University of Southern Queensland

Faculty of Engineering and Surveying

Risk Mapping in the Condamine River Catchment Basin

A dissertation submitted by

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Abstract

Erosion and Salinity are two of the most significant environmental problems impacting on agricultural lands in Australia. Currently 48000 hectares of Queensland are seriously affected by salinity, and an estimated 3100000 hectares of Queensland are also likely to be affected by the year 2050 (Gordon, I. 2002). When this is combined with approximately 20 to 60 tonnes of top soil per hectare being lost from cropping areas on an annual basis (Carey, B, Harris, P. 2001), it has become apparent that action needs to be taken. Through instigating efficient land management practices we must aim to prevent the formation of saline soils and water ways and at the same time limit the loss of top-soil through erosion.

A key tool in the management of salinity and erosion is the process of ‘risk mapping’. This tool has already been successfully used for salinity and erosion risk mapping as well as in other areas such as Fire Risk Mapping (Rural Fire Service, Queensland) and Forest Health Risk Mapping (Department of Agriculture, C’wealth).

Risk mapping uses input datasets which reflect environmental (both natural and human) attributes such as vegetation, soils, terrain, waterways, geology and rainfall. These data sets can be manipulated to show environmental indicators for various issues.

It will be a key objective of this project to create salinity and erosion risk maps for the Condamine River Catchment Area using environmental data-sets in a ‘weighted overlay’ process.

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Date

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Firstly I must acknowledge the Queensland Murray Darling Committee Inc. (QMDC) for providing the data used during the analysis stages of this project. Also my sincerest thanks are extended to my co-workers at QMDC who have provided wisdom and professional guidance throughout the year in both my project work and professional development.

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Chapter 1

Introduction

1.1 Introduction

With salinity and erosion becoming more evident in agricultural areas of Queensland it is essential that the remaining ‘quality land’ is preserved and not allowed to degrade further. At the same time, it is imperative that relevant stakeholders manage and rehabilitate land already severely affected or under threat of becoming degraded.

The main method of managing land to ensure that further degradation is avoided is to initiate stringent management plans which invest in strategic rehabilitation or land management. This management can be achieved efficiently through the use of risk maps (sometimes known as hazard maps).

It is therefore the rationale of this study to map salinity and erosion risk in the Condamine River Catchment Area (See Chapter 3, Section 2). This will be further discussed in Section 1.2 (Rationale of the Study) of Chapter 1.

1.2 Rationale of the Study

The rationale of this study as mentioned in Section 1.1 of Chapter 1 is to use the process which is referred to in this project as risk mapping to map the susceptibility of a selected area of land (through the use of environmental indicators) to environmentally degrading processes such as salinity and erosion.

The risk maps created for this project will have a broad range of management applications within the study area for the project. However it must be noted that due to previous legal issues relating to salinity data being used at the wrong scale, the output maps for this project are only designed to be accurate at a regional scale and are not accurate or necessarily representative of salinity or erosion risk at property scales.

1.3 Objectives

This project encompasses a number of broad objectives ranging from the conducting of research into the environmental issues of salinity and erosion through to investigating and using GIS software to create risk maps. A more in-depth and complete list of the objectives of this project are:

- To conduct research into the environmental and economical effects of salinity and erosion
- To document and evaluate available software which are used for assessing risk
- To ground truth datasets and determine the accuracy of input data-sets;
- To use the input data-sets in a ‘weighted overlay’ process in ‘Model Builder’ to create accurate (based upon accuracy of input data-sets) salinity and erosion risk maps.

1.4 Scope and Limitations of the study

This study is conducted using available GIS data to model risk in the Condamine River Catchment Area. Therefore the accuracy of the results presented in this study is only true as the quality and accuracy of the data used. However despite the limitations in regards to input data-sets, the scale at which they are useful at and accuracy, they have enabled a broad understanding of the risks in the Condamine River Catchment Area. Data-sets (relating to environmental indicators) have not been included in this project since they were not available at the commencement of this project.

The key message delivered by this project is to recognize that whilst the data-sets used in the project can enable better understanding of risk from salinity and erosion their accuracy is an aspect of research that needs to be addressed in more detail.

Chapter 2

Literature Review

2.1 Introduction

The purpose of this literature review is to provide back ground information for the processes modelled during this project. Therefore information presented in this chapter is directly linked with later chapters of this dissertation. The following information has formed the knowledge base for decision making in regards to reclassifying datasets to accurately show the potential risk of land to salinity and erosion.

2.2 Risk Mapping

Risk mapping is a mapping process which is described by the name which the process is given. Risk mapping is the process of mapping potential risk from any given number of scenarios of situations in a visual manner. Risk mapping generally provides output in the form of data which can be reclassified into a percentage or other form of ranking which can then be used to show the level of risk associated with a process.

Risk mapping can be used in any number of scenarios including in this case, the mapping of erosion and salinity risk within the Condamine River Catchment Area. Risk mapping has and continues to be used in numerous fields including Fire Risk Mapping, Forest Health Mapping as well as for choosing ideal residential development sites.

2.3 Weighted Overlays

The weighted overlay process has many applications. Due to the topic of this project, this chapter will only focus on relevant sections of this process.

The overlay process can be conducted with either vector or raster data, however for the purposes of this dissertation, vector overlays will not be considered as they are too time consuming and there is the risk of creating many sliver polygons within an area such as the study area for this project. Therefore this section will focus on introducing the processes associated with the overlay of raster data within a GIS environment.

The overlay of raster data involves the "overlaying of GRID cells of one raster layer to another layer (See Figure 2.1) (Apan, A, 2003, p 5.13) using a common evaluation scale". (Model Builder Help: Overlay Process, 2000) This common evaluation scale is comprised of numbers which are assigned by the user.

1	1	1	1	4		4	4	3	3	3		5	5	4	4	7
2	2	1	1	4		4	4	1	1	3		6	6	2	2	7
2	2	1	4	4	+	4	4	1	1	3	=	6	6	2	5	7
2	2	1	3	3		4	1	1	2	2		6	3	2	5	5
2	3	3	3	3		4	4	3	2	4		6	7	6	5	7

Figure 2.1 - Arithmetic Overlay Operation: Addition
(DeMers, 1997, p.331 *in* Apan, A, 2003, p 5.14)

Where a simple overlay process can only directly overlay raster data-sets, a weighted overlay process gives the GIS user an extra level of control during the overlay process which in an essence allows them to manipulate the influence a particular data-set may have on the output of the overlay process.

This ability for a user to use particular data-sets to influence the output data can be seen in Figure 2.2 below. In this example the soils input layer is given a higher rating than the elevation and slope data, hence giving it a greater influence on the output data.

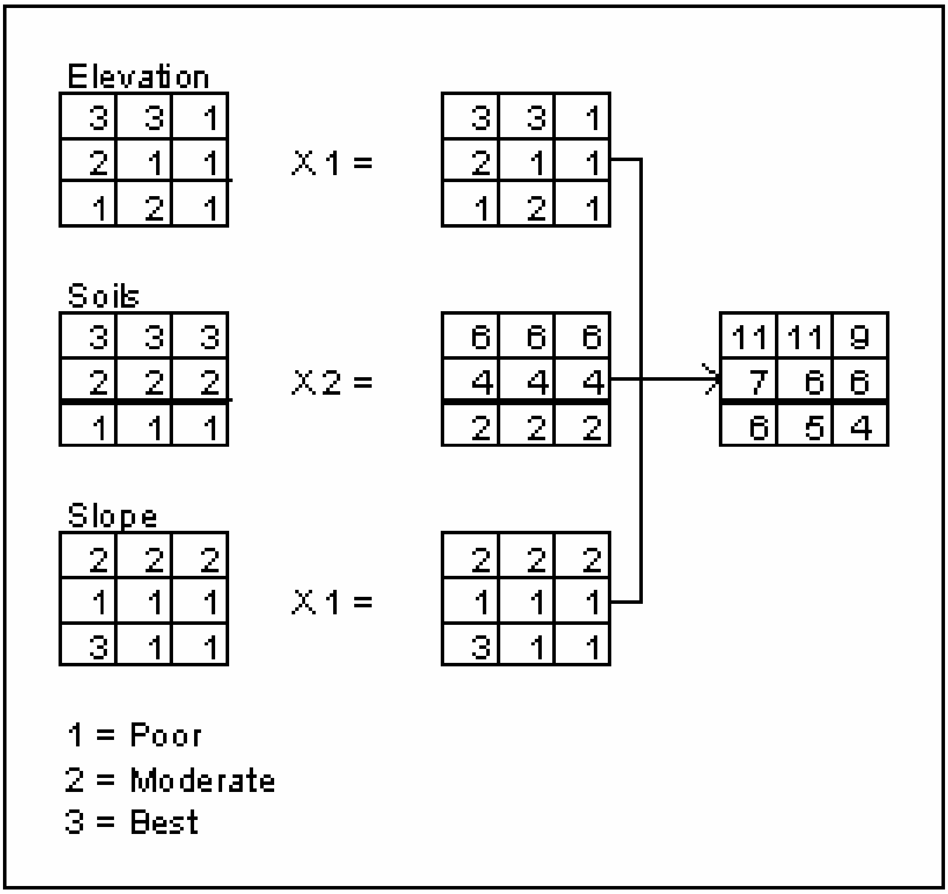

Figure 2.2 – Weighted Overlay Process

(Davis, 1996, p.234 *in* Apan, A, 2003, p 5.20)

2.3.1 Model Builder

'Model Builder' is a component of the 'Spatial Analyst 2.0 Extension' for the GIS platform, 'ArcView 3.2' which is a product of 'ESRI' (Environmental System Research Institute) (It is also an addition to the Spatial Analyst Extension in ArcGIS 9). It provides the capacity for the user to build spatial models which are represented in a graphical manner through the use of flow charts/tree diagrams (See Figure 2.3).

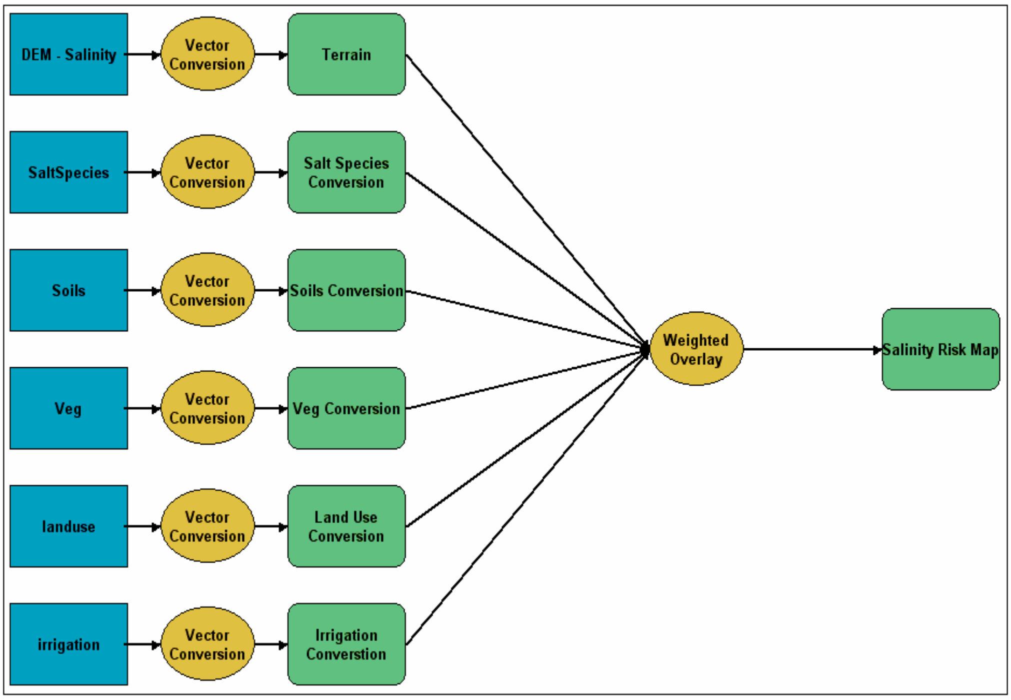

Figure 2.3: ‘Model Builder’ – Diagrammatic Modelling Process

This diagrammatic representation of modelling procedures within ‘Model Builder’ provide a number of advantages. These advantages range from it being reusable and shareable with others, providing easy modification of models to explore "what if" scenarios, to obtaining different solutions (Model Builder Help: What is Model Builder?, 2000) as well as allowing users to run components of models individually to reduce processing time.

‘Model Builder’ incorporates an extensive range of data manipulation and conversion functions including:

- Vector to GRID Conversion
- DEM to GRID Conversion
- Point Interpolation
- Slope Calculation
- Aspect Calculation
- Hillshade Calculation
- Contour Calculation
- GRID Reclassification
- Buffering
- Arithmetic Overlays
- Weighted Overlays

During the course of this project two data manipulation procedures were undertaken within the ‘Model Builder’ environment to create the salinity and erosion risk maps. These procedures were ‘Vector to GRID Conversions’ and ‘Weighted Overlays’. However a number of other processes could have been incorporated into the modelling processing including:

- Buffering
- Slope Calculation; and
- DEM to GRID Conversion.

However it must be noted that these processes were excluded from the processing in the ‘Model Builder’ environment due to the constrictions on what raster data formats were accepted as well as issues of personal preference.

2.4 Salinity

2.4.1 Introduction

Salinity is a term used to describe the salinisation ("the accumulation of salts in soil" (Miller, G, T, 2004, p G13)) of soils and waterways. For the purposes of this research project the term salinity will refer to only the processes of soil salinisation, as the study area for this project is inland as well as their being insufficient waterways information to model the potential risk of rivers to salinity.

Salinity is a form of extreme environmental, social and economical degradation. However it must be noted that salinity or salinisation is a natural environmental process, this process has led to ''significant salt storages within the non saturated zone of Queensland soils". (Working Party on Dryland Salting in Australia, 1982, p 12)

Salinity costs the national economy $200 million annually through lost revenue (Warnick, 2003). Currently there is an estimated 48000 hectares of land in Queensland which is seriously affected by salinity. (Gordon, I, 2002) Whilst this area may seem insignificant in the scope of a state the size of Queensland, it doesn't seem so insignificant when the current estimates for 2050 of areas seriously affected is 3.1 million hectares, an increase of almost 6500% (Gordon, I, 2002).

2.4.2 Soil Salinity

It is generally recognised that there are two forms of soil salinity; they are Dryland Salinity and Irrigated Salinity. These forms of soil salinity are very similar with the only distinguishing difference between the two forms of salinity being human induced environmental activities.

The level of severity at which each of these two forms of soil salinity form at is dependent on a number of factors including the salt:

- stored in the groundwater tables
- stored in the soil profile; and
- in the water used for irrigation

Other major factors which contribute to the formation and severity of salinity include:

- the position or depth of the ground water table in the soil profile
- the state of the environment (i.e. whether vegetation is present and what sort of vegetation it is)
- rainfall Levels
- land use practices; and
- the position of the location within the landscape.

2.4.2.1 Salt Stores / Historic Salt

In Australia there are significant stores of existing salt in the unsaturated and saturated (water table) sections of the soil profile. This has been the result of ongoing environmental processes including:

- the weathering of parent material (rocks) over time and the subsequent release of salt stored in the parent material
- the depositing of salt from sea mist; and
- the intrusion of salt water into the fresh ground water tables.

In most cases the existing salt stores in Australian soil profiles are deep enough to ensure that they have little to no impact on vegetation growth and health. It is through human induced actions such as irrigation and tree clearing that these salt stores are able to rise higher in the soil profile.

2.4.2.2 Ground Water Table Height

The height of the ground water table in the soil profile is determined by the volume of water present in the water table as well as the depth of shallowest layer of impermeable bedrock (prevent water from filtering further down in the soil profile).

The height of the ground water table increases as the level of water filtering down through the soil profile increases. This occurs primarily as a result of tree clearing and irrigation processes.

The processes by which the ground water tables rise as a result of irrigation salinity are fairly simple as there is a localised increase of water entering the soil profile as a result of irrigation. However implications of tree clearing and the associated rise in ground water tables is more complex.

Vegetation (particularly deep rooted native vegetation) plays a major role in the extraction of water from the soil profile through the process of transpiration. This extraction of water from the soil profile generally ensures that the extraction from water tables and any recharge is kept at equilibrium so that water tables stay at approximately the same level (See Figure 2.4).

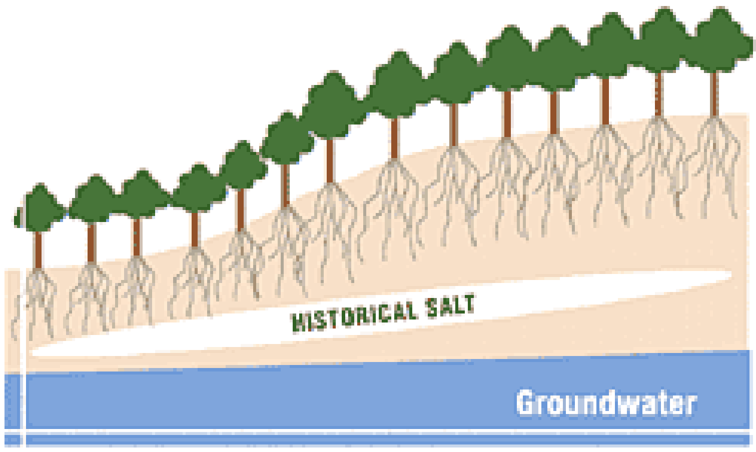

Figure 2.4 - Role of Vegetation in maintaining ground water levels (Fitzroy Basin Association, 2004)

However once the trees are cleared from an area the rate of recharge is generally higher than the rate of extraction through either transpiration or evaporation. This will cause the water tables to rise over time (See Figure 2.5).

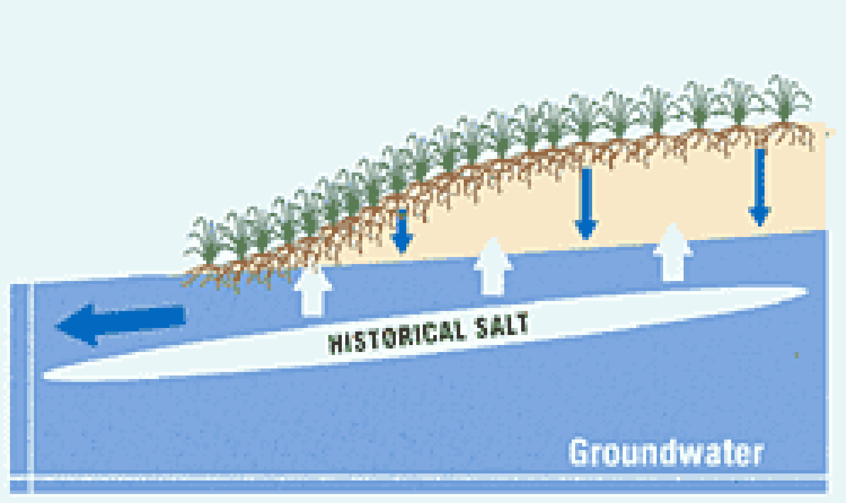

Figure 2.5 – Rising Water Tables
(Fitzroy Basin Association, 2004)

The effects of clearing vegetation become more apparent in the short and long term if the clearing is conducted in areas of a catchment known as recharge zones. These zones are where the majority of the water, which makes its way to the groundwater tables enters the landscape. (A technical definition describes recharge zones as “the area in a catchment where the net movement of water is downwards to the groundwater.” (Ghassemi, F, et al, 1995, p 516))

This means that the water tables in that catchment are more likely to rise at a quicker rate as there is less deep rooted vegetation in the soil profile to extract water before it reaches the ground water table. This means that over time the ground water table will rise within the soil profile and bring with it the salts from lower in the soil profile.

Over time if left un-checked, the increased infiltration of water into the ground water tables can cause the tables to rise to the point that they infringe on the root growth zone of plants (See Figure 2.5) or in some cases to the surface of the soil (saline seeps). This creates conditions in which a majority of vegetation is unable to survive.

2.4.3 Dryland Salinity

Dryland Salinity is a process heavily influenced by the clearing of vegetation as mention earlier in this chapter. In the case of dryland salinity it is caused by the clearing of trees for cropping and grazing. The clearing of trees allows an increased flow of water into the ground water tables over time causing the ground water tables to rise. This in turn moves historic salts (See Figure 2.5) closer to the surface and into the root growth zone of plants which reduces or negates the ability of vegetation to survive.

2.4.4 Irrigated Salinity

Irrigated salinity unlike dryland salinity can occur even if tree clearing has not occurred. This is because large quantities of water are being applied directly to the landscape on a regular basis. This water filters directly to the ground water table (See Figure 2.6) and will cause it to rise higher in the soil profile.

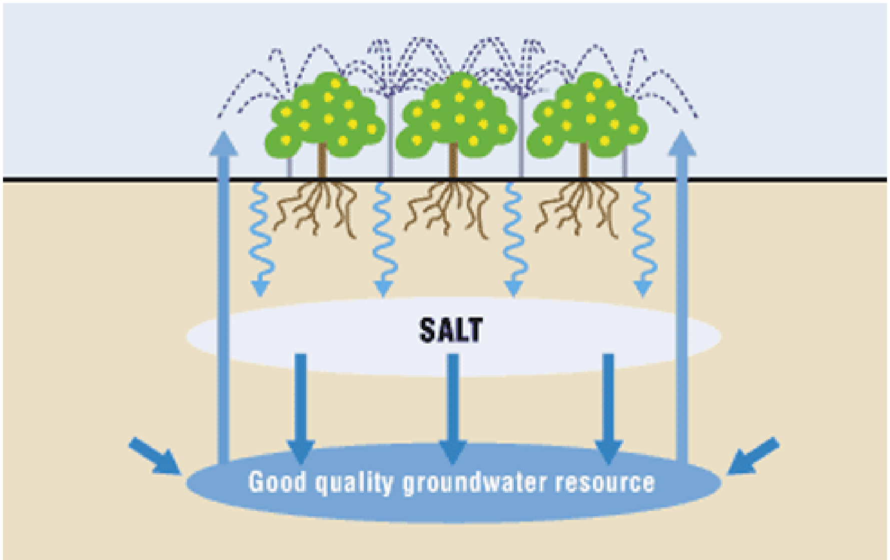

Figure 2.6 – Processes of Irrigation Salinity
(Australian Government – National Action Plan for Salinity and Water Quality, 2004)

The main problem with irrigated salinity is that whilst irrigation is not conducted all year round in the majority of cases allowing the water table to recede during periods without irrigation, the salt in the soil profile does not recede with the water table. As a consequence the salt becomes trapped higher up in the soil profile, limiting vegetation growth even when the ground water table is considerably lower in the soil profile.

2.5 Erosion

2.5.1 Introduction

Erosion is "the detachment, entrainment, transportation and deposition of soil and other earth materials" (Toy, T.J, Foster, G.R, Renard, K.G, 2002, p 1) by the actions of wind and water in conjunction with gravity.

The process of erosion is both naturally occurring and essential to shaping of the earth and is "largely responsible for the shape of the earths land surface today" (Toy, T.J, et al, 2002, p1). Erosion is considered to be one of the most essential yet destructive process on earth as on one hand it is responsible for the breakdown of parent material (rocks) which in turn forms new soils and yet on the other hand it is "capable of destroying the productivity of the land in just a few years or even months" (Toy, T.J, et al, 2002, p1).

Whilst erosion is a naturally occurring process its destructive power can and is increased as a result of human activities such as cropping and grazing. It is because of these activities that erosion rates in Australia have increased over the past 100 years by anywhere from 10 to 100 times the original rate (Carey, H, Harris P, 2001). As a result of these increased erosion rates, approximately 20 to 60 tonnes of topsoil per hectare is lost on an annual basis on the Darling Downs (Carey, H, Harris P, 2001).

Erosion is a complex process and like salinity, its formation rates and severity is dependent on a number of factors including vegetation cover, land use practices, soil structure and terrain slope and length. The individual process of both wind and water erosion and how the above mentioned contributing factors influence the severity of erosion will be discussed in the following sections of this chapter.

2.5.2 Wind Erosion

Wind erosion is caused when the forces applied to the soil by the wind are greater than the resistance of the soil to these forces (Toy, T.J, et al, 2002, p43). The resistance levels of soils depend on the level of moisture present in the soil profile, this is because moisture binds soil particles together increasing their resistance to wind erosion. Therefore wind erosion rates are generally low when there is a high level of soil moisture and high when soil moisture content is low.

There are “three forms of wind erosion; these are creep, saltation and suspension transport modes” (Toy, T.J, et al, 2002, p44) (See Figure 2.7)

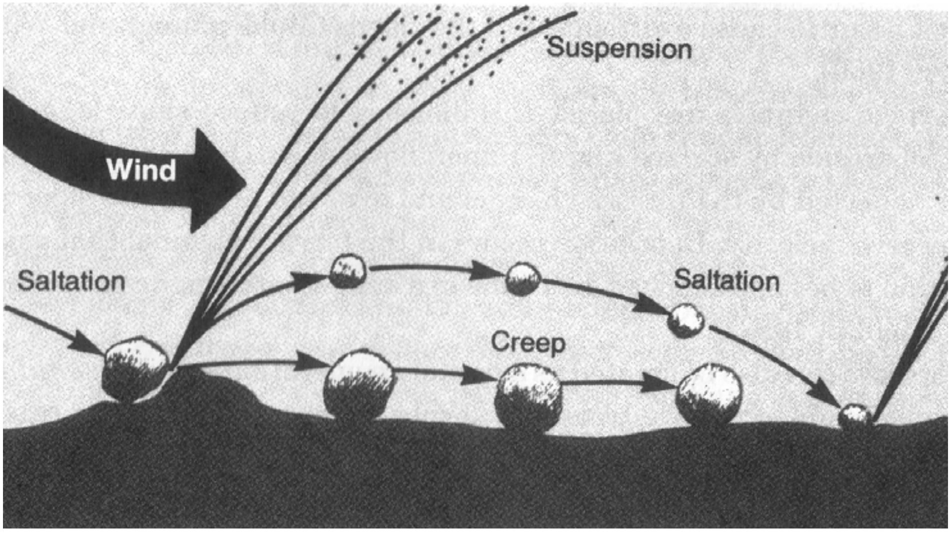

Figure 2.7 – Three Forms of Wind Erosion
(Toy, T.J, et al, 2002, p44)

The ‘transportation mode’ named ‘creep’ is a process where larger sized earth/soil particles are pushed along the ground without becoming airborne (See Figure 2.7) (this is due to the weight of the particles).

‘Saltation’ is a wind erosion process whereby lighter particles of earth/soil ‘skip’ across the surface of the land and become airborne as a result of coming into contact with small irregularities in the landscape often dislodging further particles (See Figure 2.7). Finally the ‘transportation mode’ of ‘suspension’ is when the finer earth/soil particles become completely airborne and are transported across the landscape in giant dust storms (See Figure 2.7).

Wind erosion is most likely to occur in drier landscapes where there are large areas of exposed soils due to a lack of vegetative covers such as grasses and a general lack of large trees to act as wind breaks and prevent winds from reaching sufficient strength at ground level to facilitate the movement of soil particles.

2.5.3 Water Erosion

Water erosion is the most predominant form of erosion in Australia and is caused by the "stresses generated by rain drop impact, and surface runoff" (Toy, T.J, et al, 2002, p25). Therefore water erosion can be described as the detachment, entrainment, transportation and deposition of soil and other earth materials through the process of the hydrological cycle.

There are a number of different forms of water erosion which occur in the environment, these forms include:

- Rill Erosion
- Tunnel Erosion
- Mass Movement
- Sheet Erosion
- Gully Erosion; and
- Stream Bank Erosion

However due to the modelling of erosion as a generalised form of degradation in this project the remainder of this section on water erosion will be dedicated to outlining the impacts of vegetation, soil and slope on water erosion rates.

Vegetation serves two purposes in the prevention of water erosion. Firstly the foliage of vegetation acts as a barrier between rain drops and the soil surface. This barrier does not altogether prevent raindrops from reaching the soil surface but rather reduces the velocity at which the rain drops hit the soil surface. Vegetation roots also serve the purpose of acting as a stabilisation mechanism which aids in holding the soil profile together and reduces the susceptibility of the soil profile to all forms of water erosion.

The size of the soil particles in the soil profile also dictates the susceptibility of the soil profile to erosion with smaller soil particles being at greater risk of erosion than large particles. This is because larger soil particles have a greater mass and hence require water movement of a greater force to move them (i.e. sandy soils (finely grained) will be at greater risk of erosion than clay soils (coarsely grained) due to the relative difference in soil particle size)

Slope is another critical factor in determining the force of the water on the landscape. As water travels down a slope it picks up velocity and hence has a greater potential to cause erosion. The length of a slope also plays a role in the erosion rates of an area. For example a long moderate slope may have the same potential for erosion as a short steep slope.

2.6 Summary

When using environmental data-sets to map the potential risk of a particular area to forms of environmental degradation or any form of degradation or danger in general, it is essential to have a complete and thorough understanding of all literature regarding that form of degradation.

Therefore it was the aim of this chapter to provide sufficient information in regards to the degrading processes of salinity and erosion so that both the readers and the author of this dissertation have sufficient knowledge of the processes in order to understand issues discussed in later chapters of this dissertation.

Chapter 3

Methodology

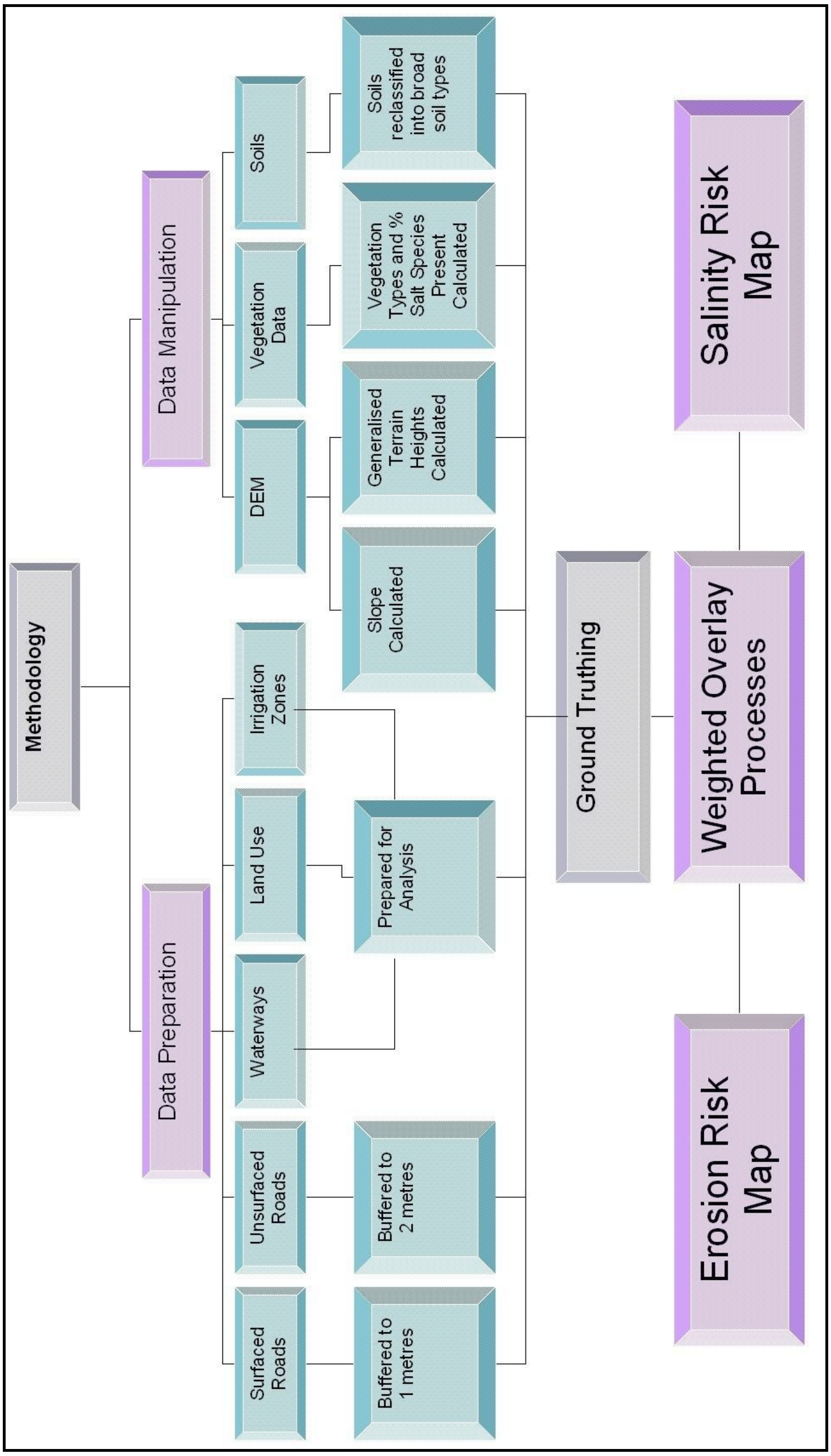

Figure 3.1 – Methodology Flow Chart

3.1 Introduction

This chapter is devoted to explaining, in detail, the data manipulation and processing steps that occurred through the course of this project, as well as documenting the role 'Model Builder' an extension of 'ArcView 3.2', played in this project.

3.2 Study Area

The study area that was selected for this project is in the South Eastern corner of Queensland, Australia (See Figure 3.2). The area is made up of 15 smaller sub-catchment areas covering a total area of approximately 24434 km^2. The study area can be best described as the catchment area for the Condamine River which is a dominant natural feature running down the centre of the study area (See Figure C1, Appendix C). Hence for the purposes of this dissertation the study area for this project will be referred to as the Condamine River Catchment Area or the CRCA.

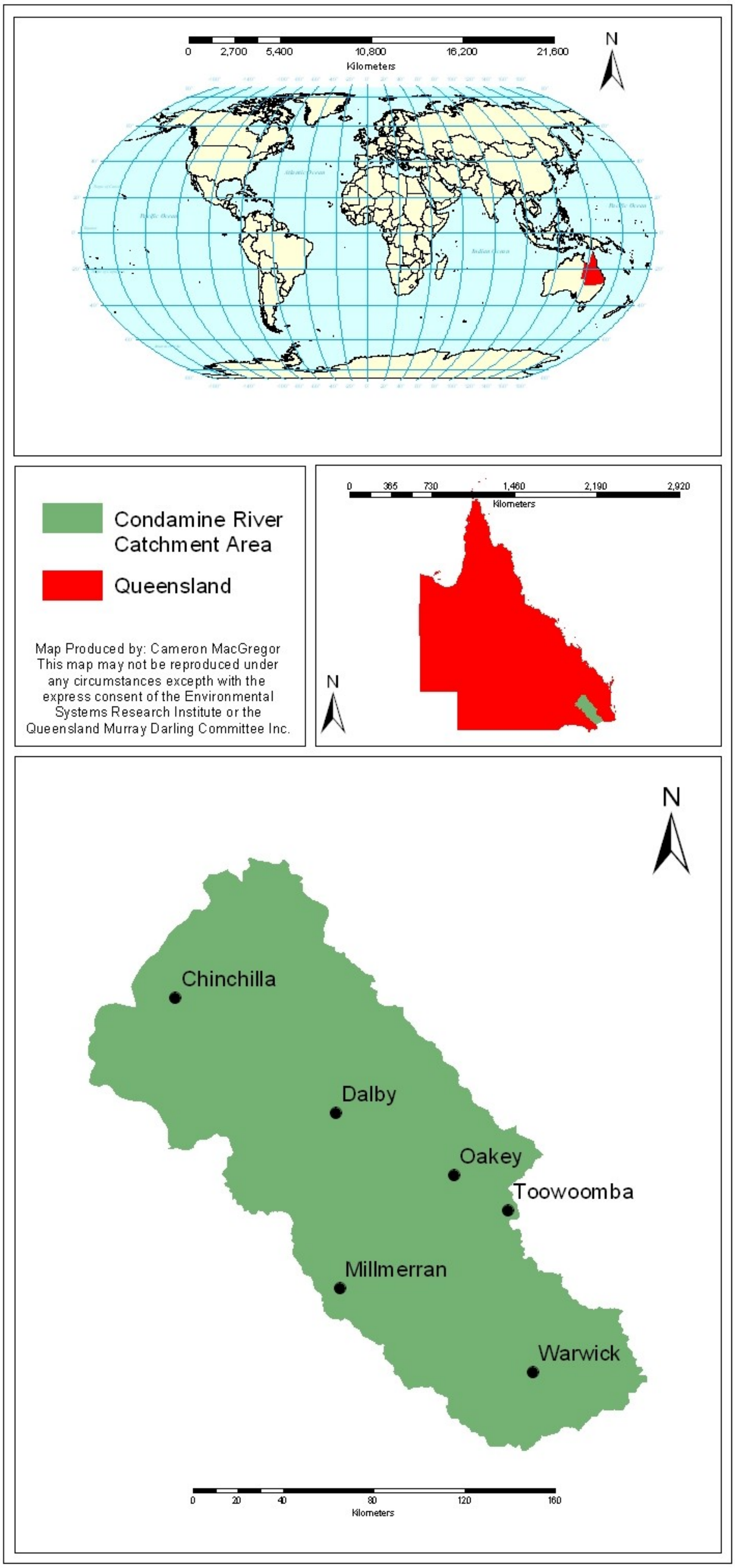

Figure 3.2 - Study Area: Condamine River Catchment Area

Due to the size of the study area there is a wealth of background information which could be included within this chapter, however to keep this chapter concise the information presented is only relevant to the topic of this project.

The CRCA is mainly an agricultural area comprising of vast tracts of grazing and cropping land. Typical scenes which may be encountered in the study area are shown in Figure 3.3 below.

Figure 3.3 - Common land uses within the CRCA

The percentage of land use within the CRCA varies; with cropping and grazing consuming approximately 78% (See Figure 3.4) of the total land area or approximately 19058 km^2. With State and National Forests consuming approximately 10% of the land. Other land uses include such activities as urban, industrial, piggeries, and poultry (12%).

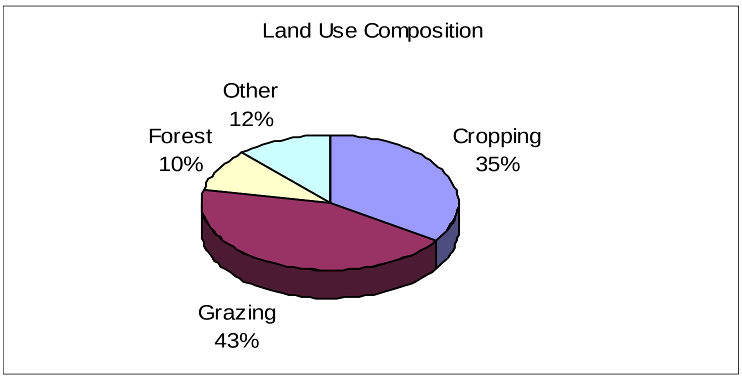

Figure 3.4 - Land Use Composition
(Sinclair, Knight and Merz, 2001)

Climatic conditions within the CRCA vary due to the large size of the area. However with respect to salinity and erosion the following table (Figure 3.5) represents core information regarding rainfall, evaporation and minimum and maximum temperature averages on an annual basis.

Category	Averages
Rainfall	600 to 800 millimetres
Evaporation	Between 1800 and 2400 millimetres
Minimum Temperature	6 to 16 degrees
Maximum Temperature	21 to 27 degrees

Figure 3.5 - Climatic Averages within the CRCA
(Bureau of Meteorology, 2004)

3.3 Data Analysis

During this project there were two distinct stages which were conducted in order to produce the output salinity and erosion risk maps. These stages were:

- data pre-processing; and
- data manipulation

Data preprocessing was defined by converting data to the correct coordinate systems as well as modifying it to realise its full potential. The data manipulation stage was categorized by adding the data into the ‘Model Builder’ environment and setting weights to various data-sets.

For the analysis processes of this project two separate computers were used. A standard computer was used for pre-processing whilst a high performance computer was used during the weighted overlay procedure due to the size of some of the GRID data-sets.

The specifications for the computers used during the analysis stages of this project are:

1. Data Pre-processing
   Pentium 4, 2 GHz Processor, 512 Mb RAM
2. Data Manipulation
   Pentium 4, 2.4 GHz Processor, 1024 Mb RAM

The data used in this project originated from a variety of different sources including the Environmental Protection Agency, Department of Natural Resources and Mines, Sinclair Knight and Merz, GeoScience Australia and CSIRO (Commonwealth Scientific & Industrial Research Organisation). However all data was made available by the Queensland Murray Darling Basin who has full access to the data. A list of data used in this project can be found in Table 3.1.

Data Name	Point	Line	Polygon	Raster	Other
Vegetation (RE)					Table
Surface Roads					
Unsurfaced Roads					
Soils					
DEM					
Land-use					
Irrigation					
River Systems					

Table 3.1 – List of base data-sets used in project

3.4 Data Pre-processing

This section is dedicated to outlining the processes of this project as well as the steps that were taken in order to prepare the data for use in weighted overlay stages of this project.

3.4.1 Data Projections

An essential step in overlay and other analysis procedures is to ensure that all data used as inputs is in the same projection. If data-sets are not in the same projection they will not project to the same place on the earth and hence will not be able to be used in analysis. Therefore the first stage of this project was to find out what projections the data was in and then to re-project it to a common projection. The common projection chosen for this project was GDA 1994 (Geocentric Datum of Australia) MGA (Map Grid of Australia) Zone 56. This was because all study areas for this project fell into Zone 56 of the Map Grid of Australia.

In order to re-project the data used in this project the following projection software was used; ‘ArcView 3.2 – Projection Utility’.

3.4.2 Data Clipping

A preliminary stage of this project was to clip available data to the CRCA extent. This served a number of purposes including a:

- reduction in data storage requirements; and
- reduction in time required to complete analysis

Upon completion of the data clipping for this project, the data storage space was roughly only a quarter of what it was previously.

This stage was also necessary for the Digital Elevation Model as it was missing certain files that ‘ArcView 3.2’ required. Therefore it was reclassified in ‘ArcGIS 8.3’ and converted to a ‘shapefile’; this shapefile was then clipped to the study area.

3.4.3 Ground Truthing

A necessary component of any analysis procedure is to determine how accurate the data being used is. If the data being used in the project is being collected as part of the project it is possible to ensure certain standards or levels of accuracy by setting strict standards for data collection. However if pre-existing data is being used, it is often very difficult to determine the accuracy of data unless:

- accurate, complete and reliable metadata exists for each data-set; or
- extensive ground truthing is undertaken to assess the accuracy of data-sets

Ground truthing generally involves going to planned locations within the study area for a project and recording all environmental or physical attributes from that location required for the assessment of data being used in the project.

Ground truthing generally can occur in two manners, both these can provide information to determine a reasonable measure of accuracy. The methods of ground truthing data are to:

- ground truth the data by visiting locations to provide full coverage of all attributes in each data-set; or
- ground truth the data by visiting locations which ensures that the study area is adequately covered.

The ideal method of ground truthing would be a combination of the above mentioned methods. This is because it is necessary to check both the attribute and positional accuracy to ensure that the data is consistent across the entire study area.

For the purpose of this project a combination of the above mentioned methods was rejected in favour of exclusively using the second method of ground truthing. Whilst this method of ground truthing does not provide as accurate a measure of accuracy as the previously mentioned method, it was the only available method which could be conducted with time and cost restrictions associated with this project.

Ground truthing for this project occurred throughout the project study area; it involved visiting 27 locations through out the CRCA and covering a distance of over 600 kilometres. (See Figure 3.6) For more detailed information regarding data collected during ground truthing see Appendix B.

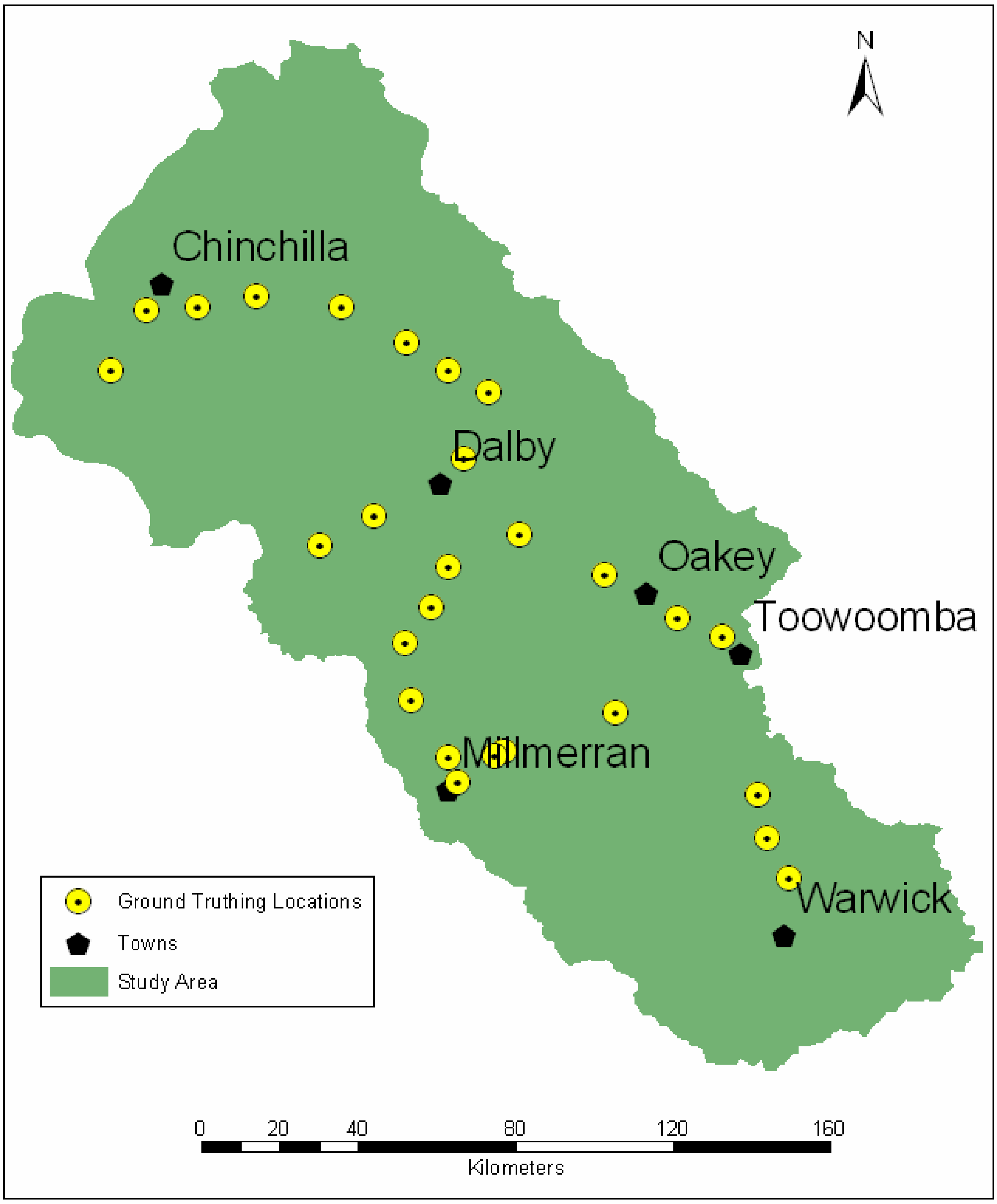

Figure 3.6 – Ground truthing locations

At each location a number of attributes were recorded in accordance with data-sets being used in the analysis stages of this project. The attributes recorded included:

- Latitude, Longitude and Height (above MSL (Mean Sea Level)) of the location using a Trimble GPS Unit ('GeoXT')
- Soil Type (See Figure 3.7)
- Vegetation Type
- Land-Use
- Distance to Roads and Rivers (if visible)
- Slope; and
- Photograph and image direction.

Figure 3.7 – Soil Record Photo (West of Pittsworth)

At these points it was opted to physically record the attributes using pen and paper rather than organizing data dictionaries in the GPS (Global Positioning System) Unit. This was because it was determined that whilst in the field, attributes could be recorded in a shorter period of time, hence allowing for more locations to be visited in a shorter period of time. This decision was again justified upon completion of ground truthing when problems occurred trying to copy data from the GPS unit across to a computer using the 'Terra Sync' software developed by 'Trimble'.

Upon completing the ground truthing, recorded GPS points were converted to a ‘shapefile’ and physically recorded attributes were entered into the ‘shapefile’s’ attribute table. This information was then compared to the existing data-sets; from this a level of certainty was determined.

3.4.4 Vegetation Data

The vegetation data used for this project originated from the Environmental Protection Agency. This data consists of two core elements; a ‘shapefile’ officially titled ‘Regional Ecosystems’ (RE01) listing basic information and a series of unique identifiers which are useful mainly for professionals and experts, and a Microsoft Excel Spreadsheet (Comma Separated) containing the ‘bulk’ or in-depth information in regards to species present within vegetation patches to dominant vegetation types (Open Woodland, Grass Land etc.).

For the vegetation data to be considered of any use for this project it was necessary to combine both information sources for a more ‘complete’ data-set. Initially it was thought that the two tables (dbf (data base file) file associated with the ‘RE’ shapefile and the spreadsheet) could be simply joined in the ArcGIS environment. However due to the immense volume of data present within the ‘RE’ spreadsheet, the tables were joined but the ‘RE Description’ columns (most important source of information) were shortened to the maximum length of table columns in ‘ArcGIS’.

Therefore it was determined that the primary process of information amalgamation would be conducted manually in a Microsoft Excel Environment. In this environment the following information was extracted for all vegetation patches within the CRCA:

- species name
- dominant vegetation type
  (See Appendix C for list)
- total number of species; and
- number of salt tolerant species.

Upon the extraction of species names from the detailed vegetation descriptions, these were then searched using a list of salt tolerant vegetation species (See Appendix C) compiled by the Department of Natural Resources and Mines (Wright, A, Egan, S, Westrup, J, Grodecki A, 2001). The number of salt tolerant species for each patch was then counted, and compared as a percentage with the total number of species present for all vegetation patches. This extracted information was then extracted and added into the attribute table of the ‘RE’ data.

3.4.5 Soil Data

The soils data used in this project used a base layer which is known as Md_Soils. This data was extracted from the Atlas of Australia Soils which consists of 1:100,000 map sheets and is maintained by the CSIRO. The soils information in this data-set is categorized by soil descriptions described in the Atlas of Australian Soils. This meant that data was categorized under titles such as Black Sodosols, Red Ferrosols and Leptic Rudosols.

These soils types where then reclassified into the broader soil types of Clay, Loam and Sand. This reclassification was based upon soil descriptions provided in the Australian Agricultural Assessment 2001 which provided information on soil types and attributes. This information was utilized and soil types were reclassified into the categories (mentioned above) based upon what component (i.e. Sand, Clay, Loam) was dominant in the soil type.

However it must be noted that this reclassification may not be as accurate, as the information used for the reclassification was based upon national categorization guidelines. However due to a lack of in-depth information being available regarding soil composition for this project area, little choice was left but to reclassify in the above mentioned way based upon available literature.

3.4.6 DEM Derived Data

During the course of this project two data-sets were derived from the DEM (Digital Elevation Model) used for this project. The majority of the data-sets were created for use during analysis and will be discussed in this section however other data-sets were created purely for map aesthetics such as the hillshade which can be seen in Appendix C, Figure C1.

Two operations were conducted using the Spatial Analyst Extension for ArcGIS 8.3, these operations involved the:

- creation of a Slope Raster
- reclassification of the DEM into more defined changes in terrain height.

Each of these files was created with an output resolution of 25 metres. This was because the accuracy of the input data-set was plus or minus 25 metres. The slope file was then reclassified to allow for easier use in 'Model Builder'. The percentage slope values were then reclassified into broader categories which can be seen below in Figure 3.8. The results of this reclassification can be seen in Figure 3.9.

New Value	Old Value
Little to no Slope	<=5
Gentle Slope	<=10
Moderate Slope	<=20
Steep Slope	<=40

Figure 3.8 – Slope Reclassification Values

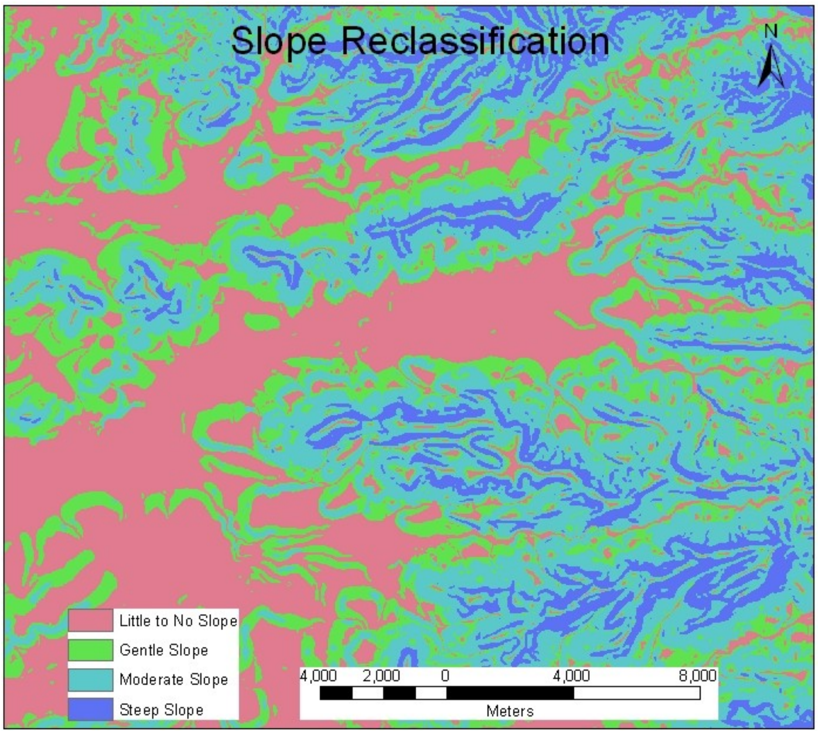

Figure 3.9 – Slope Data-set (Percentage)

3.4.7 Roads and River Network Data

Roads and river systems data were used in this project. However they were only used in the creation of the erosion risk map. The use of these data-sets may however have implications for assessing the potential danger of infrastructure from high salt levels through processes such as 'salt cancer'.

The road data consisted of two 'shapefiles', one showing surfaced roads and the other showing un-sealed roads. These data-sets were 'buffered' to 1 and 2 metres respectively. These buffered areas were considered to be areas most at risk of erosion. However no evidence was found clearly documenting relationships between the type of road (i.e. surfaced, unsealed) and rates of erosion at critical distances from road networks. Also the original data-sets were represented by 'polyline' features and no records were kept of road width and quality, (all of which may have an influence on run-off/erosion patterns).

Like the road data, the river network data was also provided in 'polyline' format and generally lacked any great depth of valuable information regarding river flows and strengths or whether the rivers were seasonal or flowed all year. Therefore like the roads data the area of erosion risk was said to be within a buffer area of 5 metres. This buffer area was not able to take into consideration varying river widths or changes in river shape over time; however the implications of this problem will be discussed further in Chapter 6.

3.5 Data Processing

3.5.1 Introduction

During this project all the data processing occurred within a component of the 'ArcView 3.2' Extension, 'Spatial Analyst 2.0' called 'Model Builder' (See Chapter 2.3.1).

Therefore this section will be devoted to explaining how 'Model Builder' was used and how weights were assigned to values within data-sets.

3.5.2 Salinity Risk Map

This component of the data processing saw the use of six data layers in a weighted overlay process in Model Builder. These data layers were:

- Soils Data
- Salt Tolerant Vegetation
- DEM
- Vegetation Type
- Land-use; and
- Irrigation Areas

Each data-set was loaded into an 'ArcView 3.2 Project' as well as another 'shapefile' containing an outline of the CRCA which was used to set the extent ("the area on the Earth's surface covered by the data used" (Environmental Systems Research Institute Inc. 2000)).

In the model builder environment a number of variables were set under the ‘model defaults’ menu before any data layers were added to the model. These variables were:

- extent
- cell size
- evaluation scale.

The extent, as mentioned on the previous page was set to the boundary of the CRCA. The cell size was set to 25 metres as it was the resolution of the DEM and the only documented level of accuracy for all data-sets. The evaluation scale for this project was set as ‘1 to 5’ (1(Low Risk) to 5 (High Risk)) this was because it was thought to be the largest scale that could be used based upon the depth of data-set attributes. After setting of the defaults, the data layers were then added into the modelling environment (See Figure 3.10)

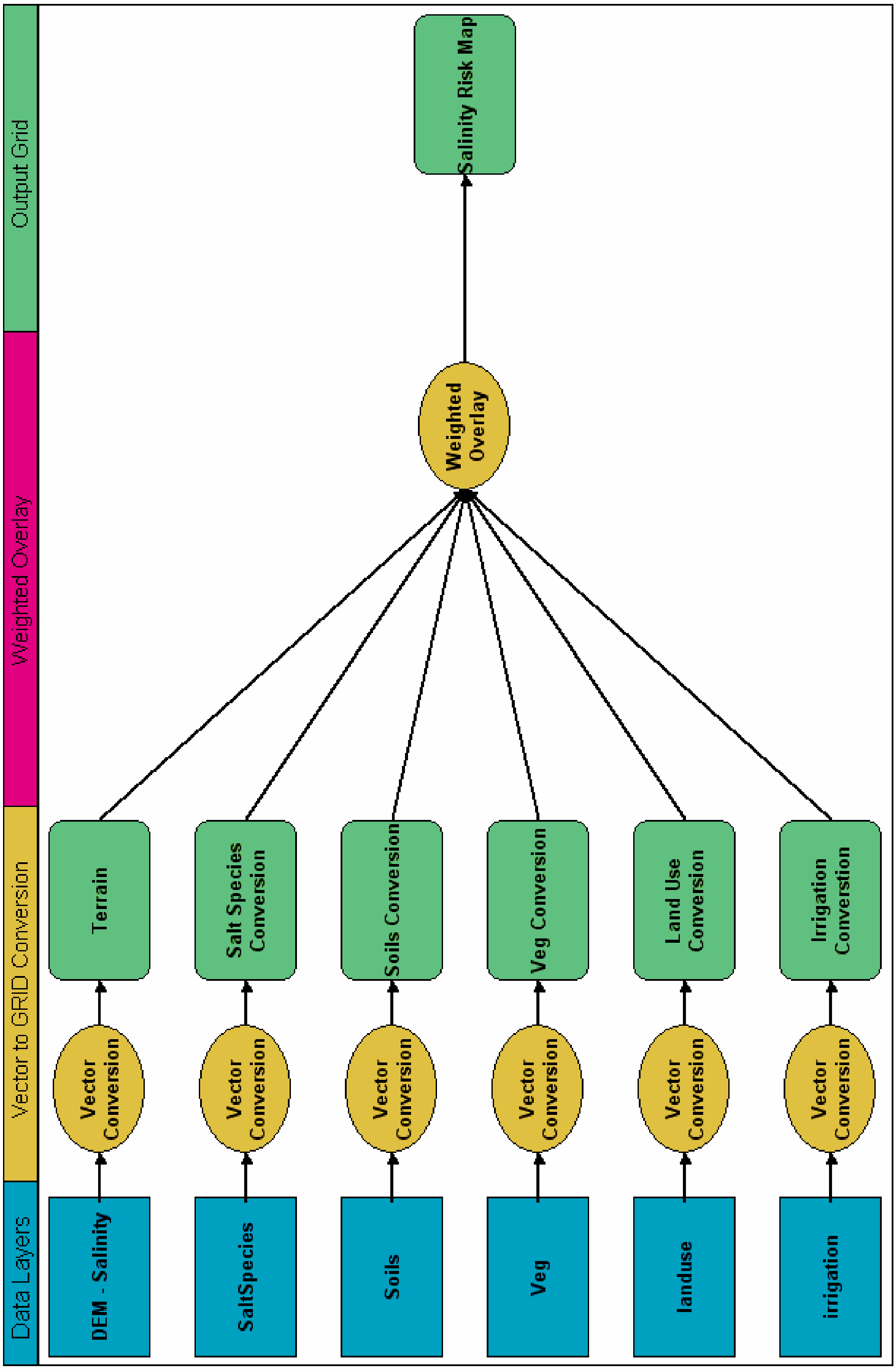

Figure 3.10 – Salinity Risk Model

These layers then had the relevant attribute selected as the category to be used in the ‘Vector to GRID Conversion’ process (See Figure 3.11).

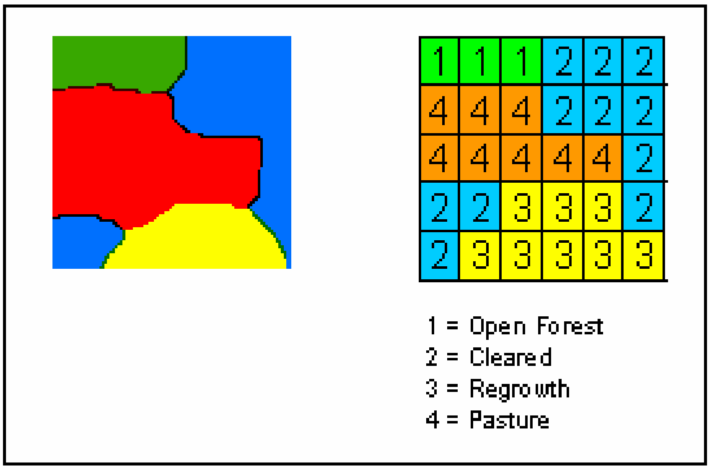

Figure 3.11 – Vector to GRID Conversion

In this process each data set was given a new name which was then given to the output GRID data-sets (See Figure 3.12).

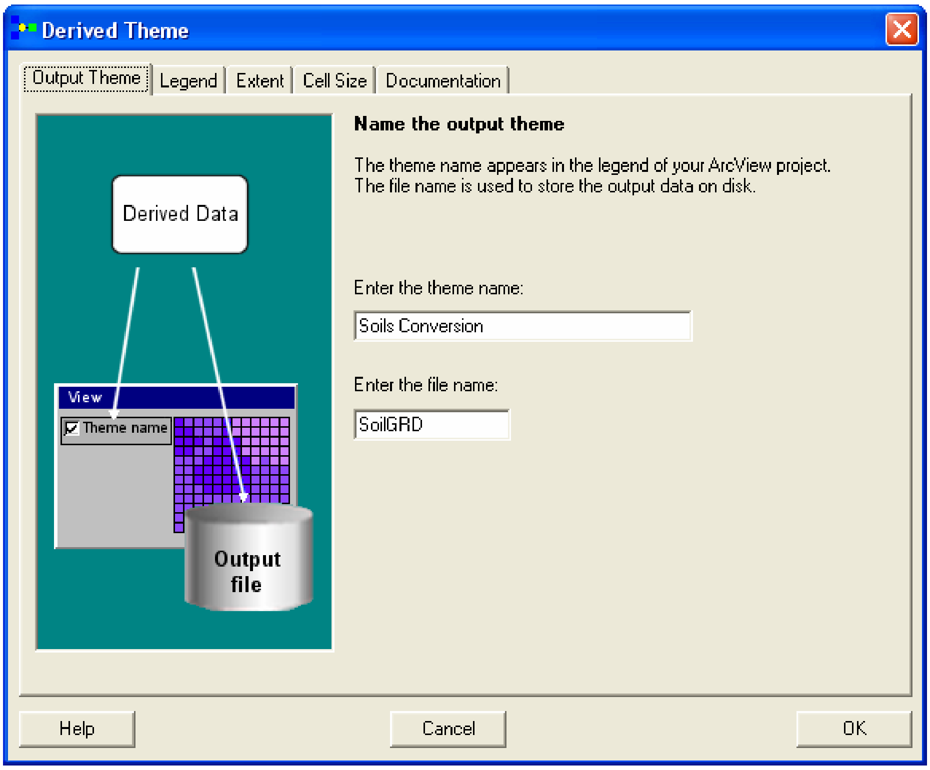

Figure 3.12 – Print Screen: Vector to GRID Conversion Setup

During the weighted overlay process these GRID files were weighted using a series of 'scales' (1 to 5) and '%influences' (totalling 100%). (See Figure 3.13)

Input Theme	%Influence	Attribute Name	Scale Value
Salt Tolerant Vegetation	20	High Risk	5
		Moderate Risk	3
		Low Risk	2
		No Risk	1
		No Data	Restricted
Soils	10	Clay	5
		Loam	3
		Sand	1
		No Data	Restricted
Vegetation Type	30	Fern Thicket	3
		Clear	5
		Open Forest	2
		Open Woodland	2
		Rain Forest	1
		Shrubland	3
		Tall Open Forest	1
		Vine Forest	3
		Vine Thicket	3
		Wetlands	4
		Woodland	1
		No Data	Restricted
Land-use	5	Cotton	5
		Cropping	4
		Dairy	3
		Forestry	1
		Grazing - Cattle	4
		Grazing - Sheep	4
		Industry	3
		Irrigated Cropping	5
		National Park	1
		Grazing - Other	4
		Piggery	3
		Poultry	3
		State Forest	1
		Unclassified	Restricted
		Urban	2
		Water Body	Restricted
		No Data	Restricted
Irrigation Areas	5	Irrigation	5
		No Data	Restricted
DEM	30	High Risk	5
		Moderate Risk	4
		Low Risk	3
		Little to No Risk	1
		No Data	Restricted

Figure 3.13 – Salinity Risk Weightings

These weights were then used to combine the input GRID data-sets in the weighted overlay process (See Figure 2.2) to create the output/salinity risk map.

Upon completion of the weighted overlay process the output GRID was converted to ‘shapefile’ format. This ‘shapefile’ was then used in conjunction with the CRCA ‘shapefile’ to remove the ‘Restricted’ values which resulted from the rectangular shaped extent polygon created by ‘Model Builder’.

3.5.3 Erosion Risk Map

The process used to create the erosion risk map was very similar to the process used to create the salinity risk map. This is largely due to the similarities in the way each form of degradation forms. The major difference between these two weighted overlay processes is that some data-sets were removed and other data-sets replaced them to form the erosion risk model. In all, eight data layers were used during this analysis stage (See Figure 3.14). These values were:

- Un-sealed roads
- Surfaced Roads
- Soils
- Vegetation Type
- Land-Use
- Irrigation Areas
- Rivers; and
- Slope (derived from DEM)

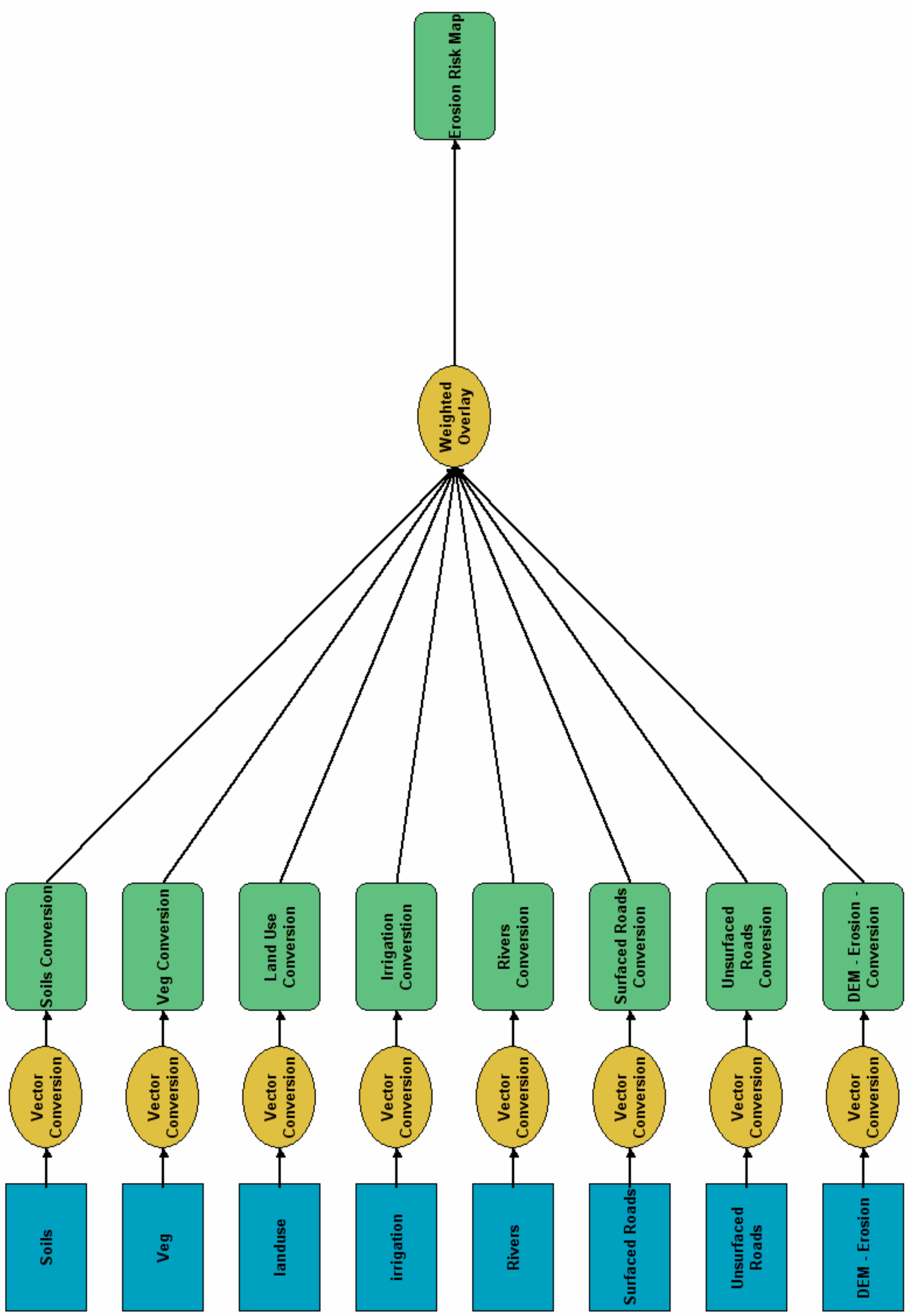

Figure 3.14 – Erosion Risk Model: ‘Model Builder’

Due to large similarities between this erosion risk map and the salinity risk map, discussion of the processes that occurred during this project will not be discussed; instead this section will focus on the weightings assigned to the data-sets in the erosion modelling. The modelling process for the erosion risk map, like the salinity risk map used the CRCA boundary as its extent, a cell size of 25 metres and a rating scale of 1 to 5 for ‘layer’ attributes. The weightings and scale values for the erosion risk map can be seen in Figure 3.15.

Input Theme	%Influence	Attribute Name	Scale Value
DEM	25	Steep Slope	5
		Moderate Slope	3
		Little to No Slope	1
		No Data	Restricted
Soils	10	Clay	1
		Loam	3
		Sand	5
		No Data	Restricted
Vegetation Type	30	Fern Thicket	4
		Clear	5
		Open Forest	3
		Open Woodland	3
		Rain Forest	3
		Shrubland	3
		Tall Open Forest	2
		Vine Forest	3
		Vine Thicket	3
		Wetlands	4
		Woodland	2
		No Data	Restricted
Land-use	5	Cotton	4
		Cropping	4
		Dairy	3
		Forestry	2
		Grazing - Cattle	3
		Grazing - Sheep	3
		Industry	2
		Irrigated Cropping	4
		National Park	2
		Grazing - Other	4
		Piggery	4
		Poultry	4
		State Forest	2
		Unclassified	Restricted
		Urban	2
		Water Body	1
		No Data	Restricted
Irrigation Areas	5	Irrigation	4
		No Data	Restricted
Un-sealed Roads	10	Un-sealed Roads	4
		No Data	Restricted
Surfaced Roads	5	Surfaced Roads	2
		No Data	Restricted
Rivers	10	Rivers	4
		No Data	Restricted

Figure 3.15 – Erosion Risk Weightings

3.6 Summary

This chapter is designed to give the reader an in-depth understanding of the pre-processing and processing steps taken as a component of the analysis stages of this project. This chapter does not aim to discuss the implications of the weightings, the validity of the process or any possible improvements that could be made to increase the accuracy and level of certainty at which the maps created through this process could be used. Instead this will be left to Chapters 5 and 6.

Chapter 4

Results

4.1 Introduction

The aim of this chapter is to present the salinity and erosion risk maps created as a result of the analysis conducted for this project. This chapter will also discuss the relative accuracies of each map based upon ground truthing work conducted as part of the project.

4.1 Results: Salinity Risk Map

The salinity risk map for this project took into account six input data layers: soils, vegetation, salt tolerant vegetation, land-use, irrigation, and a DEM. These data sets were then combined in a weighted overlay process to form the map shown in Figure 4.1. The accuracy of this map cannot be given in a physical sense, i.e. no plus or minus figure can be given on accuracy. This is due to a lack of documentation for the input data-sets used. Therefore the only measure of accuracy which can be used for this map if a percentage level of certainty. To calculate the level of certainty for each map, a number of factors including the ground truthing data were compared with the original data-sets. This allowed a level of certainty to be determined. The comparison of ground truth data with existing data-sets can be seen Table 4.1.

	Existing Data Sets				
Location	Slope	Soils	Vegetation	Land Use	Location Accuracy
1	✓	✓	✓	✗	75%
2	✓	✓	✓	✓	100%
3	✓	✓	✓	✗	75%
4	✓	✗	✓	✓	75%
5	✓	✓	✗	✓	75%
6	✓	✓	✓	✗	75%
7	✓	✓	✓	✗	75%
8	✓	✓	✓	✓	100%
9	✓	✓	✓	✓	100%
10	✓	✓	✓	✓	100%
11	✓	✓	✓	✗	75%
12	✓	✓	✓	✓	100%
13	✓	✓	✗	✓	75%
14	✗	✗	✓	✓	50%
15	✓	✓	✓	✓	100%
16	✗	✓	✓	✓	75%
17	✓	✓	✓	✓	100%
18	✗	✓	✓	✗	50%
19	✓	✓	✓	✓	100%
20	✓	✓	✓	✓	100%
21	✓	✓	✓	✓	100%
22	✓	✓	✓	✓	100%
23	✓	✗	✓	✓	75%
24	✓	✗	✓	✓	75%
25	✗	✗	✓	✓	100%
26	✓	✓	✓	✓	100%
27	✓	✓	✓	✓	100%
Attribute Accuracy:	85%	81.50%	92.50%	78%	84.25%

Table 4.1 – Salinity Risk Map Accuracy

This process of determining accuracy has led to the determination that the salinity risk map can be used with an 84% level of certainty. This figure is based upon the averages accuracies of the attribute accuracies. The implications of this accuracy indicator are discussed in Chapter 5.

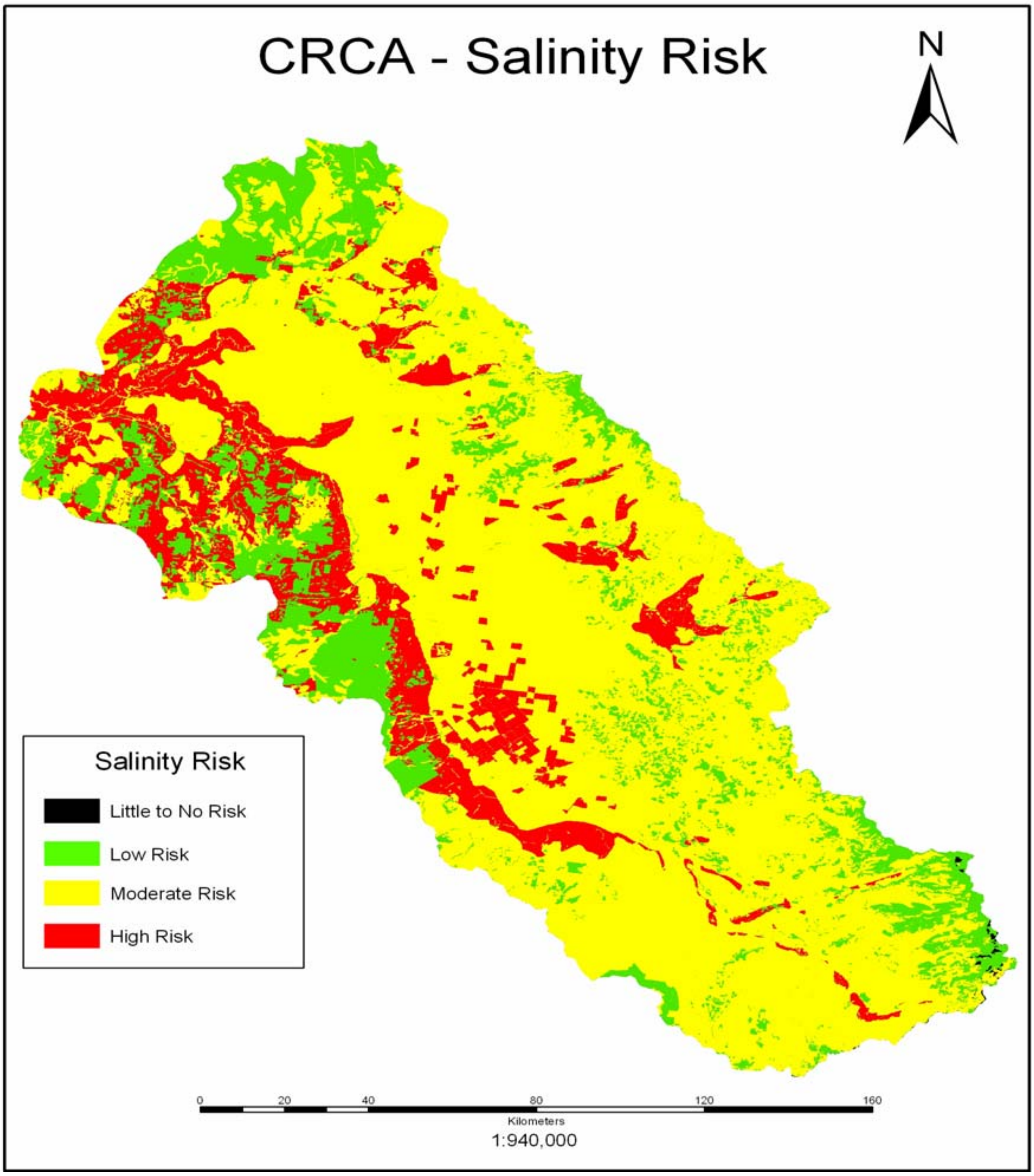

Figure 4.1 – Salinity Risk Map

From this analysis, figures were determined for the total of areas under each risk category. These figures can be seen in Figure 4.2:

		Little to No Risk	Low Risk	Moderate Risk	High Risk
Salinity Risk	Percentage	0.179%	16.283%	68.013%	15.523%
	Area (km^2)	43.736	3978.540	16618.097	3792.844

Figure 4.2 – Salinity Risk Statistics

4.3 Results: Erosion Risk Map

The erosion risk map for this project took into account eight input data layers: soils, vegetation, land-use, irrigation, rivers, surfaced roads, un-sealed roads and a DEM. These data sets were then combined in a weighted overlay process to form the map shown in Figure 4.3. Like the salinity risk map accuracy, the accuracy of the erosion risk map was calculated based upon averages derived by comparing ground truthing data with the pre-existing data-sets. The accuracies can be seen in Table 4.2:

	Existing Data Sets					
Location	Slope	Soils	Vegetation	Land Use	Proximity to Roads	Location Accuracy
1	✓	✓	✓	✗	✗	75%
2	✓	✓	✓	✓	✗	100%
3	✓	✓	✓	✗	✓	75%
4	✓	✗	✓	✓	✗	75%
5	✓	✓	✗	✓	✗	75%
6	✓	✓	✓	✗	✓	75%
7	✓	✓	✓	✗	✗	75%
8	✓	✓	✓	✓	✓	100%
9	✓	✓	✓	✓	✗	100%
10	✓	✓	✓	✓	✗	100%
11	✓	✓	✓	✗	✗	75%
12	✓	✓	✓	✓	✗	100%
13	✓	✓	✗	✓	✗	75%
14	✗	✗	✓	✓	✗	50%
15	✓	✓	✓	✓	✗	100%
16	✗	✓	✓	✓	✗	75%
17	✓	✓	✓	✓	✗	100%
18	✗	✓	✓	✗	✗	50%
19	✓	✓	✓	✓	✗	100%
20	✓	✓	✓	✓	✗	100%
21	✓	✓	✓	✓	✗	100%
22	✓	✓	✓	✓	✗	100%
23	✓	✗	✓	✓	✗	75%
24	✓	✗	✓	✓	✗	75%
25	✗	✗	✓	✓	✗	100%
26	✓	✓	✓	✓	✗	100%
27	✓	✓	✓	✓	✗	100%
Attribute Accuracy:	85%	81.50%	92.50%	78%	11%	70%

Table 4.2 – Erosion Risk Map Accuracy

Based upon the accuracy results presented in Table 4.2, it is noticeable that the positional accuracy of the road's data is poor. It is the addition of this road data-set which caused the significant drop in overall location accuracy when compared to the salinity risk map.

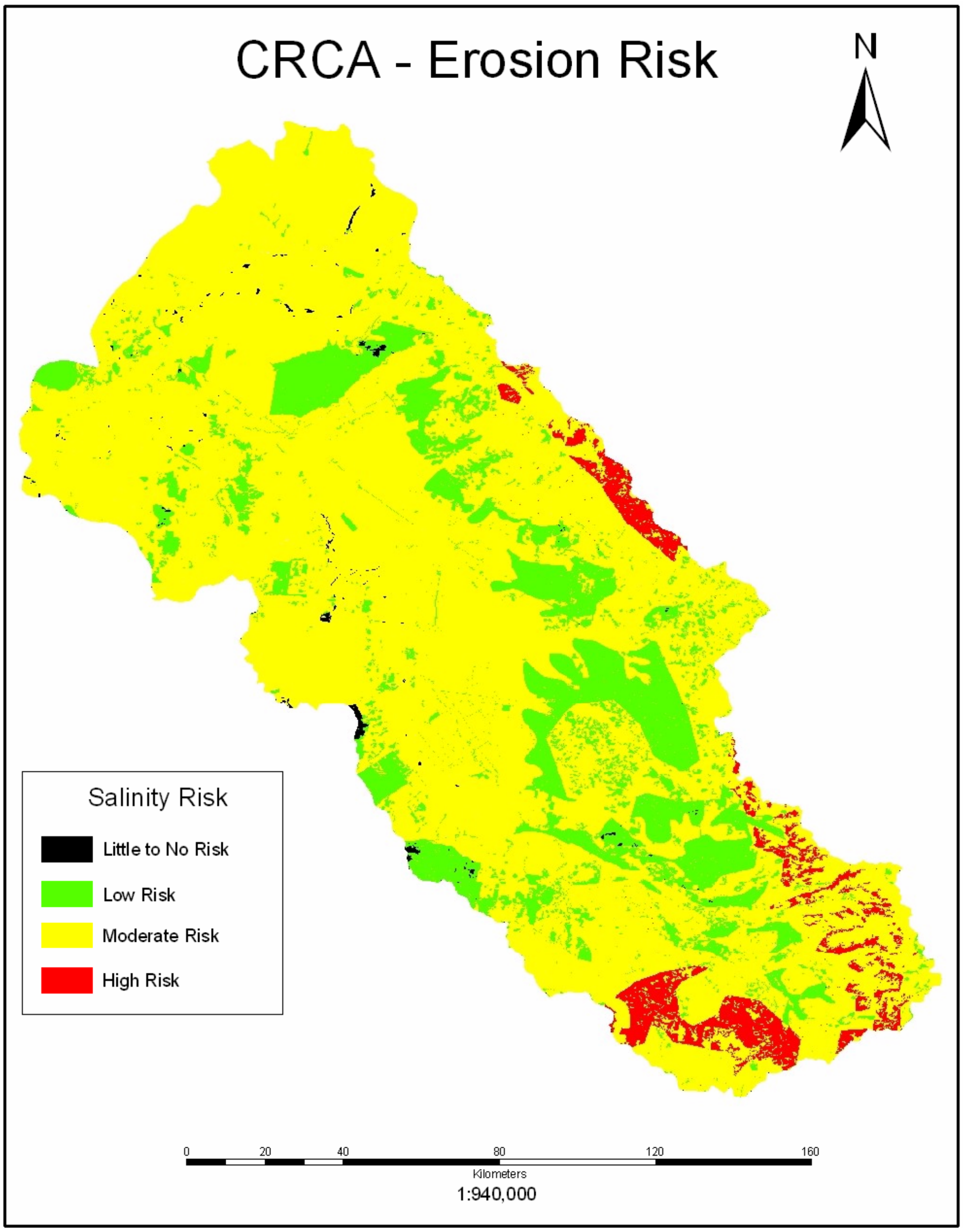

Figure 4.3 – Erosion Risk Map

Like the salinity risk map, analysis figures were determined for the total of areas under each risk category, these figures can be seen in Figure 4.4:

		Little to No Risk	Low Risk	Moderate Risk	High Risk
Erosion Risk	Percentage	0.268%	39.786%	56.008%	3.945%
	Area (km^2)	65.482	9721.194	13684.830	4963.909

Figure 4.4 Erosion Risk Statistics

Chapter 5

Discussion

5.1 Introduction

This chapter aims to discuss various issues which resulted from this project, including data accuracy and quality as well as data weightings.

5.2 Data Pre-processing

During the data-preprocessing stages of this project a number of data-sets underwent processing in order to make them usable during the weighted overlay processes conducted during this project. The processing steps which occurred during this project which require discussion are:

- Ground Truthing
- Soils Data Generalisation
- Buffering of ‘polyline’ features
- Use of Regional Ecosystem Data

5.2.1 Ground Truthing

During this project ground truthing was conducted to evaluate the accuracy of input data-sets used. Using a GPS unit and recording the attributes present at each site, as described in Chapter 3, a total of 27 locations were visited.

Whilst this number is relatively low, considering the size of the study area, it was also considered sufficient considering the nature of this project and time and funding limitations. Ideally a more extensive ground truthing process should have occurred. It is this author's opinion however that the level of ground truthing should vary based upon the size of the study area and the level of accuracy required from the analysis.

Ground Truthing for this project was originally designed to be conducted so that a complete coverage of the data-set attributes was obtained. However due to accessibility, time and funding constraints, ground truthing occurred close to roads and ended up being conducted in a manner which tried to give even coverage to all of the study area.

Whilst the first mentioned method of ground truthing is generally considered to be the best, there is a need to spread out ground truthing. If ground truthing was conducted to gather coverage of all attributes, certain areas might be neglected and hence accuracy estimates would not be applicable to the entire study area. The ideal way to ground truth data would be a combination of truthing by data attributes and by area coverage. For recording of attributes in the field it would have been ideal to have environmental specialists on hand to aid in the recording of attributes with particular reference to soils and vegetation type and species. However practical considerations and the requirements of this project meant that this was not required.

It was also decided before ground truthing commenced that post processing of location coordinates would not occur, as the best document accuracy of the input data was plus or minus 25 metres, which is less reliable than un-processed GPS coordinates.

5.2.2 Soils Generalisation

The soils data used in this project (as described in Chapter 3) was derived from the Atlas of Australian Soils. This data is extracted from 1:100,000 map sheets and is extremely generalised as it is based upon a system of Australia wide soil classifications.

Therefore the decision to generalise these data-sets even further into the categories of clay, loam and sand, presents more issues such as whether these classifications are indicative of soil types on the ground. The reclassification method used also doesn't take into consideration soils which are 60% clay and 40% loam (would be reclassified as clay under reclassification method used) and the effects that this may have on the susceptibility of land to salinity and erosion.

However the decision to generalise the soils data by reclassifying it into the broad categories of clay, loam and sand was made due to a lack of literature regarding the susceptibility of soil types in the Atlas of Australian Soils to salinity and erosion. Literature regarding susceptibility of clay, loam and sandy soils to salinity and erosion can on the other hand be found quite readily.

Despite the use of generalised soils data in this project, new soils data would be ideally collected at a scale of 1:50000 or better, recording: compositions, soil particle size, permeability, organic matter levels, depth and the position of the groundwater tables relative to the position of the soil surface. This would provide valuable information which could be used to more accurately weight the soils data to show its susceptibility to salinity and erosion risk.

5.2.3 River and Road Buffering

The road and river network data used in this project were all initially in ‘polyline’ format. This format would have been of little use within the weighted overlay process and hence it was decided to buffer each data-set as described in Chapter 3.

The buffering was conducted to give both the rivers and roads an ‘area of impact’ in which susceptibility to erosion was considered to occur. The buffering distances used in this project for the roads and rivers were not developed from literature on the subject as no literature was found documenting the susceptibility of roads and rivers to erosion as a function of distance from the feature.

Considering the river data, the buffered area is meant to represent the area of river prone to erosion. However this buffer distance does not take into account varying river widths and flow rates. Therefore if higher quality data for river systems was available, a variable width buffer would have been used based upon a number of factors including:

- river width
- river flow levels; and
- whether rivers were seasonal or not

Using these factors to create a variable buffer around rivers to show areas at risk from erosion would be more accurate than the method used for this project. However in order for the most accurate portrayal of erosion risk on river banks to be derived, it would be necessary to conduct statistical research in order to derive critical threshold distances at which erosion risk levels changed.

Even then, data collected would date quickly due to the natural changes in river courses due to erosion and would lower the accuracy of any output maps.

A similar problem arose using the roads data; however a greater problem with the roads data is the currency of the data. In the un-sealed roads data-set obtained from Geoscience Australia, many kilometres of un-sealed roads existed. Whether all these roads are still un-sealed or not is debatable, with many roads being visually recorded as sealed during ground truthing. Also the positional accuracy of both roads data-sets used (surfaced and un-sealed) varied extremely with some roads being out of position in the data-set by up to 280 metres and with an average error in road position of approximately 45 metres. Even though the GPS unit has a relatively large error margin before post-processing, it does not come close to accounting for errors in the road's data-sets.

5.2.4 Regional Ecosystems Data

Two problems that arose whilst using the Regional Ecosystems data (vegetation data) were that:

- vegetation patches are assigned a generic description code which has a vegetation description meaning that vegetation patches at opposite ends of the study area may be classified as exactly the same; and
- the data does not include all areas of recently cleared vegetation.

Whilst patches are generalised into categories they are still usable for a study conducted at this scale. It is also unlikely that coverage of vegetation data of higher quality exists for the entire study area (due to the large costs associated with recording in-depth vegetation information in the field). Therefore the Regional Ecosystems data-set was considered to be the best available vegetation data with other sources such as GeoScience Australia having very generalised data-sets.

5.2.5 Potential Data Sets

The data-sets used in this project were used primarily due to their availability. However this doesn't mean that they are the only data-sets which could be used to improve the portrayal of salinity and erosion risk within the study area. Aside from collecting new data, a number of known data-sets, which have been used in previous studies and are generally available at similar accuracy levels to data used in this project, are available and would have been used in this project if they had been available.

Other data-sets that could have been used to portray erosion risk during this project are:

- Rainfall Erosivity
- Regolith Stability
- Land form

(Australian Government - Forest and Wood Products Research and Development Corporation, p 99)

Other data-sets which could have been considered for the salinity risk map include:

- Geology: Dykes, Fault Lines and Salt Stores
- Rainfall Levels
- Landscape Curvature
  (Searle, R, Baillie, J, 2003. p 10)
- Groundwater position
- Groundwater salt levels; and
- Soil Permeability

5.3 Data Processing

The only component from the data processing that needs discussion is the assigning of weights to individual data-sets. For this project, weights were assigned in most cases as a result of research into the processes of salinity and erosion. However in some cases, such as the roads and rivers, other methods were used as described earlier in this chapter. It could be seen to be significant that the weightings used for this project whilst considered to be accurate were based upon research of previously published reports and books detailing salinity and erosion processes, some of which were published up to 30 years ago.

To ensure that weightings are 100% correct it would be necessary to verify decisions with a number of experts in various fields such as salinity and erosion and even more specifically soil and vegetation scientists. However even if this occurred, there may be a difference between advice offered by each experts on how data-sets should be weighted and what data-sets should be given a higher level of importance in the overall weighted overlay process. Therefore it must be understood that the assigning of weights is a very subjective process and will not always be correct.

Chapter 6

Conclusions & Recommendations

6.1 Introduction

This chapter is dedicated to making recommendations and conclusions from the work conducted in this project and suggesting what possible improvement could be made to both the data and processes used in this project.

6.2 Conclusions

This project set out to map salinity and erosion risk within the CRCA using environmental data-sets. Based upon these environmental data-sets both the salinity risk and erosion risk maps were produced to 84% and 70% accuracy respectively.

Whilst this accuracy is not outstanding it is acceptable based upon the size of the study area and the quality of the data-sets being used. Accuracy could easily be improved upon by conducting a more thorough ground truthing process and investigating other available data-sets. However it must be noted that the accuracy of the salinity and erosion risk maps is only suitable for such a large area as used in this project and the use of the maps for a smaller area (i.e. property level) would be unsuitable and would not provide an accurate view of salinity and erosion risk. Instead these maps would be most useful as a preliminary tool to decide which areas of the CRCA needed to be examined in greater detail.

6.3 Recommendations

6.3.1 Introduction

The potential uses for the risk maps created during this project are limited mainly due to the scale at which these maps are accurate. However other factors such as quality and the breadth of input data-sets used also play a role in the usability of the maps. Therefore the most beneficial application/use of these maps would be for identification of areas which require further investigation. The aim of this section is to identify methods for which the risk mapping process could be improved.

6.3.2 Recommendations for Usage

Due to the quality of the data used in this project and the scale at which it is accurate, it is recommended that the maps not be used at any scale larger than that of a sub-catchment scale (i.e. 1:100,000 – 1:250,000). This is due to the fact large proportions of data used during this project were extracted from either 1:100,000 or 1:250,000 map sheets.

6.3.3 Recommendations for Further Action

The processes used during this project could be enhanced through a number of improvements which may vary taking into consideration: the intended use of the maps, the size of the study area, the scale at which the maps are required for planning and budget constraints.

A list of possible improvements that could increase the usability and accuracy of the salinity and erosion risk maps includes:

- inclusion of additional data-sets to improve the accuracy of the process of showing the potential risk of an area.
- collection of new data-sets for increased accuracy (both temporal and positional) and quality (feasibility study required) with particular reference to vegetation, soil, land-use, river and road width and geological data
- consultation with experts on salinity and erosion as to how various data-sets should be weighted or collected to best represent the potential risk of an area; and
- comparison of risk maps with salt level data to gain a measure of how well the risk maps ‘held up’.

6.3.3 Recommendations for Further Study

During the process of this project it was difficult to find literature in some areas which would allow for the reclassification of values present in the data-sets used. Therefore it is a recommendation of this study that study be conducted into the following area:

- determining of critical distance thresholds from roads (both surfaced and un-surfaced) in regards to erosion risk.

6.4 Summary

It must be noted within this chapter that whilst the collection of new data-sets specifically for the purposes of mapping risk is ideal where existing data is not of high enough quality, it must be understood that data collection of this scale is a major undertaking which would require substantial expenditure as well as strict monitoring of collection standards and quality.

Therefore in the majority of cases and with the current level of impact of salinity and erosion on the environment the collection of new data is not feasible for a large study area. This is despite the inherent benefits. In some cases data collection costs may be more then the costs of collecting soil salt levels, particularly over a small study area. Therefore before any major undertaking in this area, (particularly with the collection of new data), feasibility studies are a necessity and no work should be conducted before these studies are completed.

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Appendix A

Project Specification

University of Southern Queensland
Faculty of Engineering and Surveying

ENG 4111/4112 Research Project
PROJECT SPECIFICATION

For:	**Cameron MacGregor**
Topic:	"Risk Mapping in the Condamine River Catchment Area"
Supervisor:	Dr Sunil Bhaskaran
Sponsorship:	Queensland Murray Darling Committee Inc.
Project Aim:	The aim of this project is to identify the potential risk of the Condamine River Catchment Area to Salinity and Erosion through modelling "environmental indicators" in a weighted overlay process.
PROGRAMME:	**Issue B, 17th October 2004**

1. Investigate the environmental issues of erosion and salinity
2. Investigate the specific processes of salinity and erosion to better understand how each process occurs
3. Review ArcView 3.2 Model Builder
4. Model salinity and erosion through a weighed overlay process
5. Conduct ground truthing of input datasets
6. Complete dissertation documenting the processes and objectives of the project.

AGREED:

(Student) ______________________ (Supervisor/s) ______________________

Cameron MacGregor Dr Sunil Bhaskaran

_____/_____/_____ _____/_____/_____

Appendix B

Ground Truthing Records

2.1 Introduction

The ground truthing for this project was conducted over two days due mainly to the size of the study area and the time required to cover the area by car. The aim of this ground truthing was not to test the accuracy of the outputs of this project: the salinity and erosion risk maps, but to test the accuracy of the input data sets.

During the two day trip 27 locations were visited and the following attributes were collected at each location:

- Longitude and Latitude
- Location height (above mean sea level)
- Soil type
- Vegetation type
- Land use
- Slope; and
- Distance to roads

The positional accuracy (latitude and longitude as well as height were recorded using a 'Trimble GeoXT' GPS (Global Positioning System) unit. Other attributes were recorded using a manual recording process of filling out a form (can be found later in this appendix). During this trip a photo was taken to give a visual representation of the land around the point. A more in-depth analysis of the ground truthing data and its implications to the accuracy of the output data sets (salinity and erosion risk map) can be found in the 'Discussion' chapter of this dissertation.

2.2 Ground Truthing Records

Ground Truth Location: **1**		
Longitude:	151^{0} 38' 55.73"	
Latitude:	27^{0} 42' 28.98"	
Height (above MSL):	514.68 meters	
Photo Direction:	South West	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Poultry
Slope:	$< 5^{0}$	$< 5^{0}$
Proximity to Roads:	30 meters	70 meters
	Location Accuracy:	60%

Ground Truth Location: **2**		
Longitude:	151 ^{0} 23' 42.74"	
Latitude:	27 ^{0} 47' 44.72"	
Height (above MSL):	381.37 meters	
Photo Direction:	South East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	160 meters
	Location Accuracy:	80%

Ground Truth Location: **3**		
Longitude:	151 ^{0} 22' 25.48"	
Latitude:	27 ^{0} 48' 15.08"	
Height (above MSL):	388.55 meters	
Photo Direction:	North West	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Open Woodland	Open Woodland
Land Use:	Forest	Cropping
Slope:	< 2 ^{0}	0
Proximity to Roads:	10 meters	10 meters
	Location Accuracy:	80%

Ground Truth Location: **4**	
Longitude:	151^{0} 17' 25.79"
Latitude:	27^{0} 51' 57.01"
Height (above MSL):	398.81 meters
Photo Direction:	South South East

	Ground Truthing Records	Data Records
Soil Type:	Loamy Clay	Sand
Vegetation Type:	Clear	Clear
Land Use:	Pasture	Pasture
Slope:	0	0
Proximity to Roads:	10 meters	40 meters
	Location Accuracy:	60%

Ground Truth Location: **5**	
Longitude:	151^{0} 15' 58.88"
Latitude:	27^{0} 48' 33.80"
Height (above MSL):	380 meters
Photo Direction:	West

	Ground Truthing Records	Data Records
Soil Type:	Sand	Sand
Vegetation Type:	Open Woodland	Clear
Land Use:	Forest	Forest
Slope:	0	0
Proximity to Roads:	2 meters	130 meters
	Location Accuracy:	60%

Ground Truth Location: **6**		
Longitude:	151^{0} 10' 52.98"	
Latitude:	27^{0} 40' 48.59"	
Height (above MSL):	367.05 meters	
Photo Direction:	North West	

	Ground Truthing Records	Data Records
Soil Type:	Sand	Sand
Vegetation Type:	Woodland	Woodland
Land Use:	Forest	Grazing
Slope:	0	0
Proximity to Roads:	4 meters	4 meters
	Location Accuracy:	80%

Ground Truth Location: **7**		
Longitude:	151^{0} 10' 3.30"	
Latitude:	27^{0} 32' 45.65"	
Height (above MSL):	351.99 meters	
Photo Direction:	North West	

	Ground Truthing Records	Data Records
Soil Type:	Sand	Sand
Vegetation Type:	Woodland	Woodland
Land Use:	Forest	Grazing
Slope:	0	0
Proximity to Roads:	10 meters	70 meters
	Location Accuracy:	60%

Ground Truth Location: **8**	
Longitude:	151^{0} 13' 39.09"
Latitude:	27^{0} 28' 3.24"
Height (above MSL):	351.58 meters
Photo Direction:	North North West

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Pasture	Pasture
Slope:	0	0
Proximity to Roads:	6 meters	6 meters
	Location Accuracy:	100%

Ground Truth Location: **9**	
Longitude:	151^{0} 16' 6.48"
Latitude:	27^{0} 22' 31.93"
Height (above MSL):	376.76 meters
Photo Direction:	East

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	180 meters
	Location Accuracy:	80%

Ground Truth Location: **10**	
Longitude:	151 ^{0} 5' 47.73"
Latitude:	27 ^{0} 15' 33.69"
Height (above MSL):	336.67 meters
Photo Direction:	North

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Woodland	Woodland
Land Use:	Forest	Cropping
Slope:	0	0
Proximity to Roads:	15 meters	250 meters
	Location Accuracy:	60%

Ground Truth Location: **11**	
Longitude:	150^{0} 29' 51.00"
Latitude:	26^{0} 55' 34.15"
Height (above MSL):	306.15 meters
Photo Direction:	West

	Ground Truthing Records	Data Records
Soil Type:	Sand	Sand
Vegetation Type:	Clear	Clear
Land Use:	Grazing	Grazing
Slope:	$< 5^{0}$	$< 5^{0}$
Proximity to Roads:	15 meters	140 meters
	Location Accuracy:	80%

Ground Truth Location: **12**		
Longitude:	150 ⁰ 41' 42.72"	
Latitude:	26 ⁰ 46' 55.19"	
Height (above MSL):	295.95 meters	
Photo Direction:	West	

	Ground Truthing Records	Data Records
Soil Type:	Sand	Sand
Vegetation Type:	Clear	Clear
Land Use:	Grazing	Grazing
Slope:	$< 5^0$	$< 5^0$
Proximity to Roads:	15 meters	140 meters
	Location Accuracy:	80%

Ground Truth Location: **13**		
Longitude:	150 ^{0} 49' 46.45"	
Latitude:	26 ^{0} 45' 27.35"	
Height (above MSL):	318.26 meters	
Photo Direction:	West	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Open Woodland	Clear
Land Use:	Grazing	Grazing
Slope:	0	0
Proximity to Roads:	20 meters	190 meters
	Location Accuracy:	60%

Ground Truth Location: **14**		
Longitude:	151 ^{0} 1' 25.57"	
Latitude:	26 ^{0} 46' 56.89"	
Height (above MSL):	325.56 meters	
Photo Direction:	North North East	

	Ground Truthing Records	Data Records
Soil Type:	Sand	Loam
Vegetation Type:	Open Woodland	Open Woodland
Land Use:	Grazing	Grazing
Slope:	< 5 ^{0}	0
Proximity to Roads:	5 meters	160 meters
	Location Accuracy:	40%

Ground Truth Location: **15**	
Longitude:	151 ° 10' 22.05"
Latitude:	26 ° 51' 44.32"
Height (above MSL):	346.37 meters
Photo Direction:	East

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	1 meters	150 meters
	Location Accuracy:	80%

Ground Truth Location: **16**		
Longitude:	151^{0} 16' 6.32"	
Latitude:	26^{0} 55' 35.21"	
Height (above MSL):	359.66 meters	
Photo Direction:	South East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Woodland	Woodland
Land Use:	Grazing	Grazing
Slope:	$< 2^{0}$	0
Proximity to Roads:	5 meters	290 meters
	Location Accuracy:	60%

Ground Truth Location: **17**		
Longitude:	151 ^{0} 21' 35.28"	
Latitude:	26 ^{0} 58' 36.83"	
Height (above MSL):	393.57 meters	
Photo Direction:	West	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Open Woodland	Open Woodland
Land Use:	Grazing	Grazing
Slope:	0	0
Proximity to Roads:	5 meters	220 meters
	Location Accuracy:	80%

Ground Truth Location: **18**		
Longitude:	151 ^{0} 18' 12.67"	
Latitude:	27 ^{0} 7' 34.88"	
Height (above MSL):	400.93 meters	
Photo Direction:	South South East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Woodland	Woodland
Land Use:	Grazing	Grazing
Slope:	0	0
Proximity to Roads:	15 meters	190 meters
	Location Accuracy:	80%

Ground Truth Location: **19**		
Longitude:	151^{0} 25' 49.54"	
Latitude:	27^{0} 17' 57.55"	
Height (above MSL):	355.21 meters	
Photo Direction:	South East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	$< 40^{0}$	$< 40^{0}$
Proximity to Roads:	5 meters	250 meters
	Location Accuracy:	80%

Ground Truth Location: **20**	
Longitude:	151^{0} 37' 34.15"
Latitude:	27^{0} 23' 33.23"
Height (above MSL):	370.15 meters
Photo Direction:	North East

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	4 meters	100 meters
	Location Accuracy:	80%

Ground Truth Location: **21**		
Longitude:	151 ^{0} 47' 21.86"	
Latitude:	27 ^{0} 29' 24.24"	
Height (above MSL):	388.7 meters	
Photo Direction:	North East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	230 meters
	Location Accuracy:	80%

Ground Truth Location: **22**		
Longitude:	151 ^{0} 53' 33.22"	
Latitude:	27 ^{0} 53' 41.70"	
Height (above MSL):	459.08 meters	
Photo Direction:	East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	230 meters
	Location Accuracy:	80%

Ground Truth Location: **23**		
Longitude:	151 ^{0} 58' 34.14"	
Latitude:	27 ^{0} 53' 41.70"	
Height (above MSL):	626.16 meters	
Photo Direction:	North East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Grazing
Slope:	< 8 ^{0}	< 8 ^{0}
Proximity to Roads:	5 meters	180 meters
	Location Accuracy:	80%

Ground Truth Location: **24**		
Longitude:	151^{0} 58' 34.14"	
Latitude:	27^{0} 53' 41.70"	
Height (above MSL):	626.16 meters	
Photo Direction:	South South East	

	Ground Truthing Records	Data Records
Soil Type:	Sand	Clay
Vegetation Type:	Open Woodland	Open Woodland
Land Use:	Fringe Urban	Fringe Urban
Slope:	$< 20^{0}$	$< 20^{0}$
Proximity to Roads:	0 meters	210 meters
	Location Accuracy:	60%

Ground Truth Location: **25**		
Longitude:	151 ° 58' 34.14"	
Latitude:	27 ° 53' 41.70"	
Height (above MSL):	398.71 meters	
Photo Direction:	East	

	Ground Truthing Records	Data Records
Soil Type:	Loam	Clay
Vegetation Type:	Clear	Clear
Land Use:	Pasture	Pasture
Slope:	0	0
Proximity to Roads:	5 meters	5 meters
	Location Accuracy:	80%

Ground Truth Location: **26**		
Longitude:	151 ^{0} 59' 47.10"	
Latitude:	27 ^{0} 59' 35.81"	
Height (above MSL):	632.57 meters	
Photo Direction:	South East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Pasture	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	75 meters
	Location Accuracy:	60%

Ground Truth Location: **27**		
Longitude:	152 ^{0} 2' 40.42"	
Latitude:	28 ^{0} 5' 3.33"	
Height (above MSL):	387.41 meters	
Photo Direction:	East	

	Ground Truthing Records	Data Records
Soil Type:	Clay	Clay
Vegetation Type:	Clear	Clear
Land Use:	Cropping	Cropping
Slope:	0	0
Proximity to Roads:	5 meters	190 meters
	Location Accuracy:	80%

Appendix C

Project Maps and Tables

C.1 Introduction

This appendix is composed of maps and table. While the maps and tables included in this section are relevant to the project there intended use is for reference purposes only as they do not aid in the discussion of analysis sections of this project/project dissertation.

C.2 Maps

Figure C1 – Major Natural Features of the CRCA (Exaggeration X20)

C.3 Tables

Species Tolerant of Saline Soils	
Large Trees - Height 15m or more	
Botanical Name	Common Name
Acacia auriculiformis	Northern Black Wattle
Casuarina cunninghamiana	River Sheoak
Casuarina glauca	Swamp Sheoak
Corymbia citriodora	Spotted Gum
Corymbia tessellaris	Morton Bay Ash
Eucalyptus argophloia	Western White Gum
Eucalyptus brassiana	Cape York Gum
Eucalyptus brockwayi	Dundas Mahogany
Eucalyptus camaldulnesis	River Red Gum
Eucalyptus cambageana	Coowarra Box
Eucalyptus drepanophylla	Queensland Grey Ironbark
Eucalyptus grandis	Rose Gum
Eucalyptus largiflorens	Black Box
Eucalyptus melliodora	Yellow Box
Eucalyptus microtheca	Coolabah
Eucalyptus moluccana	Grey Box
Eucalyptus paniculata	Grey Iron Bark
Eucalyptus pellita	Red Mahogany
Eucalyptus raveretiana	Black Ironbark
Eucalyptus robusta	Swamp Mahogany
Eucalyptus salmonophloia	Salmon Gum
Eucalyptus salubris	Fluted Gum
Eucalyptus sideroxylon	Mugga
Eucalyptus tereticornis	Forest Red Gum
Melaleuca leucadendra	Broad-leaved tea-tree
Melia azederach	White Cedar
Medium Trees - height 5m - 15m	
Acacia ampliceps	Salt Wattle
Acacia disparrima	Southern Salwood
Acacia crassicarpa	Northern Wattle
Acacia leptocarpa	Wattle
Acacia pendula	Weeping Myall
Acacia salicina	Cooba
Acacia stenophylla	River Cooba
Callistermon salignus	White Bottlebrush
Callistermon viminalis	Weeping Bottlebrush
Carallia brachiata	Carallia
Casuarina equisetifolia	Beach sheoak

Eucalyptus burdettiana	Burdett's Gum
Eucalyptus curtisii	Plunkett Mallee
Eucalyptus sargentii	Salt River Gum
Eucalyptus spathulata	Swamp Mallee
Melaleuca arcana	Winti
Melaleuca bracteata	White Cloud Tree
Melaleuca linariifolia	Narrow-leaved tea-tree
Melaleuca quinqurnervia	broad-leaved tea-tree
Pittosporum angustifolium	Cattlebush
Small Trees and Shrubs - height up to 5 m	
Atriplex nummularia	old-man saltbush
Callistemon citrinus	Lemon-Scented Bottlebrush
Callistemon phoeniceus	Fiery Bottle Brush
Eucalyptus forrestiana	Fuchsia Mallee
Leptospermum polygalifolium	Wild May
Melaleuca nodosa	Prickly-leaved paperbark

Figure C2 – Plants Suitable for Salt Soils (Wright, A, et al, 2001)

Vegetation Type	Total Hectares
Clear	1776097.9496
Fern Thicket	537.7376
Open Forest	90063.5508
Open Woodland	169092.7927
Rain Forest	72.5837
Sedgelands	0.9698
Shrubland	4241.1887
Tall Open Forest	8120.6004
Vine Forest	10381.5698
Vine Thicket	11029.7583
Wetlands	612.8863
Woodland	382428.9618

Figure C3 – Major Vegetation Types