conversion factor (* (3.1459 / 180)) was used to convert from degrees to radians). Thus:

[*BankAreaIndex* = Tan(*TopoSlope* * 3.1459 / 180) * Cos((90 - *TopoAsp_RoadTrackAsp*) * 3.1459 / 180) * *RoadTrackWidth* * *RoadTrackDist*]

4.6 VEGETATION AND SOIL

As stated in section 3.3, the species was found to occur in tall open to closed woodland. Areas of low shrubland/heathland were suggested to be less suitable for habitation. The original attribute columns *VEGTYPE* and *FIREASSOC* (see Appendix D). in the table BFP_Veg.tab were transferred to the table BFP_VegFin.tab. These columns provided information concerning the vegetation type/dominant species, and the general vegetation structure (Rainforest, Wet, Moist and Dry Sclerophyll Forest and Heathland) for each region object respectively

Unfortunately, no mapped soil information for the selected area was available. To produce a basic soil map for the study site, the soil preferences of vegetation species within each vegetation region were used to define the associated general soil type of a region in the table BFP_VegFin.tab. With respect to the column VEGETYPE, seven different vegetation communities were classified within the study site. A vegetation guide (FRD 1995) was used to relate the dominant species of each vegetation community to a general soil type (Clay, Sand and Silt).

However, all vegetation communities within the study area were associated with clay soils. Thus, for the purpose of the present study, soil composition across the entire study site was assumed to be suitable for habitation by *Arbanitis variabilis*. The table attached as Appendix D displays the interpreted general soil type associated with each vegetation community and its vegetation structure.

4.7 THE MODEL

As precisely defined relationships between topographic/thematic elements and the species habitat preference could not be attained within the scope of the present study, tree classification ranking, additive map algebra and rule based methods were adopted to calculate the HSI for each cell.

Each element (e.g. catchment value) in a topographic/thematic category (e.g. Drainage) was divided into three discreet classes (except for vegetation {2 classes} and anthropogenic banks {6 classes}) by the MI procedure "Natural Gaps" (identifies discreet gaps in compiled data based on a number of pre-defined classes). All classes from all topographic/thematic categories, except for the category vegetation, were ranked from 1 to 18 with respect to their assumed influence on habitat suitability as outlined in Chapter 3.

A permutation factor (PF) (starting from 0,1, 2, 4, 8, 16, 32 ..) was then assigned to each rank, so that the highest ranked class received the highest permutation factor and

the lowest ranked class, the lowest permutation factor. The sum of the permutation factors for each class of category element associated with a cell, was used as the HSI for that cell. With respect to vegetation, HSI's with a value of greater than zero, were only assigned to cells located in "Tall to Open Sclerophyll Forest" (as cells located within "Heathland" were assumed to be unsuitable for habitation, see section 3.3). Table 4.4 shows the ranked order of each class and its associated permutation factor.

Table 4.4: The ranking of permutation factors with respect to classes for all category elements.

Topographic/Thematic Category	Category Element (*Column Name*)	Rank	Class	Permutation Factor
Vegetation	Vegetation Structure (*VegetationStructure*)	-	Open to Closed Forest	-
		-	Heathland	-
Drainage lines/riparian banks	Catchment Value (*Catchment*)	14	High	2048
		12	Medium	1024
		10	Low	512
	Sinuosity Index (*Sinuosity*)	9	High	256
		8	Medium	128
		7	Low	64
	Drainage Line Slope (*DrainageSlope*)	6	High gradient	32
		5	Medium gradient	16
	(continuous variable)	4	Low gradient	8
Anthropogenic Bank Formations	Bank Area Index (*BankAreaIndex*)	17	Greatest	2336
		16	Large	2192
		15	Medium – Large	2120
		13	Medium	1184
		12	Medium - Small	1104
		11	Small	776
Topographic areas of more continuous undulating slope	Topographical Slope (*Slope*)	3	High gradient	4
		2	2 Medium gradient	2
		1	1 Low gradient	1

The permutation factor is intended to be reflective of the assumed ranked influence on habitat suitability and not the magnitude of the effect on habitat suitability. The reason for using a permutation factor was to ensure there was no overlap between categories or elements within categories (i.e. as precise interactions could not be determined within the present study). One exception to the statement above, was between drainage elements and anthropogenic formed bank elements.

As different indexes were used to predict the extent of banks along drainage lines and road/tracks, anthropogenic banks were assigned approximately the same range of

permutation values as the range between the minimum and maximum sum of the drainage elements. With reference to Chapter 3, it was suggested that on average anthropogenic banks likely provide greater habitat suitability than in riparian areas. Thus, the minimum permutation factor assigned to the lowest class of anthropogenic banks was slightly greater than the minimum sum of the drainage permutation factors.

Also, as the difference between track and road width was quite significant, anthropogenic banks were assigned six classes instead of three. The table attached as Appendix E displays the permutation values assigned to the six classes of anthropogenic banks, with respect to the range of values associated with the sum of different combinations of drainage elements (i.e. 3 * 3 *3 = 27).

4.7.1 The Calculation of the Habitat Suitability Index for each Cell Object

The table BaseGrid30m was overlaid with the table cadastre. A geographic join was used to select cells from the table BaseGrid30m.tab that were located entirely within the region object in the table cadastre.tab. The selected cells were then inverted and the new selected cells deleted. This was to ensure only cells whose centroid fell within the boundary of Maiala National Park remained.

Next, the table BaseGrid30m.tab was overlaid with the tables DrainageFin.tab, TransportFin.tab and BFP_VegFin.tab. The columns headings (and their associated values), *Sinuosity* and *DrainageSlope* in the table DrainageFin.tab were transferred to the table BaseGrid30m.tab. In both cases, the geographic join "where object from DrainageFin.tab is within object from BaseGrid30m.tab" was used to relate each polyline object to the cell in which it was located. As more than one polyline object (i.e. drainage line segment) from the table DrainageFin.tab may be contained within a single cell (i.e. where drainage lines intersected within a cell region), the maximum value, with respect to both of the columns *Sinuosity* and *DrainageSlope*, was assigned to each cell.

By the same geographic join, the column *BankIndex* in the table TransportFin.tab was transferred to the table BaseGrid30m.tab. However, the value of the column *BankIndex* (i.e. index of anthropogenic bank area) assigned to each cell in the table BaseGrid30m.tab was calculated as the sum of the values for each road/track line contained within a single cell, therefore producing a total estimate of the bank area. Values in the column *FIREASSOC* were also transferred to the table BaseGrid30m.tab in a new column titled *VegetationStructure*. To assign a vegetation description to each cell, the geographic join, "where region object (BaseGrid30m.tab) is within region object (BFP_VegFin.tab)", was used. Thus, each cell was classed as Rainforest and Vine Scrub, Wet, Moist or Dry Sclerophyll Forest, or Heathland. These values were then reclassified to either, "Tall to Open Forest", or "Heathland".

The MI option " Create Thematic Maps" was employed to produce a map for each category element listed in Table 4.4. As the precise effect of each element on habitat suitability was unknown, the range of values associated with each element were grouped into classes, (based on the number of classes listed in Table 4.4) by the procedure "Natural Gaps". The method, "Natural Gaps", was chosen to reflect as much as possible, the natural variation in topographic and thematic conditions within the study site.

Six new columns were created in the table BaseGrid30m.tab titled *SlopePF, BankIndexPF, DrainageSlopePF, SinuosityPF,* and *CatchmentPF*. The values in these columns were derived from the determined ranked class ranges and the associated permutation factor (listed in Table 4.4) for the columns *Slope*, *BankAreaIndex*, *DrainageSlope*, *Sinuosity*, *Catchment and Drainage* respectively. MapInfo SQL and the "Update Column" command were used to select values within each class range for each category element and assign the respective permutation factor to the appropriate column.

Two more columns were added, *DrainagePF* and *MaxDrain_BankIndex*, to the file BaseGrid30m.tab. The value of the column *DrainagePF* was assigned as the sum of the permutation factors in the columns *DrainageSlopePF, SinuosityPF,* and *CatchmentPF*. Thus a total drainage permutation factor for each cell which contained a drainage line was assigned. A thematic map was also created for the column

DrainagePF, to represent the effect of all catchment elements on habitat suitability. To maximise the variation between drainage line sections, the maximum number of classes permitted (16) was used, and the procedure "Natural Gaps" was adopted once again to assign the range of values to each class.

When both drainage line and road/track objects were located within a individual cell object, the maximum permutation factor associated with either the drainage or the road/track section (with respect to the columns *DrainageSlopePF* or *BankIndexPF*) was used to calculate the cell HSI. This value was assigned to the new column *MaxDrain_BankIndex.*

The HSI for each cell was then calculated by adding the respective permutation factors from the columns *SlopePF* and *MaxDrain_BankIndex*. A new column HSI_PF was created to hold the respective HSI for each cell in the table BaseGrid30m.tab. Each cell was assigned a cell HSI by the MI expression:

[*HSI_PF = TopoSlopePF + MaxDrain_BankIndex*]

Finally, MI SQL was used to select cells located in the vegetation structure "Heathland". The update column was then used to assign the value of 0 to the respective row in the column HSI_PF, irrespective of whether or not other category elements (e.g. such as slope, drainage elements etc) were present within selected cells. A thematic map was produced, with ranges for each class assigned by "Natural Gaps" and the maximum number of classes permitted, selected.

CHAPTER 5 – RESULTS

5.1 TOPOGRAPHIC HEIGHT, SLOPE AND ASPECT (BASE GRID)

Figure 5.1, represents the estimated effect of topographic slope on occupation by *Arbanitis variabilis*. Habitat suitability is presumed to increase for the species as topographic slope increases. The dark red areas represent areas of high slope and comparatively, the lighter red areas, gentler slope. Slope was measured in degrees from the horizontal.
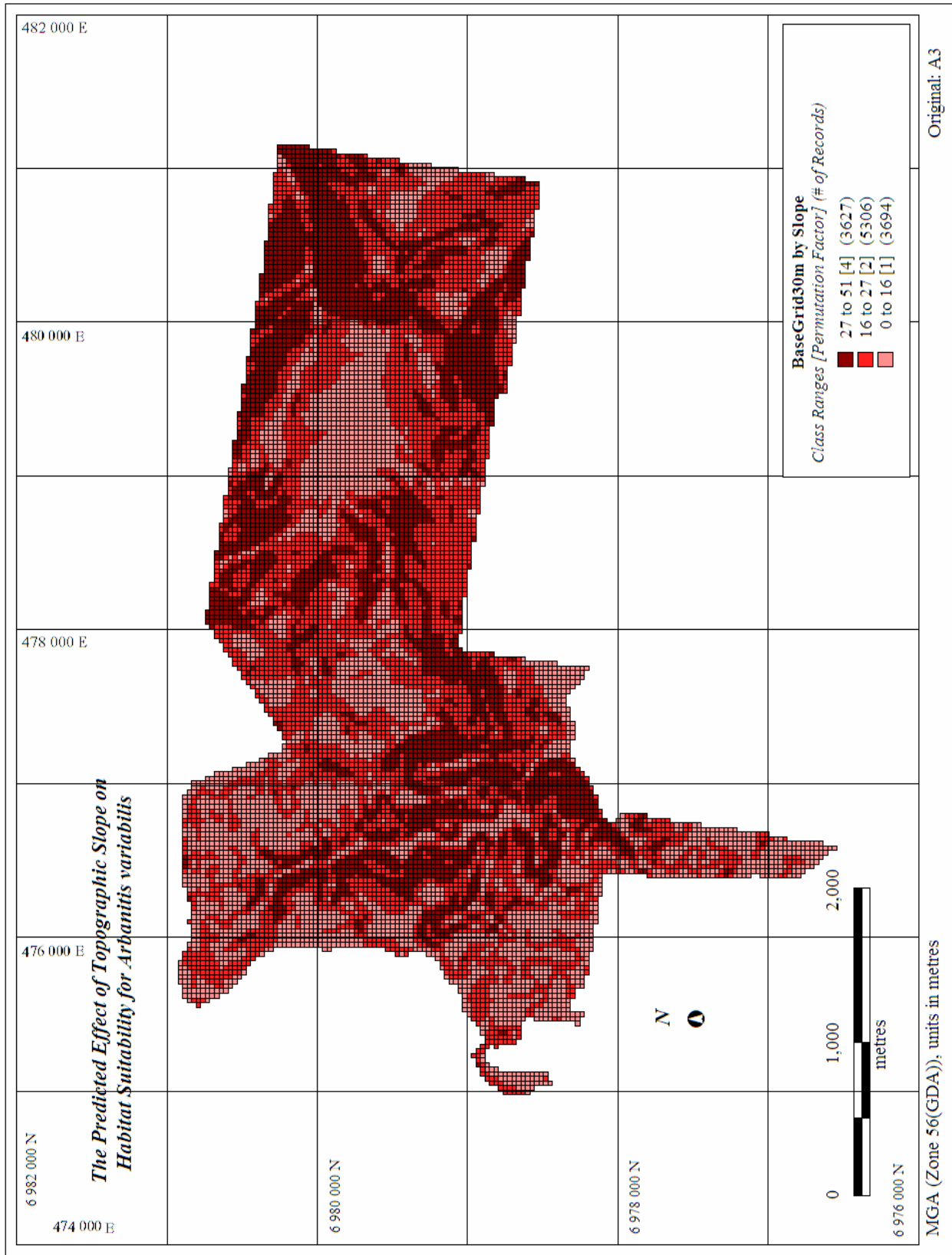
Figure 5.1: The predicted effect of slope on habitat suitability for *Arbanitis variabilis*

5.2 DRAINAGE LINES/RIPARIAN BANKS

Figures 5.2, 5.3, 5.4, and 5.5, represent the ranked effect of the drainage line elements catchment value, the sinuosity index or the extent of meandering of individual drainage line segments, the associated slope of each segment and lastly, the combined effect of all elements on habitat suitability for *Arbanitis variabilis*. With reference to each figure, the darkest cells indicate drainage lines segments with the greatest catchment area, sinuosity and the steepest gradient, respectively. The catchment index was calculated based on the accumulated number of cells upstream through which drainage lines passed. Sinuosity was calculated based on the ratio of the straight-line distance between the start and end of a drainage segment and the total horizontal distance of the drainage line segment. Drainage slope was measured in degrees form the horizontal.

Figure 5.5, depicting the combined effect of all drainage elements, was calculated by the sum of the permutation factors associated with the drainage elements, catchment area, sinuosity and drainage line slope. The increase in catchment area is assumed to have the greatest effect on habitat suitability and thus in general, the darkest cells are located along areas where the catchment value is the greatest. Even though visually delineating between each of the consecutive class ranges is not possible, all sixteen classes were kept to maximise the values associated with different combination of drainage elements, and to produce a graded appearance with respect to increasing habitat suitability.
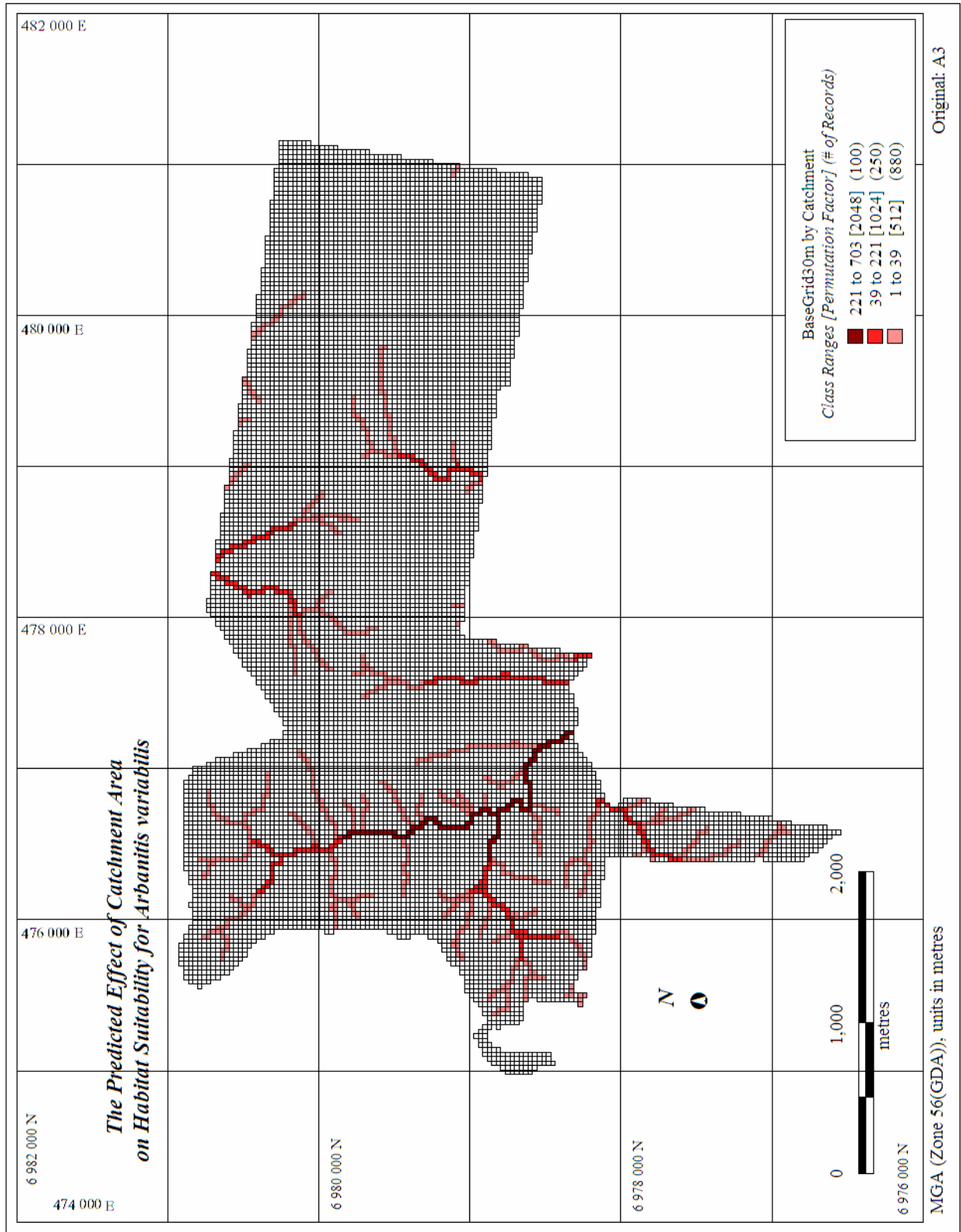
Figure 5.2: The predicted effect of catchment area on habitat suitability for *Arbanitis variabilis.*
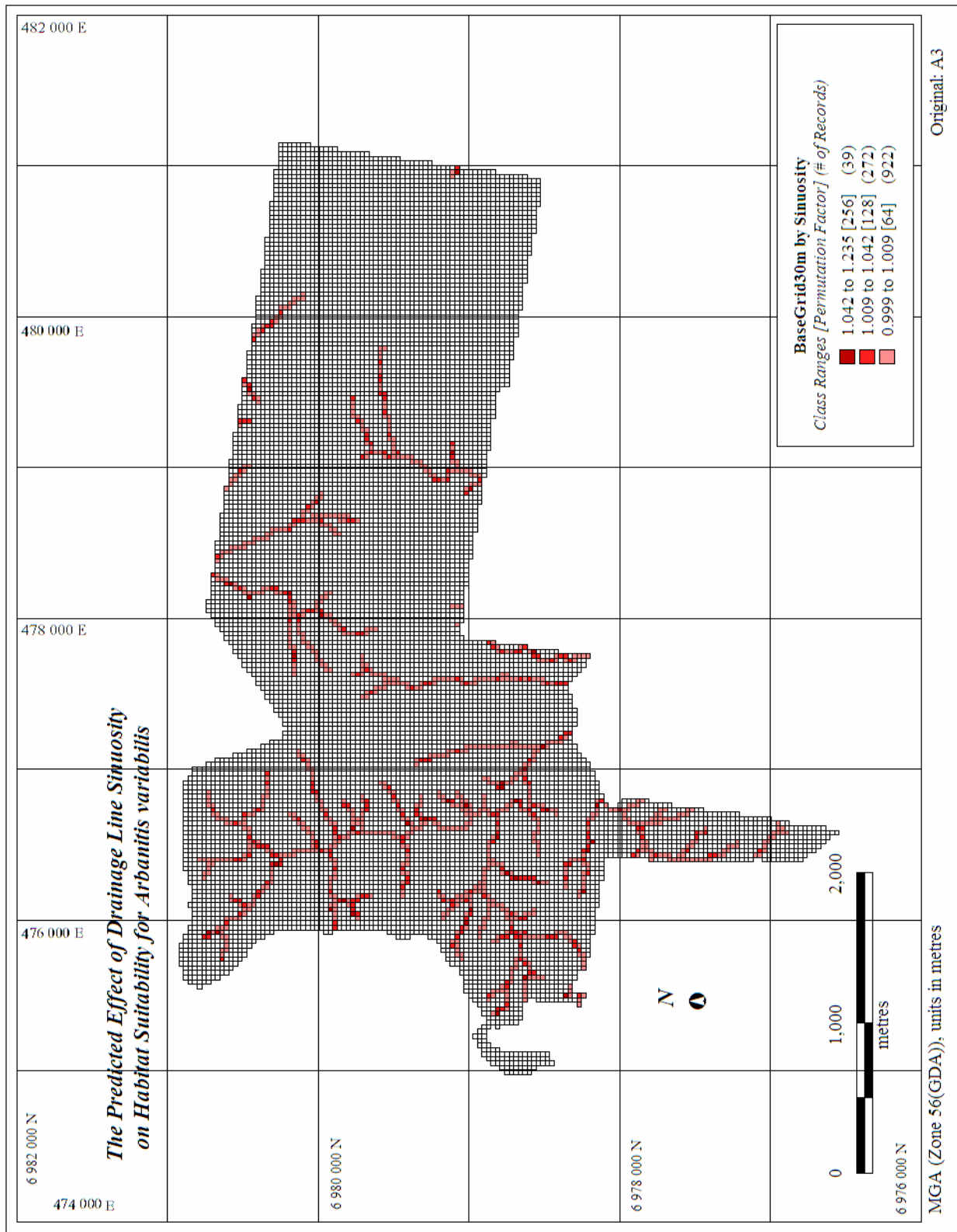
Figure 5.3: The predicted effect of drainage line sinuosity on habitat suitability for *Arbanitis variabilis*.
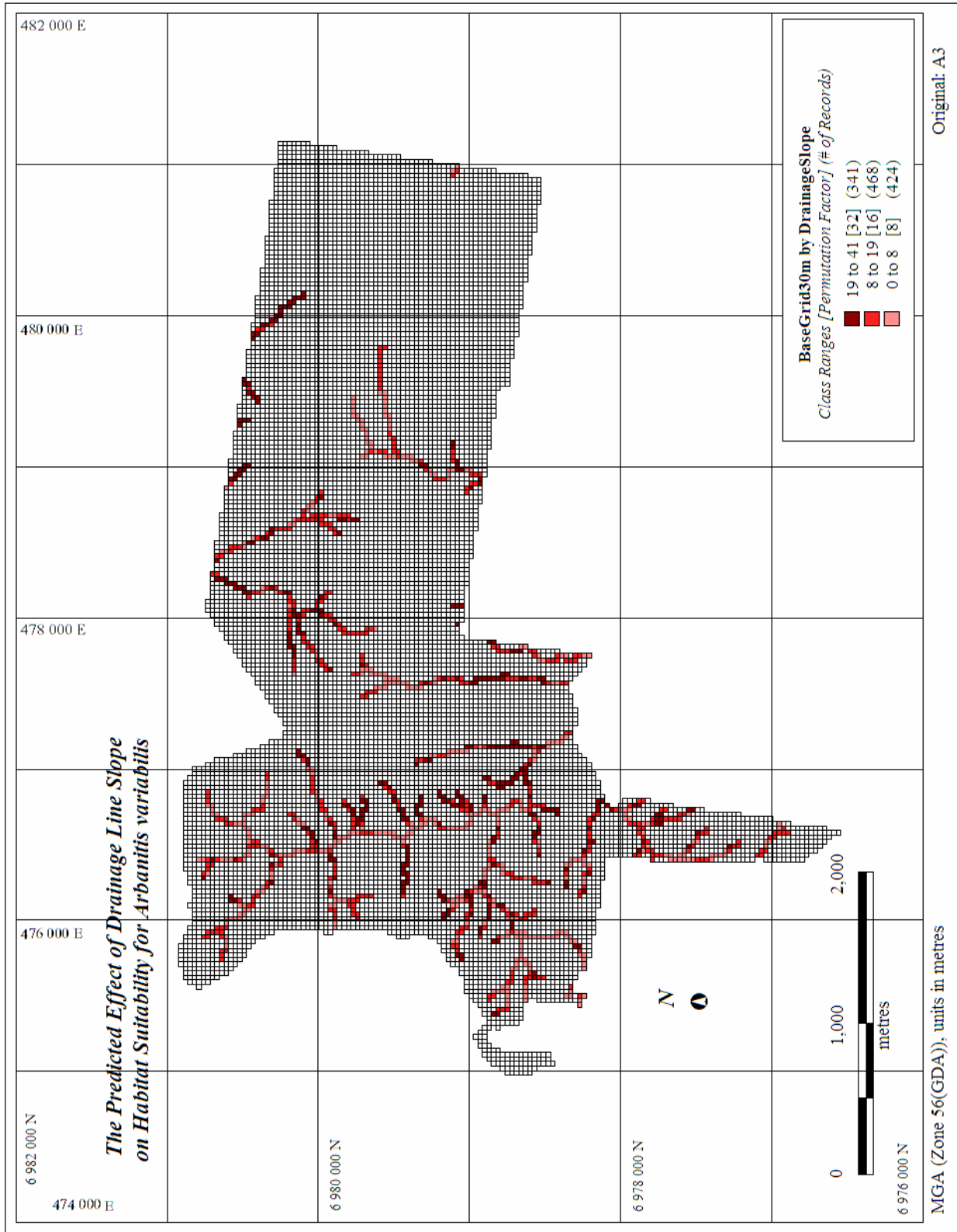
Figure 5.4: The predicted effect of drainage line slope on habitat suitability for *Arbanitis variabilis*.
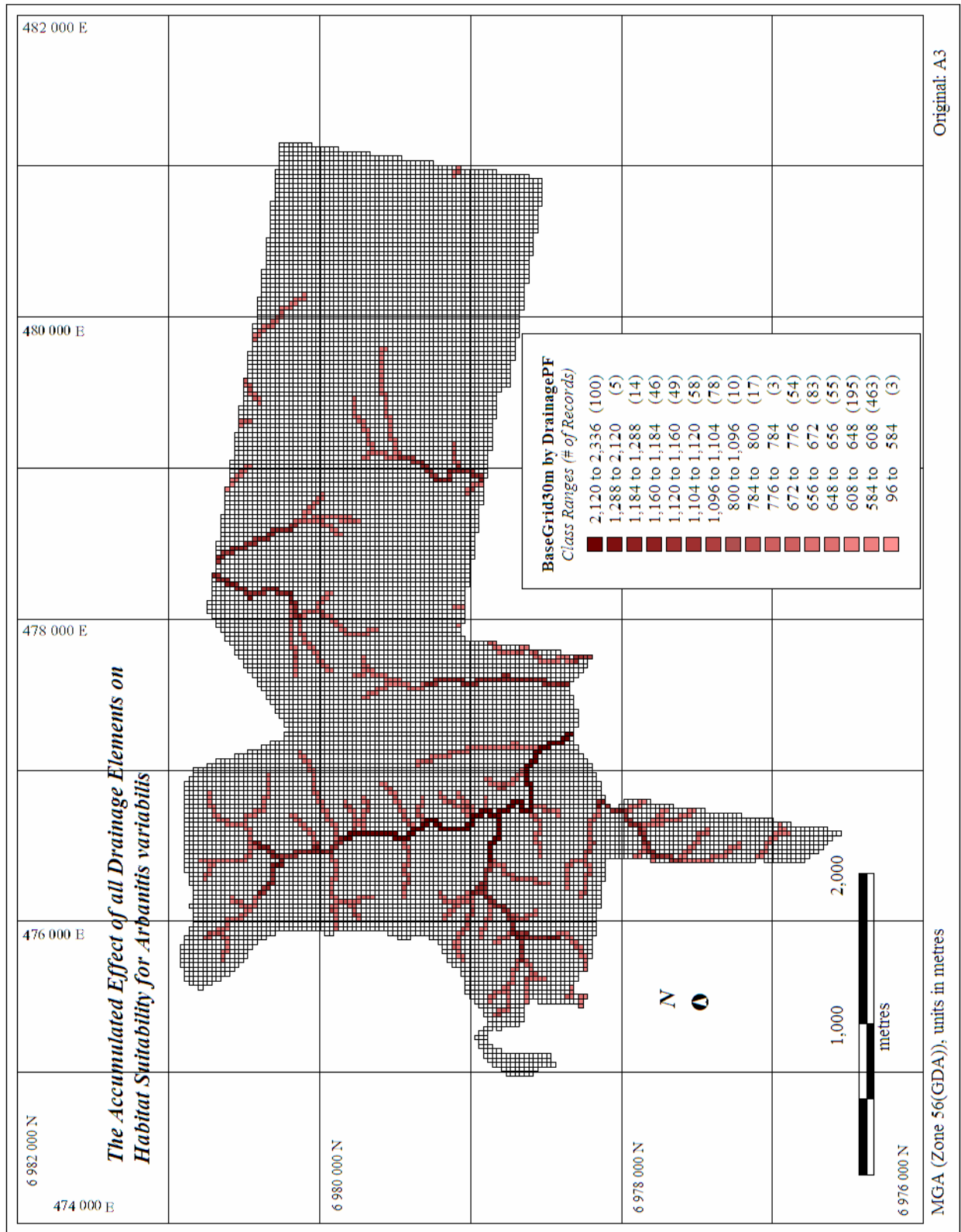
Figure 5.5: The accumulated effect of all drainage line elements on habitat suitability for *Arbanitis variabilis*.

5.3 ANTHROPOGENIC FORMED BANKS

The coloured cells in Figure 5.6 represent cell areas through which roads and tracks pass. The darker cells represent regions with theoretically larger bank areas and thus, should provide a greater extent of suitable habitat for occupation by the focal species.
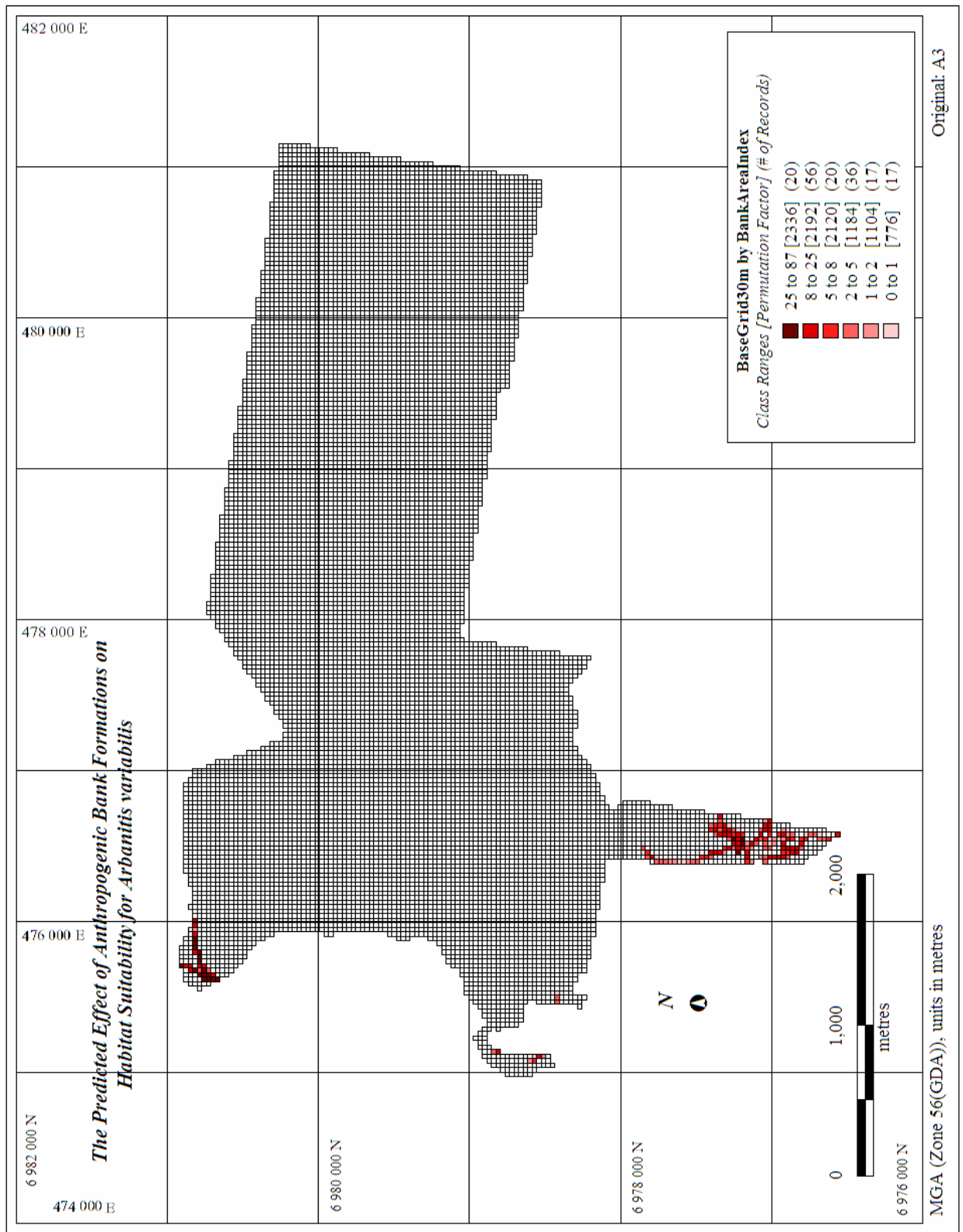
Figure 5.6: The predicted effect of anthropogenic bank formations on habitat suitability for *Arbanitis variabilis.*

5.4 Vegetation and Soil

In Figure 5.7, the two areas in which cells are not colored represent areas of "Heathland", presumed unsuitable for habitation by the species. With respect to the rest of the study site, the vegetation structure was classified as "Tall Open to Closed forest", suitable for habitation.

Figure 5.7: The predicted effect of vegetation structure on habitat suitability for *Arbanitis variabilis*.

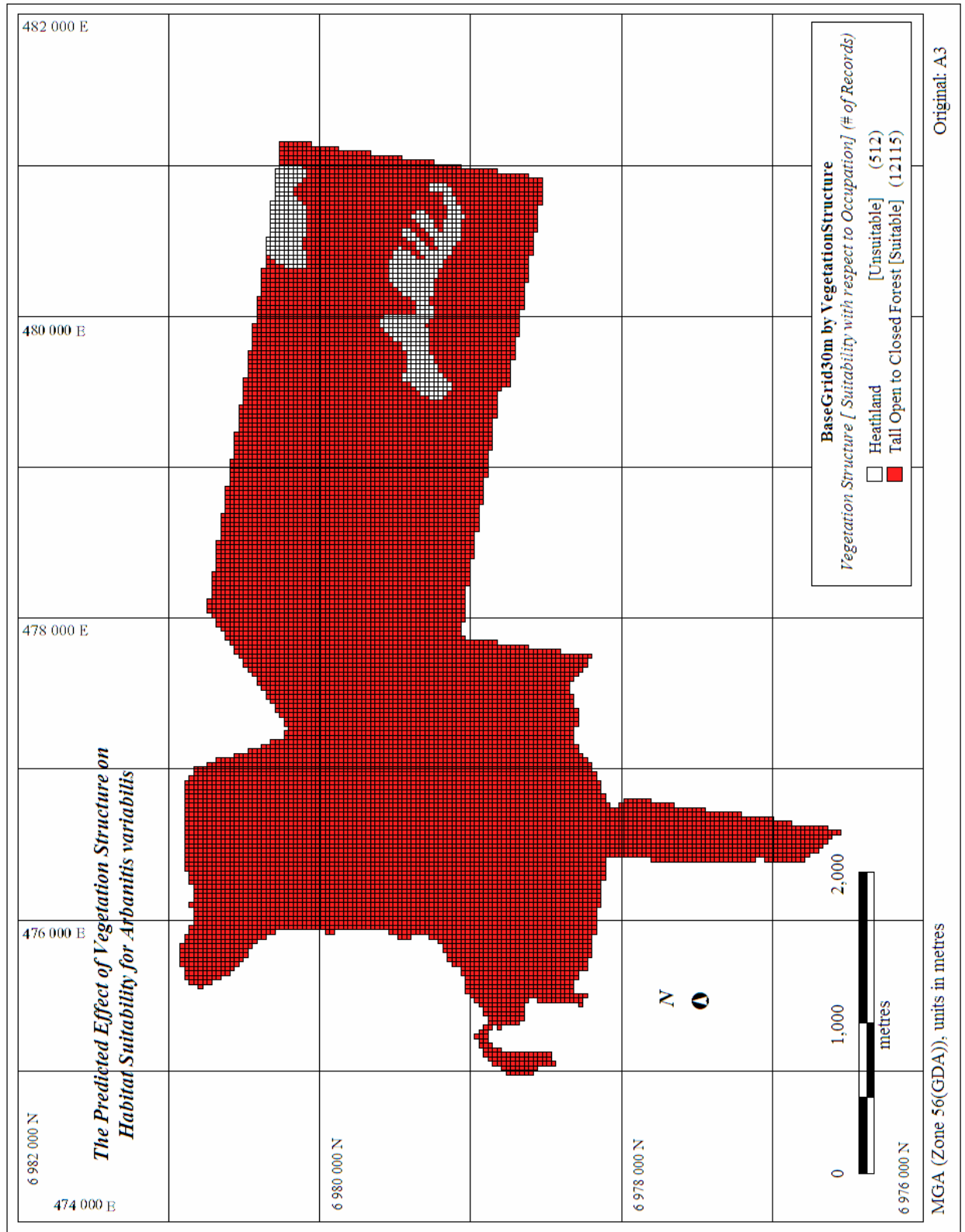As was the case with respect to defining class ranges for Figure 5.4, the method "Natural Gaps" was used to delineate discreet value ranges for the maximum number of classes allowed, sixteen. Although distinguishing between consecutive colour ranges is not possible, the maximum number of classes was retained to provide a more 'graduated' effect and maximise the possible ranges in habitat suitability for the species.

Figure 5.8, represents the combined effect of all category elements with respect to topographic parameters on habitat suitability. Anthropogenic banks and third and forth order drainage lines are depicted as the most suitable areas for occupation. In first and some second order drainage lines, the effect of drainage line sinuosity and/or gradient are observed to increase the habitat suitability of individual cells. With the inclusion of vegetation, the effect of topographic slope on habitat suitability shown in Figure 5.1 is countered in cell areas in which the vegetation structure "Heathland", was present.
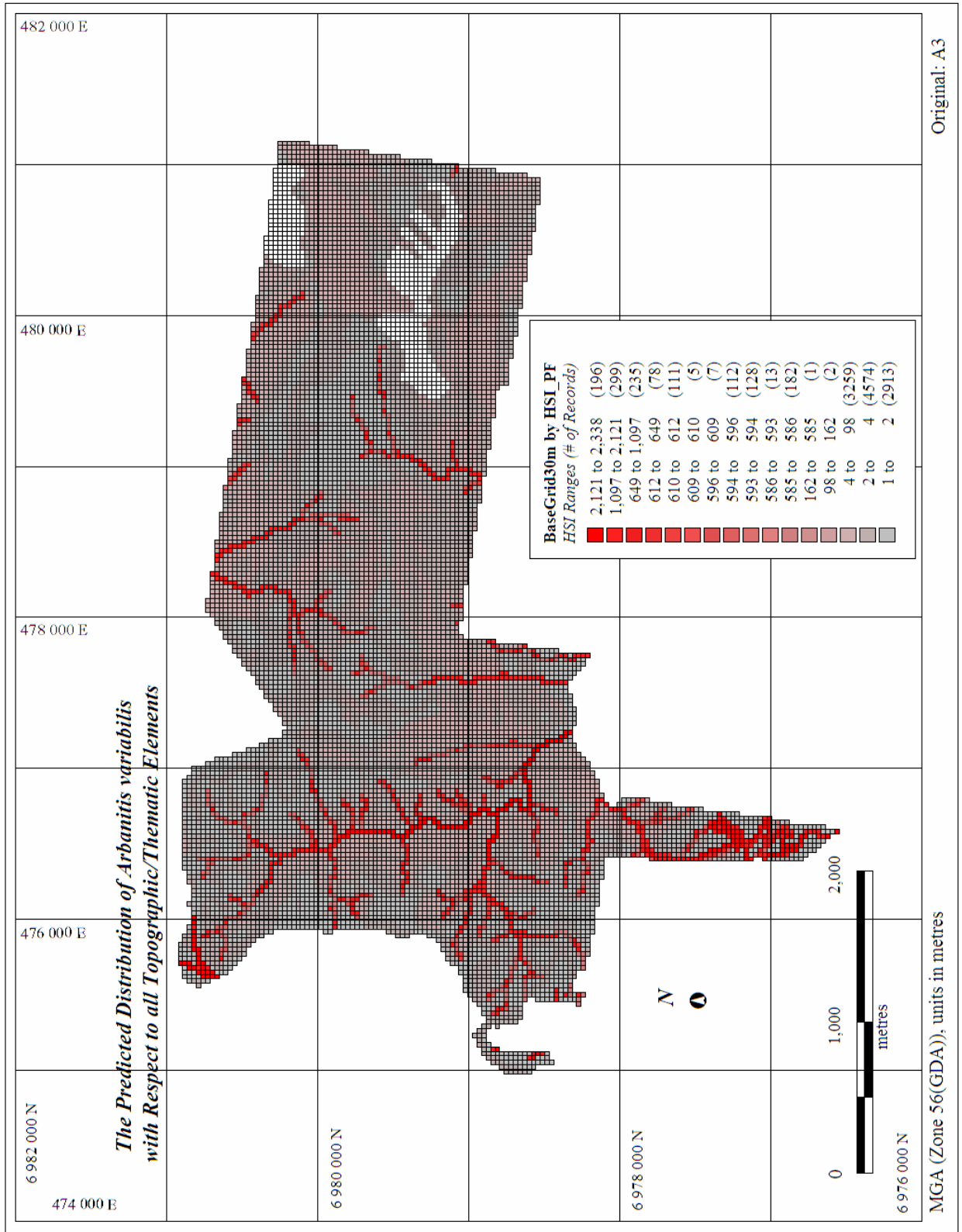
Figure 5.8: The predicted distribution of *Arbanitis variabilis* with respect to all topographic/thematic elements.

CHAPTER 6 – CONCLUSIONS AND SUMMARY

6.1 ASSESSMENT OF THE COMPLETED HABITAT SUITABILITY MODEL

The intended outcome of the present study was to delimit the species generalised distribution at a relatively small scale, based predominantly on mapped data at a scale of 1: 25 000 and to then assess the accuracy by comparing the model with the ground truth. Unfortunately, due to time constraints, the accuracy of the model is yet to be assessed. Although the general distribution of the species may be represented, a large amount of variation is likely present between elements within categories and also, between categories of topographic and thematic information due to a number of reasons.

The use of different indexes to estimate the extent of bank formations along drainage elements and anthropogenic road/tracks, significantly increases the difficulty of producing comparisons between the two categories. Furthermore, the indexes for both categories may be somewhat simplistic. As stated in section 4.5, four main assumptions were required to calculate an estimate of bank area along a road/track section, all of which may often be violated. With respect to riparian banks other factors that could not be obtained in the current study including, underlying geology and precise soil distributions may all effect the occurrence of banks along a drainage line.

Variation in the original mapped accuracy of acquired topographic/thematic layers (such as the inclusion of the walking track layer in which the mapped accuracy was presumed to be significantly limited), once again increases the variation between the predictive capability for different categories.

The basic model produced in the present study could be greatly approved upon with more comprehensive field analysis. Assessment of the variation between and within categories as outlined above, coupled with the inclusion of weighting factors and interaction terms with respect to environmental variables that affect the species distribution, would greatly improve the model accuracy.

For example, analysis of the relationship between the species demographics (i.e. population density) and the different vegetation structures (i.e. rainforest, wet, moist, dry schelrophyll vegetation and heathland) could be used to produce a weighting factor with respect to calculating habitat suitability. Assessment of the effect of high habitat suitability and occupancy zones on surrounding areas may also help to improve the model accuracy. Proximity analysis and buffering techniques could then be used to influence the HSI on neighbouring areas. The inclusion of the effect of interactions of topographic/thematic categories on habitat suitability, such as when anthropogenic banks and drainage lines were located within a cell unit, would also increase the predictive capacity of the model.

6.2 APPLICATIONS OF HABITAT MODELLING FOR TRAPDOOR SPIDER SPECIES

The extrapolation of microhabitat characteristics to large-scale topographic/thematic information, to identify a species general distribution, can only be achieved if the two factors can be linked. In many cases this may not be possible and is analogous to taking a digital photo with a set resolution and then tying to extract detailed information at a much higher resolution.

The present study suggests the microhabitat preferences of many trapdoor spider species, however, are conducive to extrapolation to large-scale topographic/thematic information, at least to provide an index of the general distribution. The focal species assumed preference for bank structures and thus riparian zones, clay based soils, particular vegetation structures and topographic slope can all be used to delimit the species general distribution over a comparatively large area. These same general categories could similarly be used for other species of riparian trapdoor spider species.

By dividing topographic/thematic values into natural classes representative of the study area and relating these classes to general habitat preferences, this method provides a comparatively simple and less costly approach than undertaking extensive fieldwork. Such models, as produced in the present study, provide a means by which to test and

confirm basic assumptions and a basis upon which more complex models can later be constructed.

REFERENCES

Ackakaya H. R. 2001. Linking population-level risk assessment with landscape and habitat models. The Science of the Total Environment. 274. 283-291.

Berry, J. 2004. Suitability Modeling. Map analysis. Topic 23**.** 1-13.
http://www.innovativegis.com/basis/MapAnalysis/Topic 23/Topic23.pdf (*accessed* 4/2005)

Bond, J. E. Coyle, A. C. 1995. Observations of the natural history of an *Ummidia* trapdoor spider from Costa Rica (Araneae, Ctenizidae). *The Journal of Arachnology*. 23. 157-164.

Christensen, N. 2000. Agents of Pattern Formation. In: Landscape Ecology: Analysis Strategies. Nicholas School of the Environment at Duke. 1-4.
http://www.env.duke.edu/landscape/classes/env214/le_strategy.html (*accessed* 4/2005)

Decae, A. E., Caranhac G. and Thomas, G. 1982. The supposedly unique case of *Cyrtocarenum cunicularium* (Oliver, 1811) (Araneae, Ctenizidae). *Bulletin of the British Arachnological Society*. 5. 410-419.

Fairweather, P. G. 1993. Abundance and structure of fossorial spider populations. Memoirs of the Queensland Museum. 33(2). 513-518.

Forest Resources Division (FRD). 1995. Trees and Shrubs. The Department of Primary Industries Queensland. 40-66.

Hillel, D. Hatfield, J. L. Powlson, D. S. Rosenzweig, C. Scow, K. M. Singer, M. J. Sparks, D. L. (eds). 2005. Encyclopedia of Soils in the Environment. Elsevier Academic Press. 463-465.

Price, P. and Lovett, S. 2002. Streambank Stability. Land and Water Australia. Australia. Canberra.
http://www.rivers.gov.au/acrobat/facts02.pdf (*accessed* 5/2005)

Main, B. Y. 1957. Biology of the *Aganippe* trapdoor spiders (Mygalomorphae: Ctenizidae). *Australian Journal of Zoology* 5. 402-473.

Main, B. Y. 1987. Persistence of invertebrates in small areas: Case studies of trapdoor spiders in Western Australia. Saunders D. A., Arnold, G. A., Burbridge, A. A. and Hopkins, A. J. M. (eds). *Nature Conservation: The Role of Remnants of Native Vegetation*. Surrey Beatty and Sons PTY in association with CSIRO and CALM, Australia. 29-39.

Main, B. Y. 1996. Microcosmic biogeography: trapdoor spiders in a time warp at Durokoppin. Hopper, S. D. (ed.). *Gondwanan Heritage: Past, Present and Future of the Western Australian Biota.* Surrey Beatty & Sons, Chipping Norton, New South Wales. 163-171.

Main, B. Y. 1999. Biological anachronisms among trapdoor spiders reflect Australia's environmental changes since the Mesozoic. Ponder, W. and Lunney, D. (eds). *The Other 99* Wales, Mosman. 236-45.

Main, B. Y. 2001. Personal communication.

Main, B. Y. (*accessed* 2005). '*Arbanitis variabilis*'. Australian Government: Department of the Environment and Heritage. *Australian Biological Resources Study*.
http://www.deh.gov.au/cgi-bin/abrs/fauna/details.pl?pstrVol=MYGALOMORPHAE;pst…

MapInfo Corporation. 2002. MapInfo Professional Version 7.

McCune, B. 2004. Nonparametric Multiplicative Regression for Habitat Modelling.
http://www.pcord.com/NPMRintro.pdf

Nelson, S. A. 2003. Streams and Drainage Systems. Tulane University. 1-9.
http://www.tulane.edu/~sanelson/geo1111/streams.htm

Northern Prairie Wildlife Research Center (NPWRC). 2001. Wildlife Habitat Management on the Northern Prairie Landscape, In: *USGS*.
http://www.npwrc.usgs.gov/resource/2001/whabmgt/info.htm

Northwood Technologies. 2000. Vertical Mapper, contour modelling and display software. Version 2.6.

Odom, R. H. Ford, W. M. Edwards, J. E. Stihler, C. W. Menzel, J. M. 2001. Developing a habitat model for the endangered Virginia flying squirrel (Glaucomys sabrinus fuscus) in the Allegheny Mountains of Western Virginia. *Biological Conservation*. 99. 245-252.

Vincent, L. S. 1993. The natural history of the Californian turret spider *Atypoides Riversi* (Aranae: Anthrodiaetidae): Demographics, growth rates, survivorship, and longevity. In: *The Journal of Arachnology.* 21. 29-39.

UBD. 2005. Brisbane Gold Coast and Sunshine Coast Street Directory, 48th Edition. A Division of Universal Publishers Pty Ltd. 85,105.

Williams, G. 2002. CERRA Invertebrates: A taxonomic and biogeographic review of the invertebrates of the central eastern rainforests reserves of Australia (CERRA), World heritage area and adjacent regions. *Technical reports of the Australian Museum*. 16. 13-14.

APPENDICES

The University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/2 Research Project
PROJECT SPECIFICATION

For: Stephen Trent
Topic: The Formation of a GIS Based Predictive Habitat Model For a Trapdoor Spider
                      Species (*Arbanitis* species)
Supervisor: A/Prof Frank Young (Faculty of Engineering and Surveying)
Associate Supervisor: Dr Barbara York Main (Department of Zoology Western Australia)
Enrolment: ENG4111 – S1, X, 2005
                      ENG4112 – S2, X, 2005

Project Aim: This project seeks to investigate the relationship between possible environmental
        parameters and the aforementioned species preferred habitat and to then utilise any detected
        relationships in predicting occupancy over a larger study area, and if possible, associated
        demographics.

Programme: Issue A, 14th March 2005

1. Research existing information concerning the ecology of trapdoor spider species and the use of
    geographic information systems in habitat modeling; also, ascertain the extent and scale of
    measurement of available topographic and environmental data over the study area.

2. Conduct a number of initial field trips to better define the extent of the study area and acquire
    preliminary observations concerning possible habitat characteristics.

3. Design and implement an appropriate sampling strategy to collect data concerning possible selected
    environmental characteristics (i.e. slope, aspect, area, vegetation type/cover, leaf litter, geology)
    relating to the species occupancy status.

4. Analyse and assess the collected field data to establish the strength of possible relationships between
    environmental characteristics and the species occupancy.

5. If information with respect to environmental and topographic data is not available, or at an appropriate
    scale, then to design and implement a suitable sampling strategy across a larger (or a separate area)
    than was conducted in the initial sampling strategy.

6. Import the collected environmental and topographic information/data into a GIS environment, and
    create a predictive occupancy model based upon the results of the initial sampling strategy.

7. Conduct a final survey to assess the accuracy of the model by comparing predictions of the model with
    ground truth.

AGREED:

_____Student   _____Supervisor

__/__/__.   __/__/__.

Appendix B: Base tables, attribute columns used and metadata

Base Table Name & Description {}	Attribute Columns Used & Description {}	Metadata
944324RE and **944331RE** {Two base tables with polyline objects representing height contour lines}	**LABEL** (integer) {The associated height value for each contour }	**General** *Projection:* Universal Transverse Mercator, GDA 1994, MGA 1994, Zone 56. *Scale:* 1:25 000. *Positional Accuracy:* average horizontal accuracy is +/- 12.5 meters and the average vertical accuracy is +/- 2.5 meters. In areas of dense vegetation, these accuracies may not be achieved. *Date:* 1992. *Producer:* The Department of Natural Resources and Mines **Other** *Format:* MapInfo Table *Lineage:* Data was derived by scanning and vectorising existing film positives that were used to produce topographic maps. *Attribute Accuracy:* The accuracy of attribute information is estimated as 90%.
944324DR and **944331DR** {Two base tables with polyline objects representing drainage lines}	-	**As above**
944324TR and **944331TR** {Two base tables with polyline objects representing roads}	-	**As above**
BFP_Veg {Region objects representing vegetation communities}	**VEGTYPE** (category) {Attribute that defined the vegetation structure (i.e.) and the predominant species of each region object} **FIREASSOC** (category) {Attribute that defined the general vegetation structure into Rainforest and Vine Scrub, Wet Sclerophyll Forest, Moist Sclerophyll Forest, Dry Sclerophyll Forest and Heathland}	**General** *Projection*: Universal Transverse Mercator, GDA 1994, MGA 1994, Zone 56. *Scale*: 1 : 25 000. *Horizontal Accuracy:* not available. *Date:* 1997. *Producer: Brisbane Forest Park Authority* **Other** *Original Format:* ESRI Shape File *Classification:* Vegetation communities and landform systems were based upon the Regional Ecosystem Descriptions Datatbase (The Environmental Protection Agency, QLD).

Appendix C: MapInfo Files (CD format)

Appendix D: The attribute columns associated with BFP_VegFin.tab

(FIREASSOC) General Vegetation Structure	(VEGTYPE) Dominant Species	Soil Association
Wet Sclerophyll Forest	Wet sclerophyll forest complex of Lophostemon confertus, Eucalyptus microcorys, Eucalyptus saligna and gully vine forest species on metamorphics sometimes with basalt enrichment	Clay
Dry Sclerophyll Forest	Dry sclerophyll open forest/woodland with Eucalyptus crebra and Corymbia citriodora subsp. variegata on metamorphics	Clay
Moist Sclerophyll Forest	Moist to wet sclerophyll forest of Eucalyptus siderophloia, Eucalyptus acmenoides, Eucalyptus biturbinata and Eucalyptus propinqua on metamorphics	Clay
Heathland	Shrubby open forests/woodland on rock outcrops (predominantly chert) sparse to dense mixed shrublayer with Corymbia intermedia, Eucalyptus acmenoides or E. carnea, Angophora leiocarpa, Eucalyptus major on igneous rock	Clay
Rainforest and Vine Scrub	Complex notophyll vine forest on basalts and andesites (12.8.5 No concern at present)	Clay
Dry Sclerophyll Forest	Open forest of Eucalyptus montivaga at high altitude on granitoid rock and adjoining interbedded volcanics	Clay
Dry Sclerophyll Forest	Mixed open forest with Corymbia intermedia, Lophostemon confertus and Eucalyptus tereticornis on granitic rock	Clay

Appendix E: Permutation factors with respect to drainage elements and anthropogenic banks.

The Range of Possible Values Associated with the Sum of the Permutation Factors of Drainage Elements (Catchment Area, Sinuosity and Drainage Line Slope)	The Permutation Factor Assigned to the Six Classes of Anthropogenic Banks
584 (i.e. low Sinuosity Index + low Drainage Line Slope + low Catchment Value)	
592	
608	
648	
656	
672	
776	776
784	
800	
1096	
1104	1104
1120	
1160	
1168	
1184	1184
1288	
1296	
1312	
2120	2120
2128	
2144	
2184	
2192	2192
2208	
2312	
2320	
2336 (i.e. High Sinuosity Index + High Drainage Slope + High Catchment Value)	2336