THE REPRESENTATION
OF PARCELS
AND
PARCEL RELATIONSHIPS
IN A
LAND INFORMATION SYSTEM

by

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Except as stated herein, this thesis does not contain any material which has been accepted for the award of any other degree or diploma in any university nor, to the best of my knowledge and belief, does it contain any copy or paraphrase of material previously published or written by another person, except where due reference is made in the text of the thesis.

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ABSTRACT

A number of functionally independent cultural parcels are in common use. These include the legal parcel, assessment parcel, farm parcel and administrative parcels. Many independent Land Data Systems have been developed on the basis of individual parcel definitions. The development of successful Land Information Systems is dependent upon the integration of these single purpose systems. This integration requires an ability to incorporate a variety of distinct parcel definitions and determine the relationships between these definitions.

This thesis examines some common parcel definitions and evaluates their relationships on the basis of six fundamental topological relations. A set of basic operations on parcels and parcel maps are defined and used in conjunction with the basic parcel relationships to develop a model for the representation of cultural parcels.

The model is tested on theoretical data and then against three different combinations of real data sets. The tests on the cultural data of the one rural and two urban data combinations proved successful.

The model is reliant upon a separate identifier for each distinct parcel definition and a knowledge of the topological relationships between each parcel represented in the model.

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The patience and sacrifices endured by my wife Margaret over the past two years are dearly appreciated, her internment as "Thesis Widow" is now over and her support and encouragement will be rewarded.

CONTENTS

1. INTRODUCTION

1.1 The areal unit problem

Man has been collecting and maintaining information in relation to the earth's surface ever since it has been possible to keep records. As a result of this, many spatial units for data collection have developed, each unit representing some portion of the earth's surface.

The most common spatial land unit (or parcel) is the legal parcel, but there are many others, including administrative, fiscal and natural parcels, each with its own definition, interpretation and use.

Systems have been developed within various organisations which are based on these units. Most single purpose systems are based on one unit, however the need to integrate the data held in these systems has spawned the development of multipurpose systems which may incorporate a number of units. The need for integration is evidenced by the duplication in the land data collection, storage and maintenance activities and the inability to combine data items held separately within the systems.

The integration of systems which are based on disparate areal units is not an easy task. The following quotes provide evidence of these problems:

> "Another major problem is very poor parcel identification in Tasmania. Duplication has resulted in over 10 different reference systems which creates many administrative problems, especially concerning the implementation of LIS strategy."
>
> [AURISA 1985]

> "...there is still a problem with compatibility between the legal and fiscal parcels in the system"
>
> [AURISA 1985]

> "Recent efforts at examining the feasibility of combining the two systems [fiscal and legal] have ended in frustration and a recognition that, at the present time, the task is too difficult."
> [Williamson 1983]

Clearly there is a need to study parcel definitions, their relationships and their subsequent representation within automated Land Information Systems.

This thesis deals with one aspect of this problem, how to model cultural data sets, some discussion on the difficulties associated with natural data sets is also included.

1.2 Objectives of Research

This thesis aims to derive and test a model which will allow the integration of multiple parcel data sets and yet allow the continued use of individual parcel definitions. To achieve this aim the thesis will:

1. Examine existing land parcel types and assess the need for retaining the individual types.

2. Examine current models for representing parcels and parcel relationships.

3. Examine the relationships between parcels and formally define relations between areal entities.

4. Define a basic set of operations on parcel based data and determine a data structure which will allow the efficient performance of these procedures.

5. Implement the derived model on a number of data sets.

1.3 Overview of thesis

Chapter 2 examines various land parcel definitions, their components, the reasons for their development, as well as why these units need to be retained.

Chapter 3 examines existing models for representing parcel relationships. Single purpose systems are considered first and is followed by an investigation of the multipurpose systems that have been developed to represent a variety of parcel data and their relationships. The inadequacies of some of these models highlight the need for a formal examination of parcel relationships.

Chapter 4 outlines the development of a formal definition of the topological relationships between areal units. The relationship between parcels of one type and parcels of different types are examined in terms of these relationships.

Chapter 5 defines and outlines a basic set of operations which are necessary for the successful implementation of a variety of parcel based data on a computer system.

Chapter 6 examines various data structures which may be used for the representation of parcel data.

Chapter 7 examines three different models for parcel and parcel relationship representation which may be built on the data structure recommended in chapter 6. Of the three models, separate layers, combined layers and structurally enhanced combined layers, the second is recommended as the most suitable.

Chapter 8 discusses the implementation and testing of the combined layers model on a theoretical data set using ARC/INFO. A theoretical data set is used so that the implementation and operation of the model can be discussed in general terms. Hence peculiarities of particular data sets may be ignored.

Chapter 9 discusses the implementation and operation of the combined layers model on three real data sets. The three data sets are a result of pilot studies in which the School of Surveying, University of Tasmania, were involved.

Chapter 10 concludes this dissertation.

2. LAND PARCELS

2.1 Introduction.

The aim of this chapter is to identify some of the more common land parcels in current use; highlight the need for maintaining these parcels and; introduce some of the difficulties in representing parcels and parcel relationships.

In examining parcels three distinct components are considered. The most important is the parcel definition or type, as this determines the location and extent of the parcel. Disparate units arise as a result of differences in definition. The next most important component are the parcel attributes, or the textual data describing the parcel. The third component of a parcel is the identifier which serves as a tool for distinguishing one parcel from other parcels in the same classification system.

Studies in the past have sought the adoption of one parcel definition for the purpose of land data collection and storage and therefore one identifier. This approach over simplifies the relationships between parcels of different organisations. Furthermore there appears to be institutional as well as technical problems if organisations were to replace their base land unit by some universal unit.

2.2 Spatial Properties of Parcels

2.2.1 Definition

The word parcel has many connotations when used in relation to land. It is most often used in terms of the legal parcel. However a parcel determined by a Soil Scientist, a Valuer or any other land based professional, may be something quite different.

The Macquarie Dictionary defines a parcel in the context of land as " a separate or distinct part or portion or section." However, a piece of land may be distinguished in many ways. A cleared piece of land may be distinct from the forest which surrounds it and so may be called a parcel, but there may not be any distinct difference between the soil of the cleared area and the soil of the surrounding area hence a Soil Surveyor may not recognise the existence of two separate parcels in this situation.

The parcel is the result of dividing the earth's surface into units with the location and extent of the parcel depending on the purpose of classification or theme. If the parcel is classified as a legal entity, then the parcel boundaries will be in different locations to the boundaries of soil parcels. Parcels are thus a convenient basis for the collection and storage of land related data of a particular theme.

2.2.2 Continuity

Continuity is the basic property of the parcel and may be considered from two aspects, namely area and characteristic.

(i) area

The principle that a parcel is continuous in area is fundamental. Disjointed areas as indicated in figure 2-1 should not be considered as one parcel. This notion is supported by Dowson and Sheppard who consider a parcel to be a distinct and continuous piece of land surrounded by similar parcels. It is also confirmed by Moyer and Fisher [1973]:

> "The Agricultural Stabilization and Conservation Service (ASCS) has come to regret its past practice of ignoring areal discontinuities in its primary units of data collection and storage."

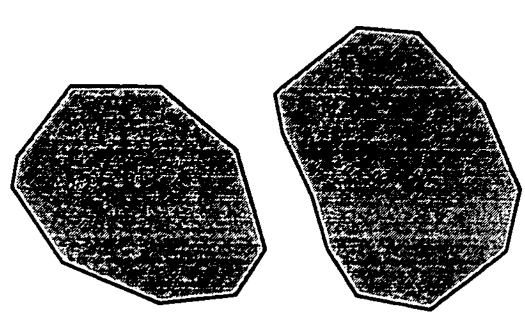

Figure 2-1

(ii) characteristic

The characteristic relates to the parcel type and depends on the purpose for which the parcel was defined. If there is a discontinuity in the characteristic, then it is represented by the occurrence of a parcel boundary.

2.2.3 Fragmentation

Unfortunately, in the development of parcel based systems in the past, the parcel has been considered a unit of record, not a unit of area. The difference between these two types of unit is negligible until there is a conflict between the continuity components of area and character. For example, an authority may designate the two distinct areas of figure 2-1 to a single record because they have the same characteristic. This conflict results in the fragmentation of the unit of record. Consequently the word parcel, which is commonly used in the study of Land Information Systems, has two interpretations.

2.3 Types of Land Parcels

Parcels types fall into two broad categories, these are cultural and natural parcels. The former are used to represent man's activities on the surface of the earth, hence this category includes states, counties, municipalities and legal parcels. Natural parcels are used to classify the earth in terms of natural features such as soil, vegetation and geology.

2.3.1 Cultural Parcels

2.3.1.1 The Legal Parcel

The legal land parcel is the most widely used unit for the collection and recording of data on land. As many as 100 to 300 separate items of information may be collected and recorded against legal land parcels [Zwart 1986]. The legal land parcel is popular because it is the smallest parcel of land that is legally recognised.

Definitions of the legal parcel tend to be confusing and requires some clarification. From the legal point of view, the parcel represents a unit of record [Simpson 1976]. Hence a legal parcel may represent a unit within a deeds register or a title register, these being the most common means of recording legal interests in land in countries based on English Land Law.

A Registry of deeds records conveyances, the creation and transfer of interests in areas of land. A conveyance will contain a description of one continuous area of land or, as in many cases, may contain several of these descriptions. These fragments within the record may be numerous and widely dispersed [McLaughlin 1975]. The fragmentation of legal parcels has led to the need to further refine its definition. This is particularly true in the United States of America where deeds registers are in common use and attempts are being made to develop land data banks based on the legal parcel.

The most common definition of a legal parcel when used as a base unit of a land data system is the one formulated by Professor Robert N. Cook:

> "A parcel is a contiguous area of land described in a single description in a deed or as one of a number of lots on a plat; separately owned, either publicly or privately; and capable of being separately conveyed. For ease of indexing data, a segment of a street, highway, railroad right of way, pipeline, or other utility easement may be treated as though it were a parcel."
>
> [cited from Moyer & Fisher]

This is the definition adopted by the National Research Council [1980] as a base unit for a multipurpose cadastre.

In this definition the requirement for areal continuity is clearly expressed to the extent that the authorities in the USA have allowed the legal unit of record, a deed, to consist of one or more parcels. However the characteristic of ownership which defines the legal parcel deserves further comment.

The legal parcel represents an area of land under the one ownership. Of course a number of adjoining areas may be owned by the one entity under separate titles. However, each of these titles of the combined area represents different units of the legal record and therefore may be conveyed to another party. The importance of maintaining the individuality of these separate legal parcels was discussed at the Conference on Compatible Land Identifiers - the Problems, Prospects and Payoffs (CLIPP). A copy of the comments made by Professor Cook on this subject, taken from Moyer and Fisher [1973], is enclosed in appendix C.

This situation is different to the previous problem of discontinuity in area. A deed which is represented by two or more descriptions, indicates a fragmentation of the unit of record. Each fragment represents a separate parcel. However, where a number of units of record come under the one ownership, then each of these units is to be maintained as separate parcels. Consequently the legal parcel, as defined by Cook, represents a continuous area of land that is capable of having its ownership transferred and not an area of land continuous in ownership.

2.3.1.2 Fragmentation within Title Registers

Fragmentation of the unit of record is common in General Law jurisdictions such as those found in the USA where Cook's definition was developed. However, they also occur under the Torrens system. Griffith [1974] claims that around four percent of all titles in New South Wales are subject to this fragmentation. The individual transfer of these fragments of a registered title is not straightforward and hence they cannot be construed as being capable of separate conveyance. An example of a legal unit of record which consists of two disjoint area is shown in figure 2-2. In such a situation a contradiction arises when the USA definition is applied to these registered titles as they may not be continuous in either area or capable of separate conveyance.

The reasons for the fragmentation of registered titles are numerous. Separate titles have been combined into one unit of record for taxation purposes, even though it is still possible to separately transfer each original portion. In other situations subdivisions have caused the balance of a title to be fragmented.

Areal discontinuities arise most frequently when the land subject to the title is severed by a road or a similar way of passage. These ways of passage, constructed or not, may be reserved roads, public roads or tram ways. They are most often owned by the crown and are parcels in their own right. Legal parcels severed by these road parcels are fragments of the unit of record but are not capable of separate conveyance. Figure 2-3 shows a typical example of a legal unit of record which consists of three disjoint areas separated by a road.

Despite these apparent discontinuities, such titles have still been treated as one parcel. That is, parcels have been treated as units of record not units of area. In Tasmania the Mapping Division of the Department of Lands, Parks and Wildlife assign Unique Parcel Identifiers (UPI) to each parcel of land shown on the 1:25000 and 1:5000 series maps. Where a title is severed by a formed road, each resulting fragment is assigned the same UPI. The Land Registration and Information Service (LRIS) in Canada has adopted a similar approach:

> "Land under one ownership which is divided by a road, railway, stream, etc., is assigned one PID [Property Identifier]."
>
> [Palmer 1984]

R.P. 612

2487 16

ANNEXURE TO CERTIFICATE OF TITLE VOL. FOL.

Recorder of Titles

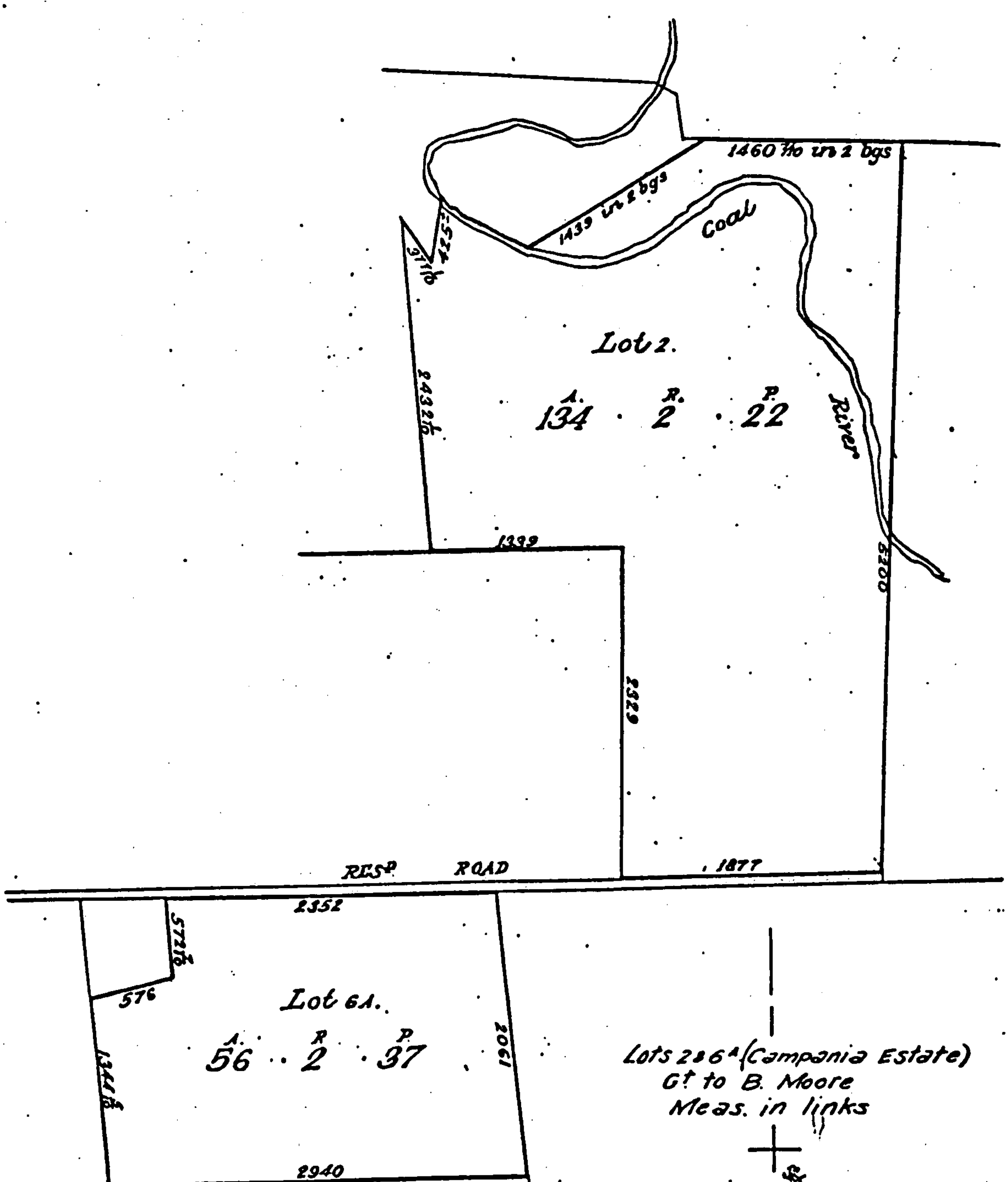

Figure 2-2.

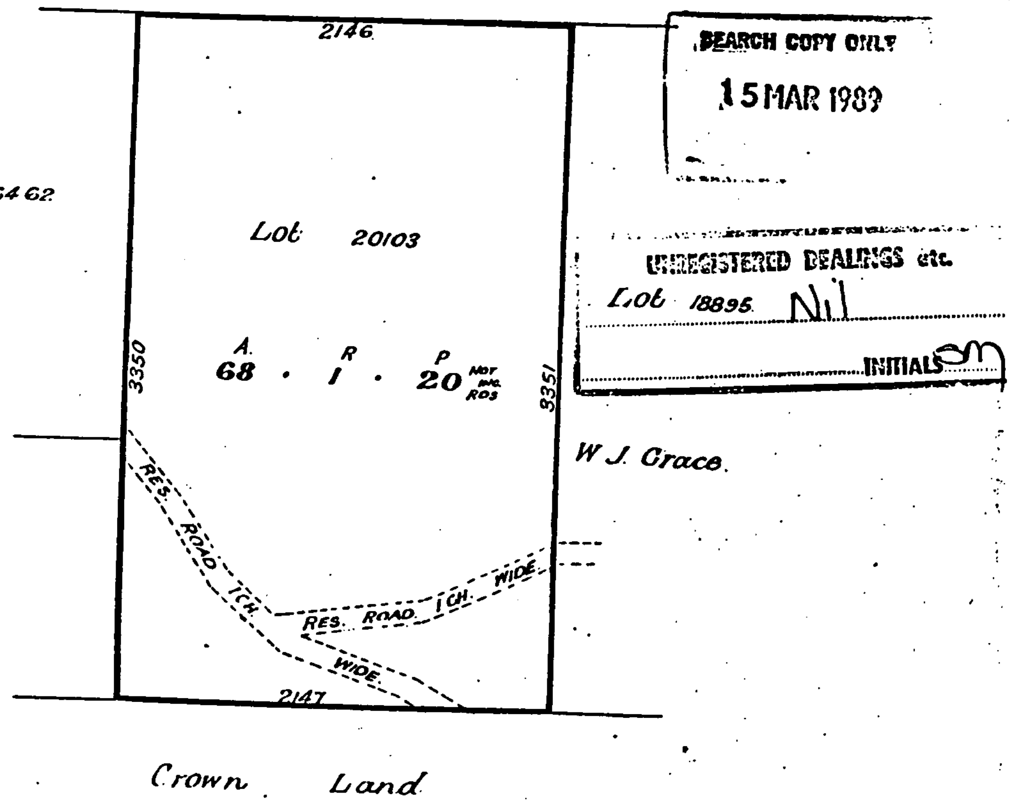

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Figure 2-3.

2.3.1.3 The Cadastral Parcel

The Department of Lands of South Australia, in developing their Land Ownership and Tenure System (LOTS), have recognised the conflict caused by fragmentation of the legal parcel in the context of Torrens titles and have therefore formulated the following definition:

> "The smallest registered unit of land, continuous in both area and ownership, and capable of being separately conveyed. If the requirements for continuity and separate conveyancing conflict, continuity shall prevail."

Providing a name for this unit creates a dilemma. It is clearly a true parcel (unit of area) as it is a distinct and continuous portion of land surrounded by other parcels. However, to call it a legal parcel obviously leads to great confusion. In South Australia it is called a basic recording unit, but this is also misleading for two reasons. Firstly it is ambiguous, as natural systems may also have a basic recording unit and secondly, it need not be the most basic unit. As will be seen later, smaller subdivisions of this parcel are often required. Bullock [1984] has referred to it as an ownership unit, however this may lead to as much confusion as the adjective legal.

The best solution is provided by McLaughlin [1975] who refers to this unit as the cadastral parcel. The parcel described is a basic unit for legal and fiscal purposes which are the general functions of cadastres and the boundaries of these parcels are defined by cadastral surveys. Cadastral systems will be discussed in chapter 4.

The main difference between a cadastral parcel and a legal parcel is that a legal parcel is a unit of record and the cadastral parcel, when used in the above context, is a unit of area. The legal parcel consists of an integral number of cadastral parcels.

2.3.1.4 Roads and other Legal Parcel Anomalies.

Roads may also be considered legal parcels since they may be owned privately or publicly by a local or higher authority. They are also a distinct area of land which fits into the legal framework. However, detailed information is not generally required for roads and so they are not an integral part of title registers. Nevertheless some authorities, such as the Survey Division of the Department of Lands Parks and Wildlife in Tasmania, do record information on roads owned by the crown.

A road parcel in legal terms may not have distinct boundaries. Their sides may be well defined but they may extend continuously to meet other boundaries. In fact it would be possible to use one road parcel to define all roads for an area as they should be interconnected (although many roads without access have been created).

Roads are generally defined by cadastral surveys in sections as it is convenient to define them in terms of cadastral parcels rather than in their own right. The breaking up of roads into convenient segments is supported by Cook in the latter part of his definition in section 2.3.1.1. This again may be taken to extremes as some of the smallest cadastral parcels in existence are road widening parcels.

Areas created by rivers, lakes and crown land are other anomalous parcels that are similar to roads . These areas may also not be recorded in title registers. For practical and completeness purposes, parcels may be created in these situations.

Anomalous parcels cause some concern in systems created to record parcel information. Consider an unformed road which severs a legal parcel as in figure 2-3. The owners of the disjoint parcels may be utilising the area of land, defined as a road, for other purposes. In fact for most practical applications the legal parcel is not fragmented, since the owner is free to cross the road whenever it is desired. This is in fact the case whether the road is formed or not. However theoretically the parcel is fragmented.

Many parcel definitions which include the condition, contiguous or continuous area of land, often consist of theoretically fragmented parcels. As will be seen in the subsequent definitions, anomalous parcels have been treated differently amongst the various cultural parcels. Thus, while tenure based cultural parcels do not include the anomalous parcel, the larger administrative units, such as census districts and municipalities do incorporate anomalous parcels.

2.3.1.5 Stratums

A legal parcel, which may be considered anomalous and tends to be avoided by system developers, is the stratum or condominium. Parcels have been defined in their purest sense as an area of land on the earth's surface. Parcel boundaries may be considered as vertical surfaces extending from the centre of the earth through the boundary location at the surface up into the universe. At least, this has been the extent of the legal parcel in the past. Hence legal parcels can be adequately defined two dimensionally. However stratums add a third dimension as various levels within the legal parcel may be owned separately. A block of apartments is a typical example. This has always been the case for natural parcels such as geology and soil whose characteristics vary with depth.

Representing the third dimension in both manual and automatic systems is difficult. True three dimensional Spatial Information Systems have only recently become commercially available. Currently the third dimension has to be modelled on two dimensional systems. This may be done by treating the third dimension as an attribute. Therefore a parcel on the earth's surface may have many attributes. A legal parcel subject to a stratum subdivision may have many owners, one for each level. A soil parcel may have many soil types. This creates a typical one to many situation which is further discussed in chapter 6.

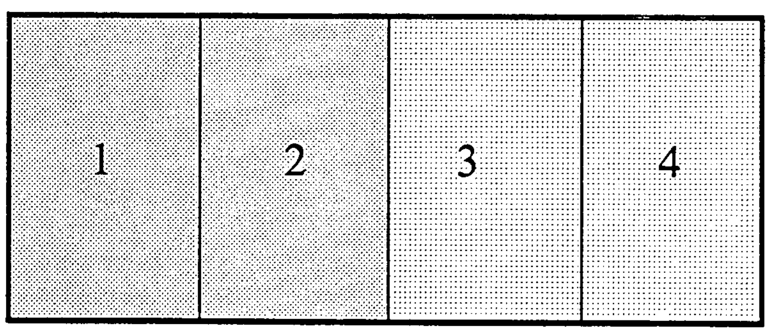
2.3.1.6 Fiscal Parcel

Fiscal parcels are often based on rate payers. A Taxation office is more interested in the entity that is paying tax for an area of land rather than the owner of the land as the owner may lease the parcel to another entity, who in turn pays the tax on the land. Hence fiscal parcels are generally defined as an area of land upon which a particular entity is paying tax.

The Fiscal parcel generally consists of one legal parcel but in some cases consists of a number of legal parcels (figure 2-4). Valuers generally have no interest in the legal parcels which fragment the fiscal parcel. Fifteen percent of the fiscal parcels in the Valtax System in Tasmania consist of more than one legal parcel [Zwart 1986].

2.3.1.7 Agricultural(farm) Parcel

The agricultural parcel is the unit used to collect information in relation to agriculture. This unit, or farm, may be managed by a number of entities such as a group or enterprise, and may consist of a number of legal parcels. Different entities may be paying rates and taxes for various portions of the farm, hence it may also consist of one or more fiscal parcels (figure 2-4).



1, 2, 3 and 4 are all legal parcels.
1 and 2 are owned by A and comprise one fiscal parcel.
3 and 4 are owned by B and comprise another fiscal parcel.
However A and B farm legal parcels 1, 2, 3 and 4 together as one agricultural unit.

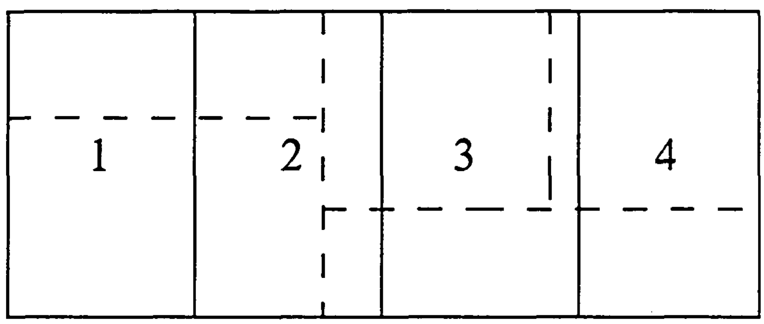
Figure 2-4.

The Department of Agriculture in Tasmania defines a farm as

> "a parcel of contiguous land which is under the common control of one or more parties, and which is of interest to the Department of Agriculture"
>
> [Fenn 1987].

This is different to the unit used by the Australian Bureau of Statistics which, according to Fenn [1987] "depends on the net agricultural income derived by the primary producer being above a certain value." Also, this later unit does not need to be continuous in area, the fragmented portions may be significantly disjointed.

Agricultural information may also be based on land use. For example, a parcel planted in peas may need to be treated separately to a parcel used for feeding livestock. Furthermore, these agricultural land use parcels may be areas within a farm and because farmers can ignore legal boundaries internal to the farm, the land use units may consist of portions of the legal and cadastral parcel (figure 2-5).



Farm in figure 2-4.
Paddock/landuse boundaries are shown as broken lines.

Figure 2-5.

2.3.1.8 Collector Districts

The Australian Bureau of Statistics collects census information based on the legal parcel. This information at this level is confidential, causing the data to be aggregated into units called collector districts. The information held at this level is available to the public.

Collector districts represent a continuous area of land designated to a particular census collector. The districts generally consist of whole legal parcels but since many collector district boundaries follow road centre lines, then they also consist of legal parcel fragments.

Collector districts incorporate anomalous parcels.

2.3.1.9 Administrative Parcels

There are many other parcels used by government departments for administrative purposes that are similar to collector districts. Examples include municipalities, wards, shires, telephone exchange districts, electricity distribution zones, counties and parishes. The majority of these boundaries will follow cadastral boundaries and so these units will consist of an integral number of cadastral parcels. However, some boundaries may be arbitrarily located through a cadastral parcel and so administrative parcels may also consist of fragments of the cadastral parcel.

Administrative parcels generally incorporate anomalous parcels.

2.3.1.10 Grant Parcels

Grant parcels are areas of land that have been alienated from the crown or state. Governments record grant information to monitor unalienated crown land. A grant register represents an historical record of legal parcels as grants are the original legal parcel.

Grants are also the source of many of the parcel anomalies caused by roads. Generally surround surveys are performed initially and then surveys of the road parcels within the grant are performed. Hence grant parcels may consist of a number of disjoint parcels. The title illustrated in figure 2-3 has not been modified since the original grant.

Grant parcels may not consist of an integral number of legal parcels since two cadastral parcels may be subdivided from separate grants and amalgamated into one legal parcel. Nevertheless grant parcels may consist of an integral number of cadastral parcels. Therefore privately owned legal parcels and some publicly owned land may be contained by one or more grants.

2.3.1.11 Summary

Most cultural units may be expressed in terms of the legal parcel. These units are specifically defined as a function of the legal parcel generally consist of an integral number of these units. However many higher order units such as administrative and detailed land use parcels may bisect some legal parcels. Nevertheless there is a high statistical dependency between the boundaries of most cultural parcels.

Unfortunately the legal parcel may have many associated inconsistencies including fragmentation of the unit of record and gaps caused by legal anomalies. As a result of the interdependence between boundaries these inconsistencies extend into the other cultural units. This is particularly true for units defined specifically in terms of the legal parcels and less evident in the higher level administrative units.

2.3.2 Natural Parcels

The types of natural parcels vary from parcels representing micro climates to parcels of land or sea. They may be non conterminous, such as parcels representing rainfall or geology, yet their relationships may be complex such as between soil, geology and vegetation parcels.

Natural parcels are also subjective. New units arise with the need to study another naturally occurring phenomenon. Boundaries are often difficult to establish because professional opinions may differ. For example, geological boundaries may vary according to the geologist. In many cases it is difficult to fix distinct boundaries such as in the case of the habitat of native fauna as their spatial distribution tends to be continuous rather than discrete.

Despite these difficulties several attempts have been made to standardise these units through taxonomy and techniques like land systems mapping such as those used by the Agricultural Department of Tasmania. These 1:100000 scale maps divided the land into parcels where:

> "A land system is defined as an area, or group of areas, which have a similar geology, topography, soils, vegetation, altitude and annual rainfall."
>
> [Davies 1987]

Techniques for determining land systems boundaries and collecting and storing the textual information vary. However, the principles used are similar and land systems mapping has become a common method of performing resource classification surveys.

2.4 Parcel Attributes

The textual data associated with the parcels is referred to as the parcel's attributes comprising single items for typical natural parcels or up to 300 for legal parcels. A parcel must have at least one attribute in order to distinguish it from other parcels of a particular theme.

It is not the aim of this thesis to derive a model for the representation of parcel attributes in particular as this has already been done in other studies(e.g. [Love 1983]). However in creating a model for the representation of the spatial components of parcels and parcel relationships, there are certain aspects of parcel attributes that need to be considered.

Parcel attributes may be quantitative or qualitative. Qualitative attributes are descriptive and apply to any portion of a parcel. For example, the name of a farmer applies equally to any portion of the farm parcel.

In contrast, quantitative attributes provide some numerical value which applies to the parcel as a whole. For example, a fiscal parcel may be assigned a particular valuation which cannot be correctly applied to a portion of that parcel. The disaggregation of these quantitative attributes may require the judgement of a professional such as a Valuer in the above example. Similar situations arise when an attempt is made to assign the stock size of a farm, or populations of municipalities to sub parcels.

2.5 Parcel Identifiers

2.5.1 Definition

> "A [legal] parcel identifier is a finite, punctuated sequence of numeric and/or alphabetic symbols that is used as shorthand for referring to a particular parcel in lieu of its full legal description."
>
> [Moyer & Fisher 1973]

This definition need not be restricted to legal parcels, other cultural and natural parcels may have similar identifiers.

2.5.2 Ideal Qualities.

Ideal qualities of parcel identifiers have been determined in other studies [Moyer & Fisher 1973], [Ziemann 1976], [Bullock 1984] and include uniqueness, simplicity, flexibility, economy, accessibility and availability. Of these criteria, uniqueness is perhaps the most important. That is, there should be a monogamous relationship between all parcels and their identifiers.

2.5.3 Formats

Three forms of identifiers are generally recognised. These are name-related, abstract, and location identifiers [National Research Council 1982]. Name related identifiers incorporate a name or abbreviation which is descriptive of the parcel being identified. The abstract identifier is often a random alphanumeric code and location identifiers include a key which enables the user to determine a geographical position for the parcel.

Location Identifiers may be further classified into three broad groups: coordinate, hierarchical and hybrid identifiers. The coordinate identifier relates some point on the parcel, usually the centroid, to a coordinate system. The hierarchical identifier is based on codes for a graded series of units, while the hybrid identifier is a combination of hierarchical and coordinate coding.

2.5.4 Compatible Identifiers

Much of the research on land units in past years has focussed on parcel identifiers as this was the most convenient means of representing a parcel as a unit in purely textual systems. The early studies (CLIPPP - [Moyer and Fisher 1973] and Zieman[1976]), isolated the large array of parcels and parcel identifiers in common use and concluded that one parcel and one identifier should be adopted by all agencies collecting information on land. For sound reasons the legal parcel, as defined by Cook, was adopted as the basic parcel and the CLIPPP conference delegates formulated a suitable hybrid identifier which was to be used universally. Other suitable identifiers have also been developed or adapted [Bullock 1984], [Ziemann 1976].

This over-simplified solution to the complex problem of disparate land unit would seem ideal, particularly in manual systems which have difficulty in handling large arrays of identifiers. However, it fails to recognise the need for the wide range of parcel definitions and corresponding identifiers and offers little compromise as the following statement suggests

> "Each parcel in the cadastre must have a unique common identifier to be used by all authorities dealing with parcel based information. This is the key that connects the map and registers in the system. Ideally, the use of this identifier by all authorities would be enforceable at law."
>
> [Williamson 1986]

This approach is impractical as it forces authorities to reject the units upon which their activities are based and adopt a unit which is inappropriate for the storage, collection, maintenance and dissemination of data that is relevant to that organisation.

The collection and storage problems encountered when attempting to disaggregate quantitative data have already been introduced. Furthermore, data storage and maintenance becomes inefficient because the records for the relevant parcels are duplicated for each legal parcel which they contain. In addition, operations and analyses in terms of the relevant units are not possible at the legal parcel level. For example, it should be possible to display graphically all farms (not legal parcels) over a certain size, or select one particular farm and show its location and extent in one simple operation.

Regardless of these technical deficiencies the institutional reforms required to introduce a new parcel definition and identifier appear to be the biggest threat to the simplistic compatible identifier approach. Existing systems are based on the unit of interest to an organisation, that is,

> "The present systems of acquiring, storing and displaying data have been designed to fit the organisational characteristics and requirements of the institutions which need these data."
>
> [Zwart 1981]

To adopt a new unit implies that these procedures may need to be changed.

Many of these problems were examined by Fenn [1987] in an attempt to adopt an existing unit when developing an agricultural information system. The existing legal and fiscal units were discarded as they were an inappropriate basis for agricultural data. The development of a new unit, as defined in section 2.3.1.7 was considered more appropriate to the needs of the Tasmanian Department of Agricultural. Consequently a corresponding identifier was developed which represented the spatial component of the parcel. To choose an existing identifier which related to a different unit would have been misleading.

This recognisable need for different units of record, and consequently different identifiers, makes it difficult for many organisations to adopt a primary identifier. Many organisations are "unwilling to accept or join in a system developed for the 'different' situation in another department." [Zwart 1981].

2.5.5 Central Cross Reference Indexes.

Fortunately, others such as the National Research Council [1983] and Bullock [1984] have come to realise the institutional difficulties of forcing a common identifier.

> "The standard identifier approach represents an attempt to achieve data integration by institutional reforms which are the most difficult reforms to implement successfully."
>
> [Bullock 1984]

Moreover, automated systems are able to handle an array of identifiers linked to a basic parcel of the system and consequently there is no need to force traumatic changes upon institutions.

> "...experience suggests that the choice of a parcel index for the multipurpose cadastre in its initial stages will be dictated by local needs and resources (particularly the need for maximum accessibility and for effective administration). Nevertheless, recent developments in the software of data-base- management systems and the increasing use of multiple indices through cross-index tables permit the use of a family of parcel identifiers."
>
> [National Research Council 1983]

2.6 Conclusion

This chapter has sought to describe some of the various land parcels that are in use and introduce some of the problems encountered when representing parcels and their relationships.

The legal parcel is the most widely used unit for the collection, maintenance and storage of land related data because it is legally recognised and its boundaries define the limit of activity of a particular entity. In some cases this entity may own or use adjoining legal parcels in which case the limits of that entity are increased by integral numbers of legal parcels. Some organisations concern themselves with the particular activities of these entities over their domain of legal parcels. Consequently they prefer to deal with that domain as a single unit and as a result, new land parcels consisting of one or more legal parcels have been defined which reflect the practice of the particular organisation. Other authorities have also grouped legal parcels into larger units for administrative purposes. As a result the legal unit has become the base for these other valid cultural units.

In contrast, natural parcels are not defined by man and cannot be correlated in such simplistic hierarchical terms. Their interpretation is subjective and their interdependence is complex producing a variety of relationships in differing situations. New units are developed for particular applications, however some standardisation has been achieved with the introduction of land systems mapping. The natural units interpreted by man are independent of the cultural units defined by man.

Unfortunately many inconsistencies have resulted during the long development of many of the cultural units. The sporadic nature of cadastral surveying and the lack of cadastral maps have resulted in legal parcel anomalies which result from gaps in the cadastral pattern such as roads, rivers and unallocated land reserved for the crown. Further, legal parcels are considered a unit of record rather than a unit of area, hence they may consist of a number of disjoint areas of land which tend to conflict with the general definition of a parcel. Consequently a legal entity can consist of a number of spatial entities. These legal parcel inconsistencies are particularly important as they carry through to the other cultural units.

There also tend to be inconsistencies between the administrative units and legal parcels as many of these larger units do not consist of an integral number of legal parcels. However the occurrences of administrative boundaries dividing legal parcels are small with census boundaries being the most frequent.

Some land parcels, such as the farm, tend to be single purpose to the extent that they are only used by the originating authorities. Others, such as many natural units, have marginal use beyond the purposes for which they were originally created. Nevertheless, they are all valid units that will continue to exist contrary to the efforts of those who believe that all land data should be collected, stored and maintained in terms of the legal parcel. These efforts fail to recognise the individual needs of the various organisations and the institutional reforms that are required. Furthermore, there appears to be complete ignorance as to the technical difficulties, in particular, the problems of disaggregating quantitative attributes of higher order parcels down to the legal parcels.

A number of inconsistencies and policies which have been introduced in this chapter need to be resolved in order to represent a variety of land parcels within a land information system. These include the fragmentation of the legal unit of record to the extent that in many cases it no longer corresponds to a unit of area; legal anomalies such as roads and unallocated areas of land which are not adequately recorded within the legal register; the disparity among parcel definitions, particularly those units which do not consist of an integral of legal parcels and; the representation of data such as quantitative attributes of higher level units which are difficult to disaggregate at the legal level.

3. EXISTING MODELS FOR REPRESENTING PARCELS

3.1 Introduction

The aim of this chapter is to introduce some existing models for representing parcels and to highlight some of their deficiencies.

These models for representing parcel data may incorporate the spatial, identifier and textual components, as introduced in chapter 2, in any combination. Models comprising only the textual and identifier components are the most common as they are easiest to represent in both manual and automatic systems.

The existing models can be grouped into two broad categories namely, single and multiple purpose. The earliest models were created for a single purpose and consequently comprise only one parcel definition. Many of these single purpose models are still in use in the form of legal registers and taxation systems. Indeed, they are still being created as evidenced by the recent introduction of the Property Identification System, Tasmania [Fenn 1987]. However the need for land data integration has highlighted the requirement for multipurpose models which allow the representation of a variety of parcel types and therefore multiple parcel data sets.

3.2 Single Purpose Models

3.2.1 Development

Man's attempts to divide the land into parcels for the recording of information date back to ancient times. Many of the earlier systems consisted only of the textual component because as a rule, reliable parcel maps were not created, although maps on clay tablets were discovered with fiscal records amongst the ruins of Sumerian villages.

These ancient and medieval systems were based on cultural parcels. If nature based data was collected, it was done on a cultural parcel basis. A note was made against each parcel as to the predominant soil or vegetation type, or whether it was cleared and cultivated. This was sufficient at that time, despite the fact that the fiscal parcel may have consisted of any number of each natural characteristic. Clearly taxation was a more important issue then, far more than natural features, hence natural parcels would not have been recorded spatially even if it were possible.

3.2.2 Cadastres

Early legal and fiscal parcel systems developed a name, cadastre, the origins of which are subject to some contention.

> "The main characteristics of a cadastre are:
> (i) it is a systematic operation;
> (ii) it is the classification and valuation of the different categories of land;
> (iii) it is the conjoint delimitation and mapping of parcels (the cadastral survey) together with the investigation into, and record of ownership and other real rights into and over such parcels and;
> (iv) it is kept continuously up to date."
>
> [Dowson and Sheppard 1952]

Hence the cadastre, as defined above, was one of the first parcel systems to make mandatory the incorporation of a parcel map.

The first modern cadastres were developed during Napoleonic times when survey techniques had improved and it had become possible to prepare large scale maps.

The preparation of the French cadastre required that a region be divided into communes which in turn were divided into sections and then fiscal parcels. Fiscal parcels were the base unit of this model and were plotted at scales of 1:2500. They were each assigned hierarchical identifiers consisting of the commune, section and lot number and the information which was collected for these units were compiled into matrices. All land data was collected as a function of the fiscal parcel including the natural data.

The French cadastre is still in current use, however it is maintained for fiscal purposes only. Legal interests in land for countries such as France, as well as England and the U.S.A. are recorded in deeds registries. Other countries such as Australia, New Zealand and Canada utilise title registers.

3.2.3 Legal Parcel Registers

A deed is a record of transfer, of one or more parcels of land, between a vendor and a purchaser. The parcel is represented by a textual description and sometimes a sketch diagram. These metes and bounds descriptions include the length and general direction of boundaries (metes) and reference to adjoining owners (bounds). They are at best vague and contradictory which makes it difficult to relate legal parcels with each other.

A major fault is that a new deed is produced each time a legal parcel is transferred with the result that there may be a number of deeds referring to the one parcel of land. Hence deed systems are people based. When an attribute, such as owners name, changes in a true parcel based system, the parcel record is updated. New parcel records should only be created when a new parcel is created by subdivision or amalgamation.

The Torrens System attempted to overcome these limitations by treating ownership as an attribute of the parcel. However most Torrens Systems are not based on systematic parcel mapping. Instead each file, which represents one legal parcel, includes a plan of the parcel in question. The parcel is defined by sporadic surveys based on adjoining surveys rather than a survey control network making it difficult to compile parcel maps.

Both Torrens and Deed registers are essentially textual models with a poor spatial reference. Consequently many of the inconsistencies introduced in chapter 2 plague these models including fragmentation and gaps resulting from anomalous parcels.

3.2.4 Other Single Purpose Models

Only single purpose models based on the legal and fiscal parcel have been introduced, however there are a number of others in current use, such as the grants registers and census data bases. These may be based on the parcel types defined in chapter 2 or other similar land units. The textual and identifier components tend to dominate these models, however some do incorporate maps in various states of currency and repair.

Single purpose models based on natural parcels are prolific amongst the earth sciences because of the specialised and subjective characteristics of these units. They consist of thematic parcel maps (choropleth maps) with attributes indicated inside the plotted parcels, and have resulted with the advent of remote sensing and photogrammetry which made the compilation of thematic maps a viable proposition. The mapping of natural parcels became a common occurrence because earth scientists from various fields could compile their own parcel boundaries. There are now many soil, vegetation and geology maps available, the CSIRO soil maps being one example.

3.2.5 Problems with Single Purpose Models

The main problem with single purpose models is that they do not facilitate integration with other data sets because of the disparity in units and identifiers. In most cases there are no cross reference indexes which enable parcels in one model to be linked to parcels in another. This is because the systems have been developed in isolation and furthermore, it is difficult to cross reference data that is based on disparate data types.

The problem is compounded by the absence of parcel maps which makes it difficult to compare the location and extent of parcels in the various models. For example, the spatial component of a torrens parcel consists only of a plan showing the extent of the legal parcel. The actual location of the parcel may be difficult to determine. Hence it is difficult to systematically correlate legal data with the data available from a soil map due to the unavailability of a reliable legal parcel map at a suitable scale.

Even data amongst single purpose cultural models based on similar parcels is difficult to correlate. The subtle differences in the parcel definitions have resulted in different identifier systems. Furthermore, cross reference systems have not been developed or maintained, and so the data sets are largely unrelated. However, because the units are similar, there are various methods for performing the links including address matching.

In Europe the usefulness of parcel maps in correlating different themes was recognised.

> "Cadastre (as a fiscal record without maps) and deed registration remained distinct and unconnected until the development of survey techniques and the production of accurate large-scale maps made land survey a satisfactory method of indicating and identifying land parcels, whether for the purpose of tax or of title."
>
> [Simpson 1976]

Consequently countries such as Germany were amongst the first to have true cadastres which were based on a fiscal/legal parcel, this at least allowed the combination of fiscal and legal data. Unfortunately Cadastral Systems as such have not developed in Australia [Williamson 1983], as a result legal, fiscal, agricultural and census models have developed independently.

Therefore the development of these unrelated single purpose models has resulted in the duplication of land data collection, storage and maintenance activities. Ownership and address is the most commonly duplicated attribute. Natural data such as soils and vegetation have been collected for both fiscal, farm and legal parcel based systems.

3.2.6 The Need for Integration

The need to integrate these disjoint systems is real. In order to manage land more effectively, a wide range of information is required, portions of which are held in any number of disjoint systems. Consequently it takes time and effort to collect data. In most cases these are not expended.

> "In practice, many decisions are made on the basis of inadequate information, in a disjointed and incremental way, and for reasons that are often subjective."
>
> [Dale & McLaughlin 1988]

Problems not only arise at the management level - every process of land administration is hindered. An individual interested in purchasing a piece of land, for instance, needs to visit a wide variety of organisations to gather basic information.

> "Foremost among the problems inherent in the current arrangement of these systems is that required information is generally not accessible in any one location."
>
> [National Research Council 1980]

Numerous studies have been performed to examine these integration problems and possible solutions [Moyer & Fisher 1973], [National Research Council 1980]. The problems can be summarised as accessibility, duplication, aggregation, confidentiality, and institutional structure. It is enough to realise at this point that effective land administration and management can only be achieved if the various systems can be integrated. Basically this requires the determination of parcel relationships.

3.3 Multiple Purpose Models

3.3.1 Multipurpose Cadastres

The need to integrate independent systems has spawned the development of multipurpose cadastres in the USA and Canada. The multipurpose cadastre, based mainly on cultural parcels, is an extension of the original cadastres developed for purely fiscal and legal purposes. A multipurpose cadastre consists of:

> "1. A reference frame, consisting of a geodetic network;
> 2. A series of current, accurate large scale maps;
> 3. A cadastral overlay delineating all cadastral parcels;
> 4. A unique identifying number assigned to each parcel and;
> 5. A series of registers, or land data files, each including a parcel index for purposes of information retrieval and linking with information in other data files."
>
> [National Research Council 1980]

Separate systems may be linked into the multipurpose cadastre model if their parcel identifiers can be related to the legal parcel which is the adopted base unit. The cadastral parcel layer, or cadastral overlay as it is called here, is invaluable for assisting in this linkage. It also assists in the graphical functions of the multipurpose cadastre, such as determining parcel identifiers for parcels whose location is the only known fact.

3.3.2 Overlapping Parcels

The multipurpose cadastre model works reasonably well when the parcel definitions of the integrated systems are multiples of the legal or cadastral parcel. However, there are a number of cultural parcels which in some cases do not satisfy this requirement because they bisect legal parcels.

Administrative boundaries provide a typical example which is illustrated in figure 3-1. Legal parcels L1, L3, L5, and L7 can be linked to municipality M1. Likewise M2 can be linked with L2, L4 and L8. However, legal parcel L6 overlaps municipalities M1 and M2. Should legal parcel L6 be linked to M2 or M1? Furthermore, how is a municipal boundary, such as the segment passing through L6, represented in the legal parcel layer which only includes legal parcel boundaries?

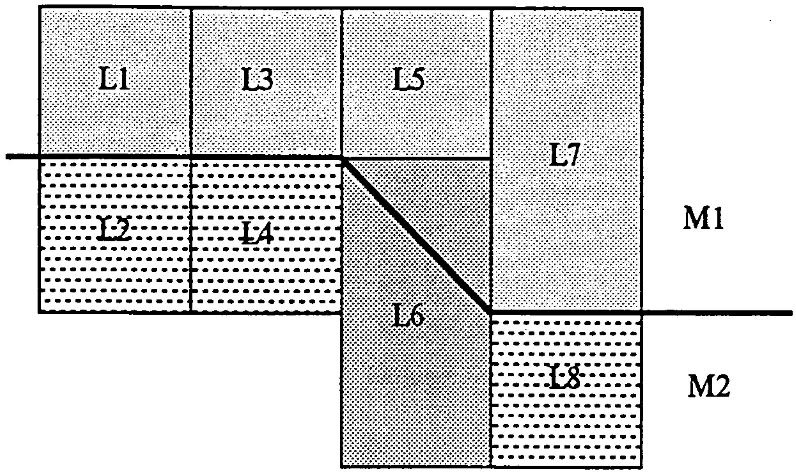


Figure 3-1.

The recommendation of the developers of the Land Registration Information System (LRIS) in Canada,is that administrative regions should consist of integral numbers of the basic unit [Palmer 1984]. Hence in the above example, the municipal boundary may be adjusted as shown in figure 3-2. Similarly, collector district units (section 2.3.1.8) may be modified to follow road boundaries instead of centre lines.

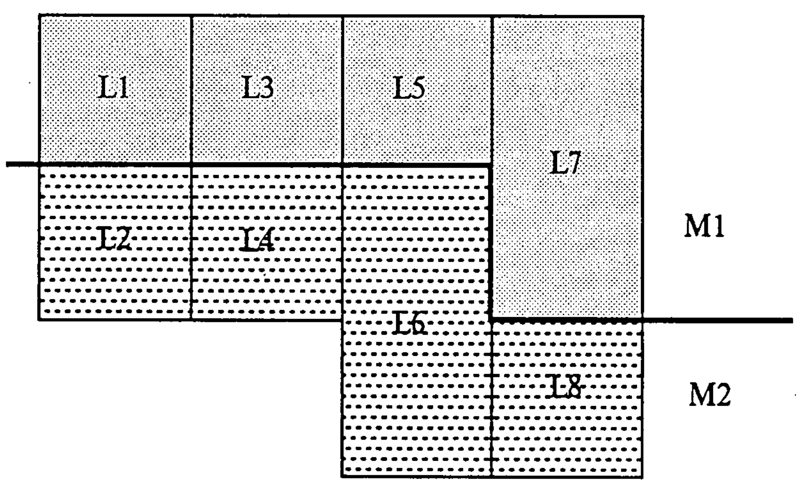


Figure 3-2

While in some cases it may be useful, if not practical, to adjust some boundaries to correspond with legal boundaries, in other cases it may not. Such a situation was disclosed in a pilot study investigating the creation of a Tasmanian Digital Cadastral Data Base (DCDB). Consider original adjoining grants G1 and G2 in figure 3-3, which may be subdivided into smaller parcels and amalgamated into one legal parcel. Clearly the amalgamated legal parcel L1 is a single parcel in its own right, but it overlaps the original grant parcels. Does legal parcel L1 receive the grant attributes of G1 or G2? The solution to move the grant boundary to match the legal parcel boundary is not viable in this case.

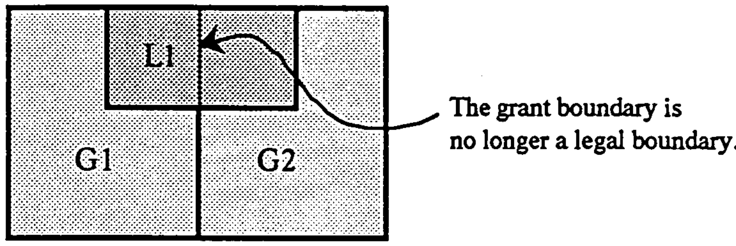


Figure 3-3.

The problem becomes more profound when cultural parcels are related with natural parcels. It is simply not possible to make soil parcels match legal parcels.

The solution is to allow the incorporation of units within the model which are smaller than the legal parcel. Cultural parcel boundaries which bisect the legal parcel represent a change in attribute from the cultural point of view, hence the legal parcel must be divided into sub parcels so that these attributes can be represented in the model to reflect the true situation. This subdivision of parcels into sub units when necessary form the basis of the overlay technique which is discussed in detail in subsequent chapters. Unfortunately the thought of dividing the legal parcel disturbs many who wish to hold to the basic legal parcel principle.

However some system developers have accepted that in these situations, the subdivision of the legal parcel is a viable alternative.

> "Andrew J. Hinshaw: There are, I guess, 15000 parcels of land [in Orange County, California] that would have one legal description, tract and lot, in the recorder's office, but we would assign two different parcel [fiscal] numbers to it, assessor's [fiscal] parcel numbers, because it would be in more than one taxing jurisdiction... However, it does not pose a problem to us because our basic reference is the lot and the block, the tract on file in the recorder's office, and we can trace back our parcels and each one of the tax bills gets subsequently issued back to that basic ownership."
>
> [Moyer & Fisher 1973]

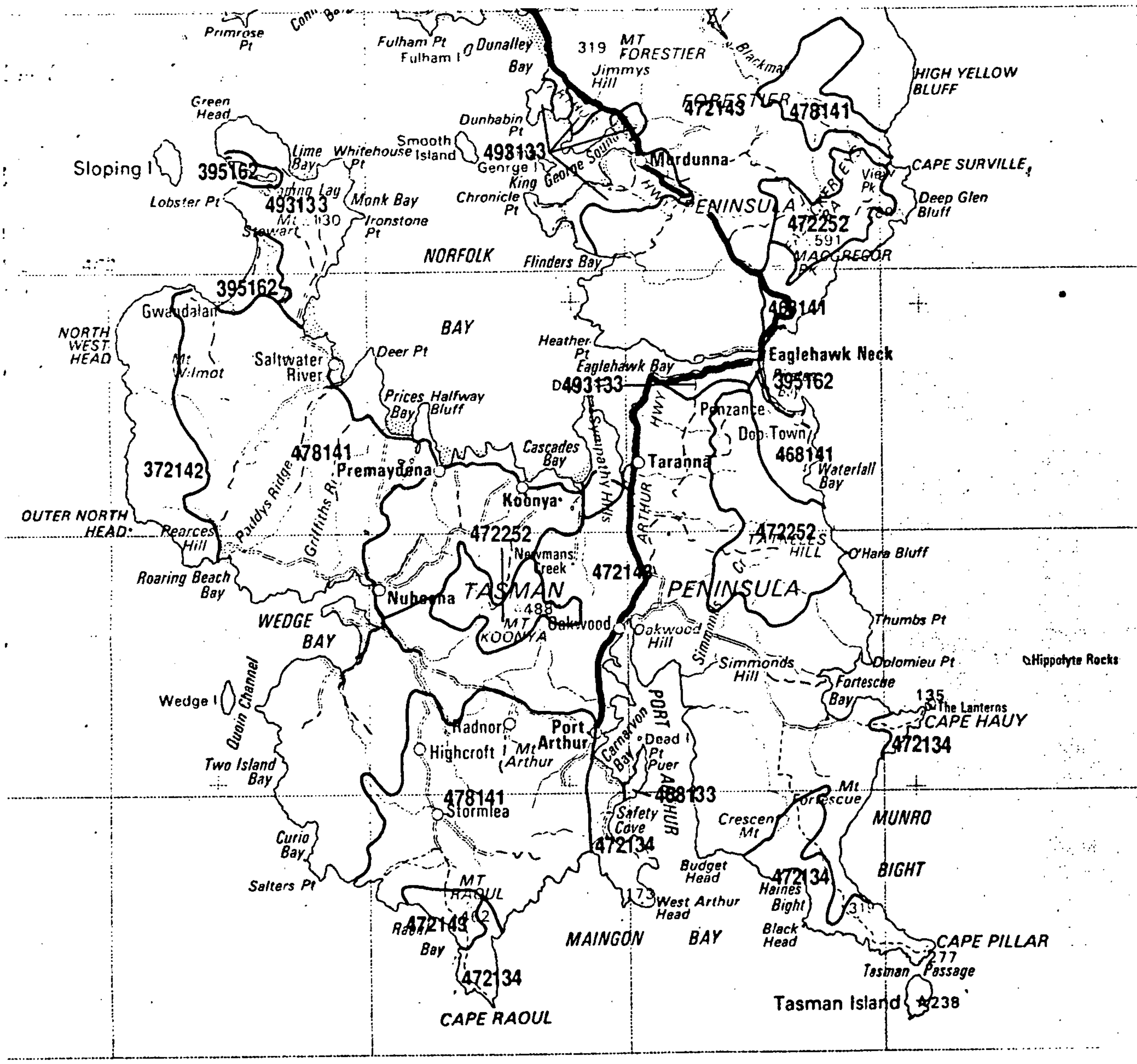
The developers of the Unique Parcel Identifier (UPI) system in Tasmania have also based their UPI parcel on subdivisions of the legal parcel. However, they were forced into this decision in some situations by the form of the UPI identifier which is partly hierarchical in that it has an embedded municipal code. Hence the cadastral mappers were confronted with a dilemma when legal parcels, such as many of the crown land parcels, overlapped a municipality. In this instance, the only solution was to subdivide the legal parcels into UPI parcels, so that each could be assigned an appropriate UPI value.

3.3.3 The Land Systems Model

Overlapping parcels are common within natural models for a variety of reasons which were introduced in chapter 2. Consequently the integration of a number of different natural models required the creation of a new unit which is a sub parcel of the parent parcels represented in the model as discussed above. This unit has a particular combination of natural attributes, a typical definition was provided in section 2.3.2.

Davies [1987] based his land system boundaries for south east Tasmania on geomorphic boundaries which were derived from stereographic aerial photography and geological maps. Each land system parcel was assigned an identifier which consisted of codes for rainfall (derived from rainfall maps), topography, altitude, geological period and geological age. The last code provided a mechanism for ensuring that each identifier was unique. A portion of the land systems map for southeast Tasmania is shown in figure 3-4, a land systems key is shown in Table 3-1.

The land systems maps highlight the advantages of combining different data sets, such as landform and rainfall, by overlay techniques, so that the individual data sets can be compared. Also maps of particular themes may be produced by aggregating similar parcels because original parent parcels can be easily recognised. For example, adjoining parcels 395162 and 493133 have the same geological period and may be recognised as one parcel for that particular attribute. Thus aggregation is technically easier to perform than overlay. Hence it is much more convenient to classify the land according to these smaller parcels.



A portion of the Land Systems map for South East Tasmania.
Produced by the Agricultural Department of Tasmania.

Figure 3-4.

LAND SYSTEMS SURVEY OF TASMANIA
REGION 6 : SOUTH, EAST & MIDLANDS

Mapped by J.B.Davies 1987, Department of Agriculture Tasmania.

LEGEND

Each of the land systems mapped on this sheet is identified by a numerical code containing six digits.

First digit: APPROXIMATE ANNUAL RAINFALL

375 - 500 mm (15-20")	1
500 - 625 mm (20 - 25")	2
625 - 750 mm (25 - 30")	3
750 - 1000 mm (30 - 40")	4
1000 - 1250 mm (40 - 50")	5
1250 - 1500 mm (50 - 60")	6
1500 - 2000 mm (60 - 80")	7

Second digit: GEOLOGICAL PERIOD

Precambrian	1
Cambrian	2
Ordovician	3
Silurian)	
Devonian)	4
Lower Devonian)	
Tremadocian) Eastern Tasmania	5
Cambrian (Mathinna Beds))	
Carboniferous)	6
Permian)	
Triassic)	7
Jurassic)	
Tertiary	8
Quaternary	9

Third digit: ROCK TYPE (OR APPARENT PARENT MATERIAL OF QUATERNARY DEPOSITS)

Acid igneous (e.g. granite)	1
Basic igneous (e.g. dolerite, basalt)	2
Sedimentary arenaceous (e.g. sandstone)	3
Sedimentary argillaceous (e.g. mudstone)	4
Sedimentary calcareous (e.g. limestone, dolomite)	5
Sedimentary rudaceous (e.g. conglomerate)	6
Metamorphic (e.g. quartzite, schist)	7
Complexes of the above	8

Fourth digit: TYPICAL ALTITUDE OF LAND SYSTEM

0 - 300m	(0 - 1000')	1
300 - 600m	(1000 - 2000')	2
600 - 900m	(2000 - 3000')	3
900 - 1200m	(3000 - 4000')	4
1200 - 1500m	(4000 - 5000')	5

Fifth digit: CHARACTERISTIC TOPOGRAPHY

Flat plains	1
Undulating plains	2
Low hills (<100m)	3
Hills (100-300m)	4
Mountains (300m +)	5
Coastal dunes and beaches	6

Sixth digit: UNIQUE LAND SYSTEM NUMBER

Used to subjectively create seperate land systems based on soil and vegetation variation or other notable differences.

The land system key for the map of figure 3-4

Table 3-1.

3.4 Digital Representation

Map representation and map related operations have recently become commercially available on computers. General operations of analysis, storage and output of spatial as well as textual data may now be performed automatically. Choropleth maps are represented digitally as parcel layers and operations such as overlay and aggregation may be performed quickly and efficiently.

These substantial benefits have led to the the current impetus for the creation of Digital Cadastral Data Bases (DCDB). However the creation of a DCDB is a vast undertaking as there are very few cadastral maps in existence. This is particularly true in countries whose land law is based on the English system which utilises deed land and title registration. This is evidenced by the fact that there are few complete working multipurpose cadastres in existence outside of Europe.

Hence the development and digital representation of parcel maps, particularly those of cultural themes, is not clearly understood. There are technical issues such as how to best represent layers which consist of parcels with various relationships between them, yet allow their integration for the purposes of storage display and analysis. For example, Palmer [1984] recommends:

> "..that an amalgamation process be introduced whereby
> several contiguous parcels under common ownership could
> be easily and simply amalgamated to form one parcel,..."

A process such as the one described would allow a DCDB to be used as a source for other cultural parcels by allowing the combination of adjoining legal parcels into one unit with the same characteristic. Techniques similar to those used in land systems models are also required in cultural models to resolve the problems of administrative and other cultural boundaries bisecting cadastral boundaries.

3.5 Conclusion

There are a variety of models currently being used for the representation of land parcel data. Many of these have had a long history and still incorporate techniques introduced over a century ago.

Single purpose models are based on a single spatial unit with corresponding independent identifiers, these characteristics makes difficult their integration with other systems. The disparity of units and the lack of suitable cross reference indexes has been the major cause of the integration problem which is further inhibited by the absence of suitably scaled maps.

Attempts are being made to modernise these systems to facilitate the maintenance and dissemination of land data held within them. However the implementation of these models on computer does not alleviate the integration problems, it merely intensifies them. The remedy to the integration problem on computers is the same as it is for manual systems in that the linking of identifiers is an essential requirement.

Multipurpose systems have been developed which also allow the integration of various land data sets. This is achieved by the adoption of one basic parcel type upon which the other parcels are implemented. In the case of natural systems a new unit was created for the land systems model to resolve the problem of overlapping parcels but the existing legal parcel was adopted as the base unit for the multipurpose cadastre. This later situation is generally acceptable because most cultural units are based on an integral number of legal parcels. However the adoption of the legal parcel as a base unit is unsatisfactory in situations where cultural parcels are not multiples of the legal parcel. These occurrences appear to be unresolved except for the procedure of modifying the data by adjusting cultural boundaries to the most appropriate legal boundary. This is an unacceptable solution in both principle and practice.

The representation of a variety of parcel types, both natural and cultural, including their inconsistencies and their relationships have not been adequately addressed or resolved by the existing models. Consequently models for the digital representation of a variety of parcel types and corresponding data sets are still relatively undeveloped. These models must be capable of incorporating miscellaneous inconsistencies such as those introduced in section 2. In addition, the models for representing cultural data sets must be capable of including a variety of different land units both natural and cultural, particularly those that produce overlapping parcels. This problem has been overcome to some extent in land systems mapping but still needs to be resolved in cultural models. There appears to be a uniform lack of understanding of the possible relationships between typical parcels and the methods used to deal with the relationships that may arise.

The next chapter will investigate parcel relationships and methods for dealing with the various kinds. This will be followed by a chapter which examines the fundamental operations on various parcel types. The examination of both these aspects is essential in the development of a suitable model for representing and integrating a variety of parcel types.

4. PARCEL RELATIONSHIPS

4.1 Introduction

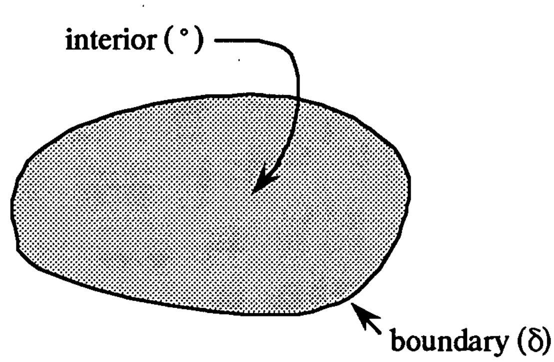
The aim of this chapter is to examine the relationships between parcels so that their inter-dependence may be unambiguously defined for the purposes of integrating their corresponding data sets.

To do this, parcels are construed as being spatial entities with a boundary and interior, with the relationships between them being examined by comparing boundary and interior intersections. It is then demonstrated that the six derived topological relationships exist between any two parcels.

After further investigation it is shown that all but one of the derived relations can be conveniently represented within a single parcel layer to facilitate integration. The remaining relation is dealt with through the adoption of a certain procedure and a new unit (which is a subset of the original parcels). An alternative theory and data structure is introduced to support this approach.

4.2 Boundary and Interior

A simple parcel is a continuous area of land with a particular characteristic or attribute. When the attribute of the land changes a parcel boundary occurs. A parcel may be represented spatially as a polygon as shown in figure 4-1.



Spatial components of a parcel.
Figure 4-1.

The sides of the polygon represent the boundary of the parcel and the interior of the polygon represents the area of land for which a particular attribute is homogeneous.

Parcels of a particular type are surrounded by similar parcels which may be related to each other in various ways. Topology is the study of relationships between spatial objects and may be used to examine parcel relationships, however the natural language descriptions are often vague. Pullar and Egenhofer [1988] developed formal definitions for topological relations in an attempt to overcome these vagaries. The discussion to follow is based on the paper by Pullar and Egenhofer.

4.3 Topological Relationships

A formal analysis of topological relationships may be based upon two basic operators, namely boundary (δ) and interior ($^\circ$). Spatial objects may be compared by examining the intersection (common parts) of their boundaries and interiors. This produces four basic criteria:

1. Intersection of boundaries $\delta \cap \delta$.
2. Intersection of interiors $^\circ \cap {}^\circ$.
3. Intersection of boundary with interior $\delta \cap {}^\circ$.
4. Intersection of interior with boundary $^\circ \cap \delta$.

The intersection of the results produced by the two operators need only be tested to establish whether they are empty or non empty.

For example, take two lines l_1 and l_2 as shown in figure 4-2. The boundaries of an interval are its endpoints and the interior is the line between the endpoints.

Figure 4-2.

The boundaries of the two lines do not intersect, hence

$$\delta l_1 \cap \delta l_2 = 0.$$

The interiors of the two lines do not intersect, hence

$$l_1^\circ \cap l_2^\circ = 0.$$

The boundaries of line l_1 do not intersect the interior of line l_2 hence

$$\delta l_1 \cap l_2^\circ = 0.$$

The interior of line l_1 does not intersect the boundaries of line l_2 hence

$$l_1^\circ \cap \delta l_2 = 0.$$

Likewise consider figure 4-3,

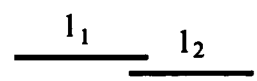


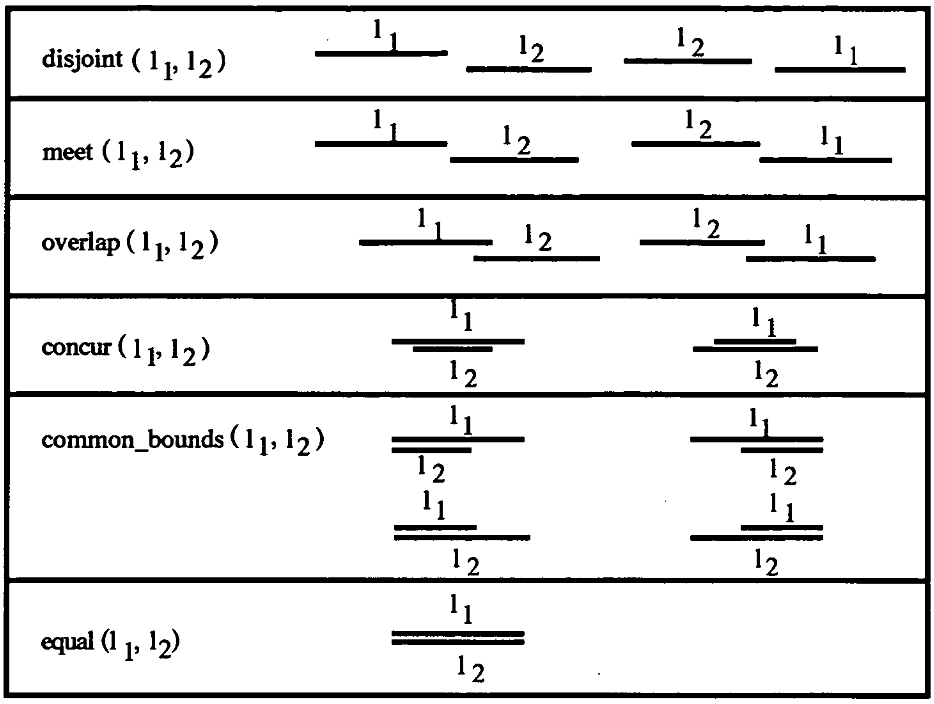
Figure 4-3.

$$\delta l_1 \cap \delta l_2 = 0$$
$$l_1^\circ \cap l_2^\circ \neq 0$$
$$\delta l_1 \cap l_2^\circ \neq 0$$
$$l_1^\circ \cap \delta l_2 \neq 0$$

The four criteria were tested by Pullar and Egenhofer [1988] against 13 possible topological relationships between intervals in one dimensional space. Topological relationships which produced the same results for all four criteria were said to be topologically equivalent. Whereas relationships with the same boundary-boundary and interior-interior results but opposite results for boundary-interior and interior-boundary were said to be topologically similar. That is, the results of boundary-interior and interior-boundary operations sometimes depend on the viewer's perspective.

4.4 Six Basic Interval Relations

Using the above principles to eliminate redundancies, Pullar and Egenhofer were able to produce a minimal set of six mutually exclusive relations. These relations are disjoint, meet, overlap, concur, common_bounds, and equal. Figure 4-4 illustrates the 13 possible interval relations, derived by Pullar and Egenhofer, categorised into the six basic relations.



The six fundamental interval relations.

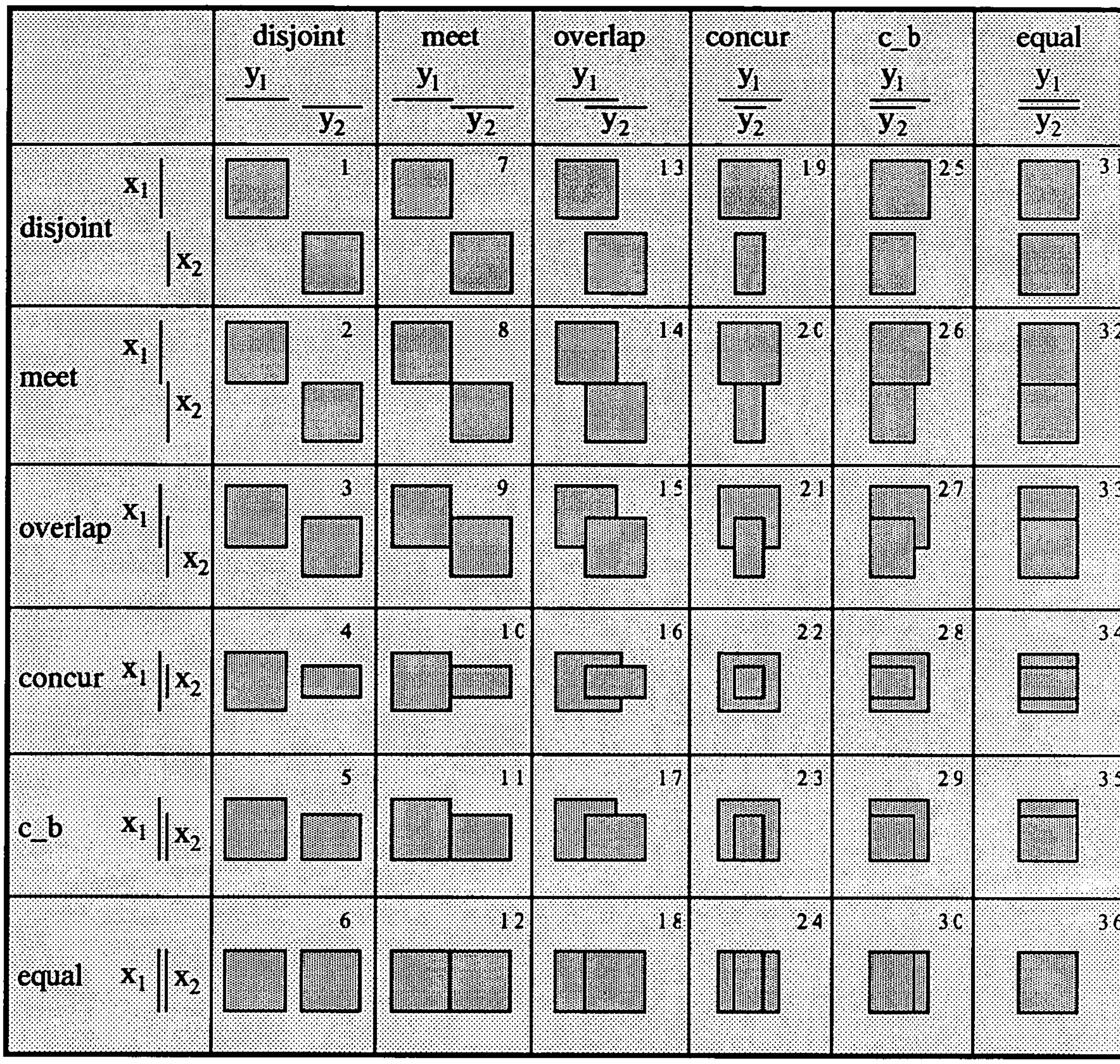
<u>Figure 4-4.</u>

Pullar and Egenhofer claim that the above "fundamental set of spatial relations is applicable for objects in an arbitrary space". Therefore these relations should also be basic to relationships between parcels.

4.5 Parcel Relations

To test their theory, we proceed in a manner similar to Pullar and Egenhofer when extending from point relationships to interval relationships.

The derivation of all possible area relations may be achieved by combining the six interval relations. Intervals x_1 and x_2 are used to represent all basic interval relations along the y axis, these are combined with intervals y_1 and y_2 along the x axis to give two distinct areas a_1 and a_2. That is, x_1 and y_1 are combined to give two sides of a square a_1. Likewise, x_2 and y_2 are combined to give a_2. The results of this procedure are shown in figure 4-5. The 36 areal relations are named AR1 to AR36 and are labelled adjacent to the objects to which they apply.



Note:

c_b indicates common_bounds,
the AR (Areal Relation) numbers appear in the top right corners.

Figure 4-5.

Each of these relations may be grouped and summarised according to their topological equivalence and similarity by examining the results of the boundary and interior operations.

The results shown in table 4-1 indicate six different groups of topologically equivalent areal relations, however there are not any topologically similar relations. Only one of the occurrences of the viewer dependent interval relations of common_bounds and concur was chosen to form the areal entities, consequently topologically similar areal relations were not represented in the diagram.

	$\delta a_1 \cap \delta a_2$	$a_1^\circ \cap a_2^\circ$	$\delta a_1 \cap a_2^\circ$	$a_1^\circ \cap \delta a_2$
$AR1(a_1, a_2)$	0	0	0	0
$AR2(a_1, a_2)$	0	0	0	0
$AR3(a_1, a_2)$	0	0	0	0
$AR4(a_1, a_2)$	0	0	0	0
$AR5(a_1, a_2)$	0	0	0	0
$AR6(a_1, a_2)$	0	0	0	0
$AR7(a_1, a_2)$	0	0	0	0
$AR8(a_1, a_2)$	$\neq 0$	0	0	0
$AR9(a_1, a_2)$	$\neq 0$	0	0	0
$AR10(a_1, a_2)$	$\neq 0$	0	0	0
$AR11(a_1, a_2)$	$\neq 0$	0	0	0
$AR12(a_1, a_2)$	$\neq 0$	0	0	0
$AR13(a_1, a_2)$	0	0	0	0
$AR14(a_1, a_2)$	$\neq 0$	0	0	0
$AR15(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR16(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR17(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR18(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR19(a_1, a_2)$	0	0	0	0
$AR20(a_1, a_2)$	$\neq 0$	0	0	0
$AR21(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR22(a_1, a_2)$	0	$\neq 0$	$\neq 0$	0
$AR23(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR24(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR25(a_1, a_2)$	0	0	0	0
$AR26(a_1, a_2)$	$\neq 0$	0	0	0
$AR27(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR28(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR29(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR30(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR31(a_1, a_2)$	0	0	0	0
$AR32(a_1, a_2)$	$\neq 0$	0	0	0
$AR33(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	$\neq 0$
$AR34(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR35(a_1, a_2)$	$\neq 0$	$\neq 0$	$\neq 0$	0
$AR36(a_1, a_2)$	$\neq 0$	$\neq 0$	0	0

Table 4-1

The areal relations are summarised as follows:

Disjoint(a_1,a_2) ⇔ AR1(a_1,a_2) or AR2(a_1,a_2) or AR3(a_1,a_2)
or AR4(a_1,a_2) or AR5(a_1,a_2) or AR6(a_1,a_2)
or AR7(a_1,a_2) or AR13(a_1,a_2) or AR19(a_1,a_2)
or AR25(a_1,a_2) or AR31(a_1,a_2).

Meet(a_1,a_2) ⇔ AR8(a_1,a_2) or AR9(a_1,a_2) or AR10(a_1,a_2)
or AR11(a_1,a_2) or AR12(a_1,a_2) or AR14(a_1,a_2)
or AR20(a_1,a_2) or AR26(a_1,a_2)
or AR32(a_1,a_2).

Overlap(a_1,a_2) ⇔ AR15(a_1,a_2) or AR16(a_1,a_2) or AR17(a_1,a_2)
or AR18(a_1,a_2) or AR21(a_1,a_2) or AR27(a_1,a_2)
or AR33(a_1,a_2) or AR28(a_1,a_2).

Concur(a_1,a_2) ⇔ AR22(a_1,a_2).

Common_Bounds(a_1,a_2) ⇔ AR23(a_1,a_2) or AR24(a_1,a_2) or AR34(a_1,a_2)
or AR35(a_1,a_2) or AR30(a_1,a_2) or AR29(a_1,a_2).

Equal(a_1,a_2) ⇔ AR36(a_1,a_2).

It is now possible to examine actual parcel relationships in terms of these six basic areal relations of disjoint, meet, overlap, concur, common_bounds and equal. They may be found both within and amongst parcel maps.

4.6 Relationships within Parcel Maps

A parcel layer consisting of more than one polygon, regardless of the theme, will consist of meet and disjoint relations. This is illustrated in figure 4-6 where an area has been divided into parcels of a particular theme, with (7,3) (12,4) 10,1) and (8,11) being examples of disjoint relations, and (7,6) (10,9) (8,3) and (1,2) examples of the meet relations.

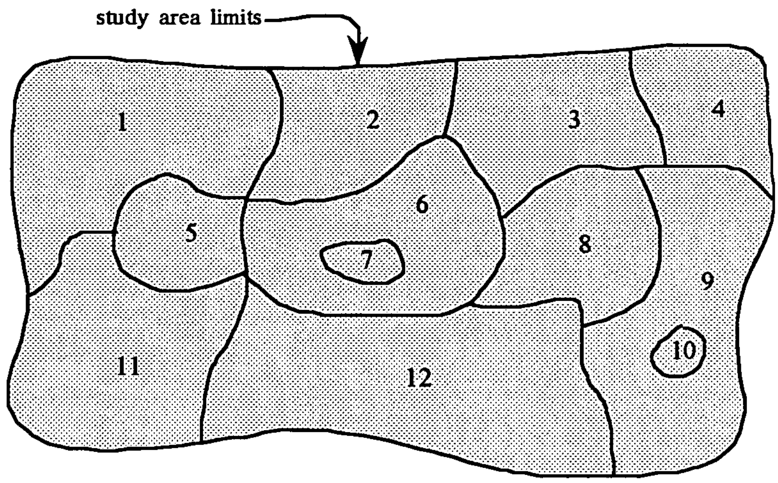


Figure 4-6.

Furthermore, many of the parcels illustrated in figure 4-6 may share a common attribute or identifier. That is, parcels 1, 5 and 11 may share an attribute A, and therefore (A,1) (A,5) (A,11) are common_bounds relations. Likewise, parcels 2, 6 and 7 may have an attribute B and therefore belong to a different class to parcels 1, 5 and 11. Hence (B,2) and (B,6) are common_bounds relations and (B,7) is a concur relation. However, parcel 3 may be the only parcel in the study area that is represented by a class with an attribute value C and so (C,3) is an equal relation

Overlap relations are not represented within a single parcel map since they only occur amongst parcels of different types.

4.7 Relationships amongst Parcel Maps

All six parcel relations may occur between parcels of choropleth maps with differing themes. The types, and corresponding number of relations that will arise, vary according to the definitions themselves. However the disjoint relation abounds in any situation regardless of theme since any two parcels not in the same vicinity are disjointed.

Parcel maps of completely unrelated themes, such as soil and legal parcels are said to be statistically independent. When compared, such maps produce a high incidence of overlap relations between parcels since the coincidence of a soil parcel boundary with a legal parcel boundary is rare(figure 4-7).

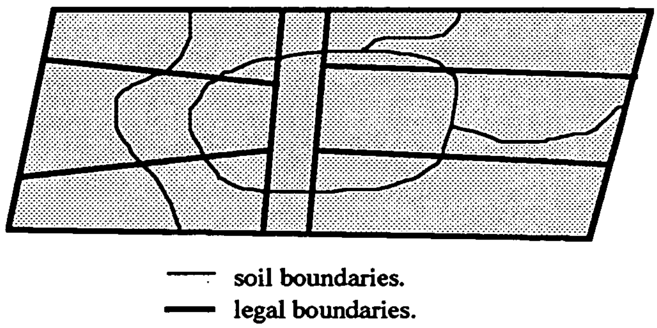


Figure 4-7.

As parcel types become more closely related the relationship between the parcels in their respective maps tend toward meet, common_bounds and equal. For example, there may be a high correlation between soil parcels and vegetation parcels. A single vegetation type may occur only on a certain soil (equal) or a number of vegetation types may only occur on a certain soil (common_bounds and concur).

The five relations of common_bounds, concur, equal, disjoint and meet are typical found in cultural layers. For example, a farm may have common_bounds relationships with legal parcels, while the concur relations may also exist as shown in figure 4-8. Furthermore, equal relations will arise when a farm consists of only one legal parcel,while a legal parcel not contained within a farm may produce either a meet or disjoint relation.

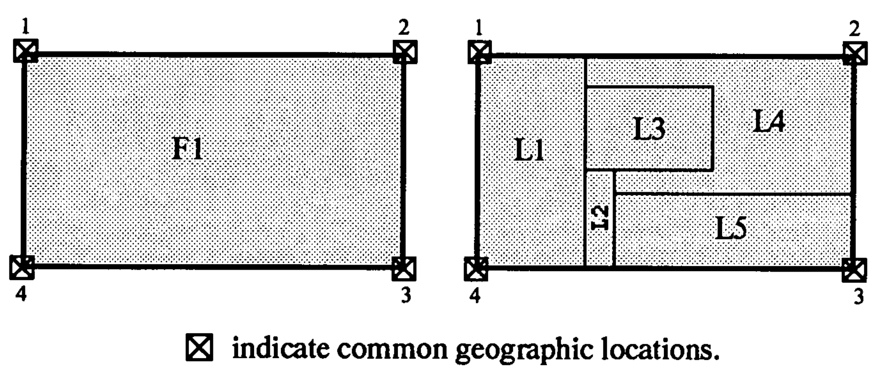


Figure 4-8.

Similar relations are common amongst most cultural units in varying degrees. Equal, meet and disjoint are the most common relation between legal parcels and fiscal parcels, with the common_bounds relations being less common. Disjoint and concur followed by common_bounds and meet are typical of relations between legal parcels and higher level administrative parcels such as counties.

4.8 Hierarchical Relations

A high incidence of common_bounds, equal and concur relations tend to indicate a hierarchy which are also most common among cultural parcels. For example, a country may be divided into states, which in turn may be divided into districts, thence into parishes, and finally into parcels. Alternatively, a state may be divided into municipalities, which may be divided into wards. In each of these hierarchies the relationship of a parcel at one level with a parcel in the next is either common_bounds or concur.

Natural parcels do not usually to reflect such hierarchical tendencies. Although parcels may be reclassified into similar groups to produce generalised parcels, this process is not so strict or well defined and may vary depending on the analyst. Also, when more intensive studies are performed to produce sub parcels, this often results in new outer boundaries.

For example, a general soil survey was performed over Tasmania at an approximate scale of 1:63000 by the Commonwealth Scientific Industrial Research Organisation (CSIRO). The Agricultural Department of Tasmania then decided to perform a more detailed survey, at a scale of 1:25000, of the alluvial parcel in the Coal River Valley. The new outer parcel boundaries of the more intensive survey did not coincide with the original boundaries. In many instances this lack of coincidence is due to the subjective characteristic of natural parcel boundaries. Consequently common_bounds relations are unlikely.

In summary, the containment or hierarchical relation may be expressed in terms of the common_bounds concur and equal relations as follows,

$$x \geq y \text{ iff equal(x,y) or concur(x,y) or common\_bounds(x,y).}$$

Where the relation $x \geq y$ may be read as x contains y, Furthermore,

$$x \ngeq y \text{ iff meet(x,y) or disjoint(x,y).}$$

Clearly containment cannot be expressed in terms of the overlap relation since a parcel A which overlaps B does not contain B nor does it not contain B.

4.9 Posets and Lattices

The theory of partially ordered sets (posets) and lattices are a fundamental branch of mathematics which have been applied to geographical data in relatively recent times. The initial applications were performed in terms of purely hierarchical geographical data [Cox 1975] however recent developments [Kainz 1988] have shown that lattice theory may also be applied to data consisting of overlapping parcels.

Although the digital representation of parcel data will be discussed in chapter 6, lattice theory is introduced here as a formal method of representing the hierarchical nature of cultural parcels, and for the purpose of demonstrating an analogous approach to the topological methods already introduced.

4.9.1 Posets

A Poset (partially ordered set) is a set P with a binary relation $\leq$, which for all x, y and z of P satisfies the following

(1) For all x, $x \leq x$ (reflexivity)

(2) If $x \leq y$ and $y \leq x$ then $x = y$ (antisymmetry)

(3) If $x \leq y$ and $y \leq z$ then $x \leq z$ (transitivity)

4.9.2 Hasse Diagrams

Posets may be visualised by using Hasse diagrams where each element of a poset is denoted by a small circle and lines between elements indicate direct containment. Elements which contain other elements are drawn at higher levels.

For example, consider a state (S) which is divided into two Municipalities, M1 and M2, which are in turn are divided into five legal parcels. The parcel layers for each of these are shown in figure 4-9. The relationship between these sets of parcels represents a poset and is represented in the Hasse diagram of figure 4-10. Note that each set contains itself and the empty set so that the empty set has also been added to the diagram.

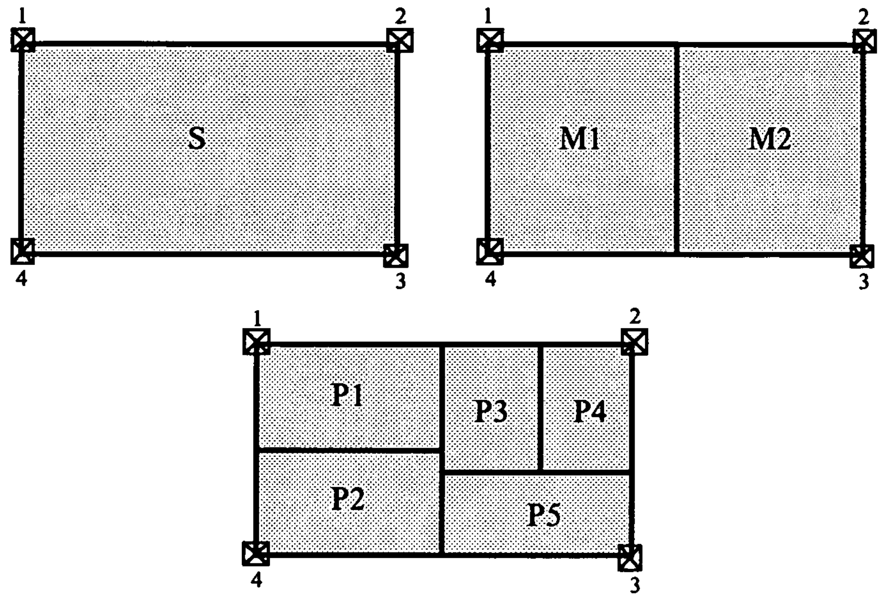


Figure 4-9.

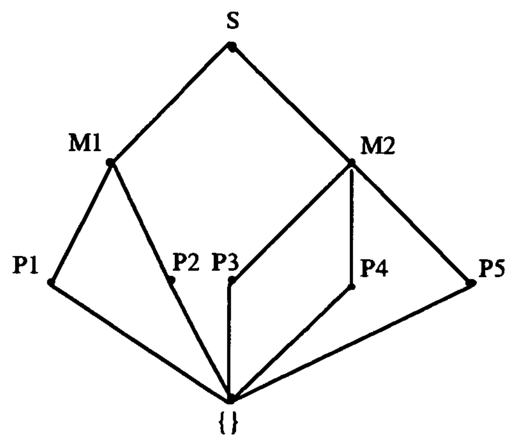


Figure 4-10.

4.9.3 Upper and Lower Bounds

Now, an upper bound of a subset x of a poset P is an element a ε P containing every x ε X. For example take subset X = {P3,P4,P5} in the poset S shown in figure 4-9. M2 and S are both upper bounds of X since they both contain P3, P4 and P5. Alternatively, if X = {P2,P3} then X has only one upper bound S which contains both P2 and P3.

Conversely, a lower bound of a subset X of a poset P is an element a ε P which is contained by every x ε X. In figure 4-9 the empty set {} is the only lower bound of the subset X = {P3,P4,P5}. It is also the only lower bound for the set X = {M1,M2} or X = {P1,P2,P3}.

The least upper bound (lub) is an upper bound contained in every upper bound. Hence if S = {P3,P4,P5} in figure 4-9 then the upper bounds of X are M2 and S, and so the least upper bound is M2. The greatest lower bound (glb) is a lower bound which contains every lower bound. The empty set {} is the greatest lower bound for subsets X = {M1,M2}, X = {P3,P4,P5} or X = {P1,P2,P3}.

4.9.4 Lattices

A lattice is a poset where every pair of elements x and y of P have a greatest lower bound and a least upper bound. The poset in figure 4-9 is a lattice since it satisfies this condition. The greatest lower bound of a pair is often called a meet and the lowest upper bound is referred to as a join.

Using the set-theoretic hierarchy enables parcel relationships to be maintained without the need for topology.

> "Lattice algebra provides a useful tool for structuring overlays by mere algebraic means without looking at topological properties."
>
> [Kainz 1988]

Cox [1975] has applied lattice theory to geographic files held by the US Bureau of the Census. The applications have been performed by assigning each basic set a unique code to which data is keyed. The codes showing the relationships between files are held in lists which are sorted in an appropriate manner to allow all set-wise analyses. The data structure used by Cox allows the identification of containment and equality between sets. Data from lower order sets may also be combined to produce aggregated or generalised information.

4.9.5 Limitations

The representation of geographical data using lattices is relatively new and consequently little understood. There appear to be significant advantages in using set theory, particularly in the areas of analysis for the purposes of integration and aggregation. Although these are fundamental parcel operations, they do not appear to be capable of graphical output which, as will be discussed in chapter 5, is also a fundamental application of a model representing parcels.

Furthermore the structures for lattice representation appear large and the operations complex as the following statement suggests:

> "Ongoing research in geographic lattice applications at the Bureau of the Census is focusing on efficient storage and retrieval of matrices and sparse matrices, and on additional representation and computational strategies for poset and lattice element operations."
>
> [Saalfeld 1985]

However, the supporters of lattice theory have recently introduced methods for dealing with overlap parcels. As will be seen in the following sections the techniques are analogous to those used in the topological method.

4.10 Overlap Relations

The overlap relation does not produce such distinct results in terms of containment. If parcel x overlaps parcel y, as in figure 4-11, then parcel x contains a portion of y and parcel y contains a portion of x. It becomes difficult to relate these parcels as containment is neither true nor false and consequently this hampers the integration of the attributes of parcels. Queries such as "what types of soil are inside certain farms" and "what types of land use are in certain municipalities" are common queries that need to be dealt with despite the overlap problem.

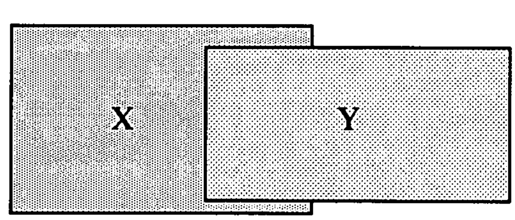


Figure 4-11.

The solution is to intersect overlapping parcels to form new parcels which are subsets of the original. That is, where a parcel boundary of X intersects the interior of a parcel Y as in figure 4-12, then Y is split into two parcels y_1 and y_2 so that (y,y_1) and (y,y_2) are common_bounds relations and so y_1 and y_2 are subsets of y as shown in figure 4-12.

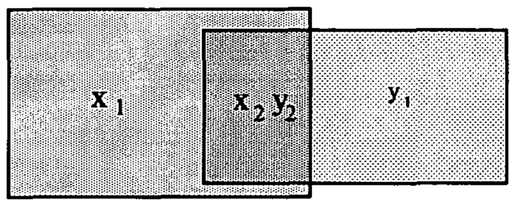


Figure 4-12.

The interior of X may also be split by the boundary of Y to produce two subsets of X called x_1 and x_2. Note that the combined intersection will also produce equal(x_2,y_2), disjoint(y_1,x_1), disjoint(y_1,x_1), meet(y_1,y_2x_2) and meet(y_2x_2,x_1).

A similar approach is used in lattice theory as illustrated by the following example taken from Kainz [1988]. Figure 4-13 shows a parcel A which contains four other parcels B, C, D and E. Parcels D and E are contained in both B and C, and parcels B and C overlap.

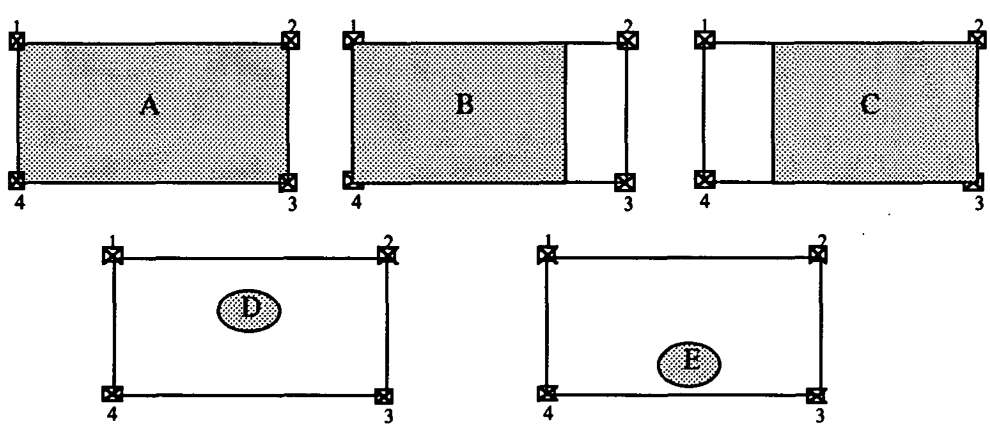


Figure 4-13.

The Hasse diagram for the poset is shown in figure 4-14 which illustrates showing that the poset is not a lattice. Elements D and E have upper bounds A, B and C, but a lowest upper bound cannot be identified since B does not contain C and C does not contain B. The greatest lower bound for D and E is the empty set.

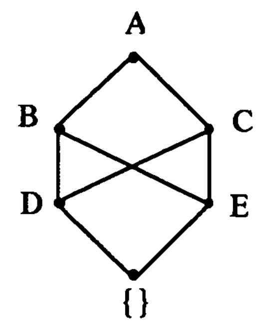


Figure 4-14.

To make this poset a lattice, a new element needs to be created which contains both D and E. This new element is the intersection of B and C (B ∩ C) or the common area of B and C which contains D and E. The Hasse diagram for the newly formed lattice is shown in figure 4-15.

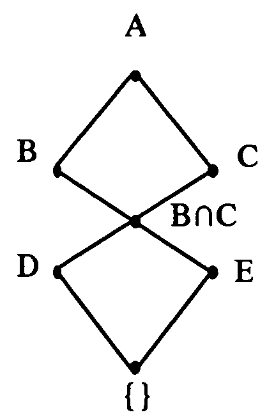


Figure 4-15

This process of forming a lattice is called the normal completion which is a well defined theory and may be found in any lattice theory text or the papers of Saalfeld [1985] and Kainz [1988]. The important aspect of this process is that the overlapping parcels B and C need to be combined to form a new element, or parcel, called B ∩ C. This will allow the formation of a lattice structure and so enable set-theoretic manipulation of the data. This is similar to the method described in the previous example for comparing overlapping parcels X and Y.

4.11 The Overlay Process

In order to compare maps which exhibit overlap relations between parcels they need to be combined to produce a new parcel map. Each parcel in the new map represents an area of land with a particular combination of the themes that are to be compared. This new map does not contain overlap parcels and the process to create it is called overlay.

Take the two parcel maps in figure 4-16 where one represents soil parcels and the other represents legal parcels.

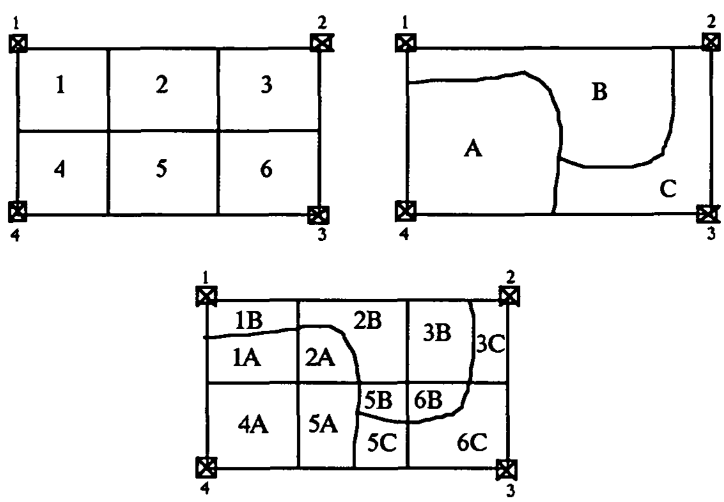


Figure 4-16

When the two incompatible maps are overlayed, a new parcel map is produced in which each parcel represents a particular combination of soil and legal attributes. It is still possible to recognise original legal and soil parcels as each sub parcel still carries the original attributes of the parent parcel. For example, legal parcel 5 can still be recognised since (5,5A), (5,5B) and (5,5C) are common_bounds relations, furthermore it is now possible to determine the types of soils inside legal parcel 5. The amount of each type may be determined from the areas of the new sub parcels.

An analogy to the overlay process may also be found in lattice theory [Kainz 1988]. Two lattices may be compared by computing their cardinal product which produces a new lattice. This new lattice preserves the parcels ordered under inclusion.

> "The computation of the cardinal product gives new elements that can be viewed as intersections of given areas in the overlay process. It must be stressed that these new intersections come without topology, only by application of order structures and basic set operations." [Kainz 1988]

4.12 Typical Relationships between Common Parcel Types

The relationships between common parcel definitions are summarised in table 4-2. The table indicates that cultural parcels generally have hierarchical, meet and disjoint relations, particularly for cadastral, legal, fiscal and farm parcels. However, when these are compared with higher order cultural parcels such as census districts and municipalities, there is a low incidence of overlap.

All relationships are possible between natural parcels. Actual conditions will depend on the natural parcel surveyor and the data capture resolution. Relations between natural and cultural parcels are generally overlap and disjoint. Although the hierarchical and meet relations are possible.

	CADASTRAL	LEGAL	FISCAL	FARM	GRANT	CENSUS	MUNICIPAL	VEGETATION	SOIL	GEOLOGY
CADASTRAL	E									
LEGAL	H	E								
FISCAL	H	H	E							
FARM	H	H	H	E						
GRANT	H	Ho	Ho	Ho	E					
CENSUS	Ho	Ho	Ho	Ho	Ho	E				
MUNICIPAL	Ho	Ho	Ho	Ho	Ho	Ho	E			
VEGETATION	O	O	O	O	O	O	O	E		
SOIL	O	O	O	O	O	O	O	A	E	
GEOLOGY	O	O	O	O	O	O	O	O	A	E

E indicates that only equal, meet and disjoint relations are typical.
O indicates that overlap and disjoint relations are typical.
H indicates that hierarchical, meet, and disjoint relations only are typical.
A indicates that all six relations are possible.
Ho indicates that hierarchical meet and disjoint relations are predominant but with a low incidence of overlap.

Table 4-2.

4.13 Conclusion

This chapter has formally examined the topological relationships between parcels. A knowledge of these relationships is essential for the development of a model that represents a variety of parcel types for the purposes of integration.

Relationships between parcels may be expressed in terms of six basic mutually exclusive topological relations called disjoint, meet, common_bounds, concur, equal and overlap. All these relations except overlap may be expressed in terms of containment. If a parcel is contained inside another parcel then either a common_bounds, concur or equal relationships exists, conversely if a parcel is not contained within another parcel then they may be described in terms of either the meet or disjoint relations. However if a parcel is neither completely insider or outside a parcel, then an overlap relation exists.

Meet and disjoint are basic parcel relations which are found whenever parcels are compared. Parcels which exhibit overlap relations may be represented in separate layers and are common amongst maps of unrelated themes. As themes become more correlated the relationships tend toward common_bounds, equal and concur which are typical of cultural maps consisting of conterminous parcel types. Parcels such as these can be ordered by inclusion and represented within a single layer. However inconsistent parcel creation in the past has resulted in a low incidence of overlapping cultural parcels which tend to be held in separate layers.

The advantage of representing a number of parcel types in a single layer is that it allows the integration of the corresponding data types for the purposes of queries based on the parcel relationships. These queries will depend on the operations which can be performed on a parcel layer and so this topic will be discussed in the following chapter. Parcels which are represented in separate layers are essentially unrelated but their data sets may be combined through the overlay process.

The overlay process is the typical solution to the integration of parcel types which overlap. Overlay produces a new parcel map based on a new unit which is a sub parcel of both the original overlapping parcels. Consequently the relationship between the original parent parcel and this new unit is ordered by inclusion and so queries based on the relationship between the two overlapping parcels are possible.

The creation of a new sub unit is fundamental to the overlay process and is also used to resolve the overlap situation in geographical data represented via lattices. Consequently the integration of data sets based on non-conterminous parcels requires the creation of a new unit as evidenced by the principles adopted in land systems mapping.

Now that the fundamental relationships between parcels have been defined, they may be used as a basis for the development of a model for representing a variety of parcel types. However an examination of the fundamental operations required to manipulate parcel types which produce these relations is also necessary and will be undertaken in the following chapter.

5. FUNDAMENTAL PARCEL OPERATIONS

5.1 Introduction

The aim of this chapter is to examine fundamental operations on parcels and parcel layers, particularly those operations which enable the implementation of the six basic parcel relations introduced in chapter 4. Overlay and parcel amalgamation are two important operations that have already been introduced. These are now examined in more detail together with other basic operations. Parcel layer creation is considered in broad terms for the sake of completeness.

The operations are discussed in terms of vector data structures which are more desirable for parcel based systems however, many of the operations are simplified if a raster structure is used.

This chapter only considers operations in terms of software, although many operations such as spatial selection and display are hardware dependent. A range of hardware options such as plotter, digitising board, tablet, mouse and graphics terminal are assumed.

5.2 Creation

The most preliminary operation of a parcel based system is creation. Numerous methods exist for the creation of parcel layers and the attachment of textual attributes. The methods used will depend on the location and condition of the source data.

Generally parcel boundaries may be digitised from an existing parcel map. The creation process will therefore need to facilitate manual digitising and the conversion of parcel coordinates. Editing techniques will also be required so that boundaries may be corrected for digitising and other errors. Parcels may be formed either during or after the digitising process, depending on the software.

Parcel layers may also be created by incorporating spatial data from another system. The ability to accept data in different formats, including those provided from remote sensing, must also be possible in the creation process.

The assignment of textual data to parcels is also basic to parcel layer creation. Textual data may be held in a separate database and so techniques will be required for adding digital data into the parcel layer database as well as linking records to parcels. It must also be possible to add textual data from manual systems such as files, books and maps.

Parcel layer creation is a significant operation in terms of time and money for any parcel based system.

5.3 Overlay

The overlay operation, as introduced in section 4.11, is fundamental to any LIS or GIS. The process combines two parcel layers to produce a third parcel layer. The parcels in this new layer represent a continuous area of attributes combined from the original parcel layers (figure 5-1).

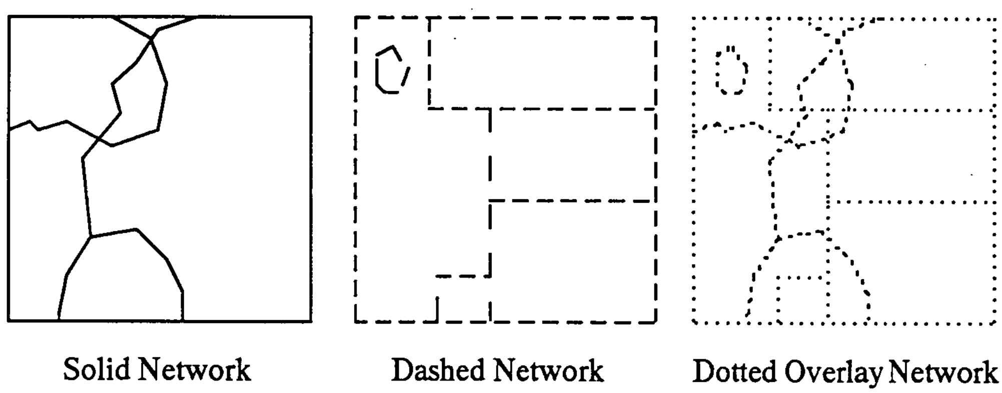
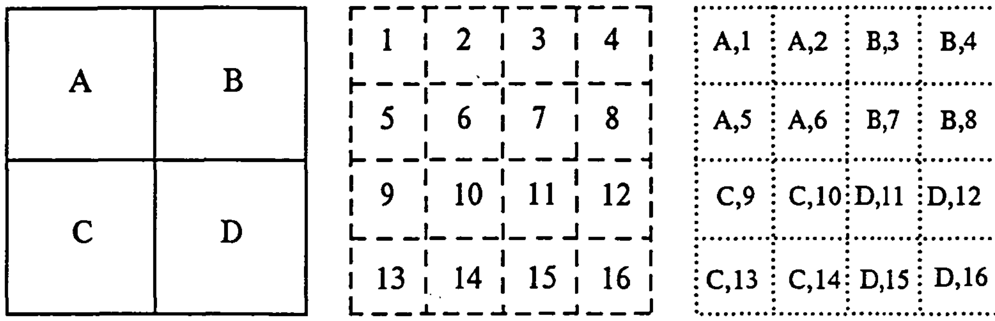


Figure 5-1.

In terms of parcel relations, overlay resolves two parcels layers containing overlap relations into one layer of meet and disjoint relations. At the same time it also produces a hierarchical relationship since parcels in the new layer are sub parcels of the original. Overlay is therefore useful for combining two layers which exhibit only hierarchical relations between their component parcels.

Consider figure 5-2, each parcel of layer one is contained entirely within the parcels of layer two. Hence if these layers are overlayed, the layer produced is spatially the same as layer one, however as a result of the overlay process, the attributes of both layer one and layer two will all be represented in the new layer.



Layer 1 | Layer 2 | Combined Layer

Figure 5-2.

The development of software to perform overlay operations on digital layers has had a number of setbacks.

5.3.1 Computing Overheads

The overlay process places heavy demands on the computer.

There are five general tasks that need to be performed:

> "(1) Given a polygon of one network, find the polygons of the other network which may potentially overlap;
> (2) Given potential overlaps, find points of actual overlap;
> (3) Be able to recognise when a new dotted polygon has been created [figure 5-1];
> (4) Identify the solid and dashed parent polygons of a dotted polygon [figure 5-1];
> (5) If possible, test new dotted polygons for topological consistency."
>
> [White 1978]

The traditional method of handling the listed tasks was to perform them separately for each pass through the layers. One layer was treated as active, the other as passive. First, each polygon in the active layer was compared with polygons in the passive layer to find potential overlap polygons, then all the intersect locations for the boundaries were determined so new polygons could be formed and so on through to task 5. The process was slow because of the numerous passes through the data.

A breakthrough was made when the Whirlpool software was developed at Harvard [White 1977]. The Whirlpool system performs all the tasks for polygon overlay with only one pass through common regions for the two layers being overlayed. Consequently, software such as Whirlpool does not place such heavy demands on CPU usage for overlay.

5.3.2 Spurious Polygons

Another major difficulty in the development of the overlay process were the problems caused when lines in the separate maps were very similar but not quite the same. Overlay in its purest form creates numerous small polygons if there are many similar boundaries which repeatedly intersect. This is not a problem when there is little correlation between the parcels of the maps but

> "When the boundaries of polygons on the source maps are highly correlated, however, serious problems arise through [the] production of large numbers of small 'spurious' polygons." [Burrough 1987]

This is particularly a problem when cultural layers, consisting of conterminous parcels, are overlayed. Many solutions have been proposed, each with varying degrees of usefulness. Rules may be developed for removing spurious polygons, but they may also result in the loss of information. For example, spurious polygons may be evaluated on a magnitude of area basis, that is, they may be rectified by removing one side of these small area polygons and merging them with the adjoining polygons. However, in some cases long narrow spurious polygons may have larger areas than valid circular polygons.

A decision also has to be made as to which spurious polygon boundary needs to be removed. Take a soil boundary of subjective nature which weaves along a legal boundary. Clearly if boundaries are to be deleted, then the more subjective boundary should be the one that is chosen. Hence boundaries or layers may need to be weighted.

5.3.3 Fuzzy Tolerance

Another approach is to allow parcel boundaries to be subject to a fuzzy tolerance. Many parcel boundaries are not exact in nature, consequently it is often appropriate to adjust coordinates on a boundary within a certain tolerance to resolve spurious polygons. The maximum amount that a point may be adjusted is called a fuzzy tolerance. Even legal boundaries digitised from paper maps can be subjected to a certain amount of fuzzy tolerance. Most boundaries, except those from numerical data, need not be considered as being in their true location.

Specifying a suitable fuzzy tolerance during each overlay process allows the software to move boundaries, by the magnitude of the tolerance, to resolve spurious polygons. Hence if a boundary in the active layer is a fuzzy distance from a boundary in the passive layer, then the active line is "snapped" to the location of the passive line as shown in figure 5-3. Notice that the whole boundary was not snapped, only the portions which were the fuzzy distance apart.

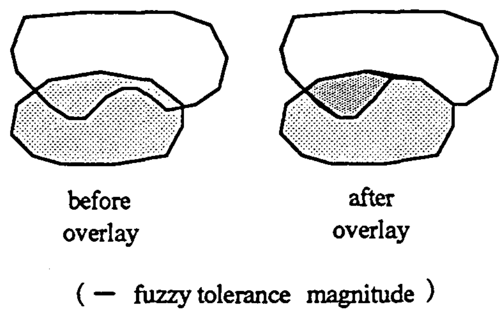


Figure 5-3.

5.3.4 Fuzzy Creep

The concept of fuzzy tolerance has been extended to improve the speed and efficiency of computing line intersections.

> "Unlike exact intersection, where two segments [boundaries] intersect only if there is a mathematical point that defines the intersection, the fuzzy intersection defines an intersection point or points when the two segments [boundaries] are within a fuzzy distance away from each other."
>
> [Guevara & Bishop 1985]

However, there are limitations to using fuzzy tolerance to resolve line intersections and spurious polygons.

Specifying a fuzzy tolerance in a map overlay process provides the software with a license to move parcel boundaries, or points on that boundary, within the fuzzy distance. The fuzzy distance may be kept small to limit the movement of boundaries, but if a layer is subject to a number of overlays, the total movement of boundary points for all overlays may be greater than the specified tolerance value. This phenomenon of boundary points moving during multiple overlays is called fuzzy creep.

> "Many problems arise in the repeated application of tolerance in a neighbourhood, potentially enlarging the neighbourhood of identity beyond the original tolerance value."
>
> [White 1978]

Although the difficulties of fuzzy creep appear to be resolved by Guevara and Bishop [1985], the problems encountered during parcel layer overlay must be considered. This is particularly important for parcels with boundaries of legal and cartographic significance, as the application of fuzzy tolerance to solve parcel overlay problems may have undesirable results such as the movement or bending of lines [Driessen 1987].

5.3.5 Quantitative Attributes

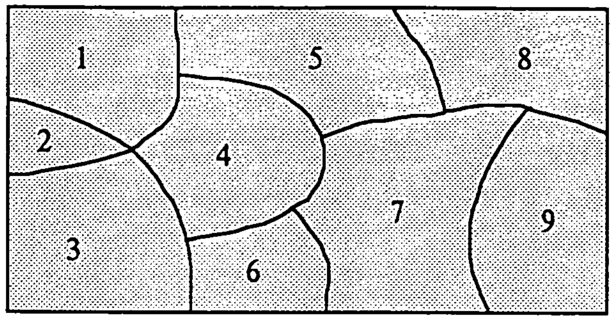
One overlay problem that is difficult to resolve is the assignment of quantitative attributes to sub parcels. Unlike qualitative attributes these values do not apply to portions of the parent parcel. The knowledge of a professional is often required to perform this task correctly, apportioning these values on an area basis is inappropriate.

The solution to this problem is data specific, different rules may be used in different situations. However as a general rule, numeric items from the original layers should not be included in the attribute table produced by the overlay process.

5.4 Spatial Aggregation

The complement of the overlay process is spatial aggregation. Figure 5-4 shows a parcel layer which may have been produced by overlaying a parcel of theme A with a parcel of theme B. Hence the layer shown consists of parcels of combined theme A and B, each parcel will have one of the attribute values a_1 to a_n and one of the values b_1 to b_n.

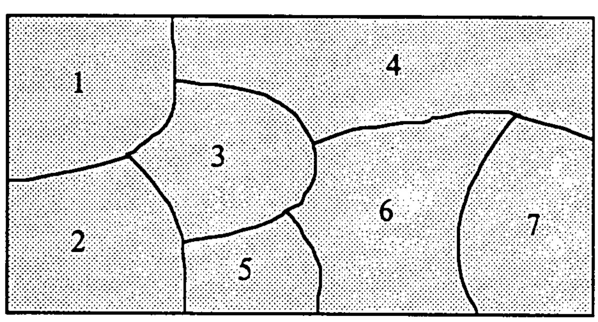
When spatial aggregation is performed, one or more attribute items are specified as a comparison set, if meet polygons share the same values for the attribute items then the polygons are merged into one polygon. For example, figure 5-5 shows the result when spatial aggregation is applied, with item A as the comparison set, to the parcel layer in figure 5-4. Consequently the common boundaries of meet polygons such as 1 and 2 are removed because they share the same attribute value (a_1). However, polygons such as 4 and 5 are not merged because their attribute values are different ($a_3 \neq a_4$).



parcel id	item A	item B
1	a_1	b_1
2	a_1	b_2
3	a_2	b_2
4	a_3	b_4
5	a_4	b_3
6	a_5	b_6
7	a_6	b_6
8	a_4	b_1
9	a_1	b_6

Figure 5-4.

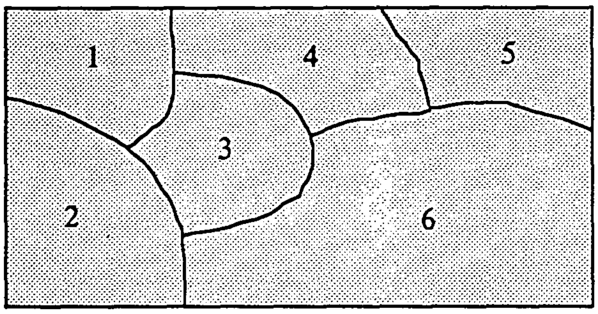
Note that only items in the comparison set are retained as attribute items in the resulting parcel layer. Items not in the comparison set are dropped from the new parcel layer because the values may not be homogeneous for the newly defined layer.



parcel id	item A
1	a_1
2	a_2
3	a_3
4	a_4
5	a_5
6	a_6
7	a_1

Figure 5-5.

Figure 5-6 shows the parcel layer produced if attribute item B is used in the comparison set. If both attribute items A and B are used as the comparison set in this example, there is no change to the original parcel layer. No two meet parcels share the same values for both items A and B. Also the parcel layer in figure 5-4 may be reproduced by overlaying the parcel layers in figure 5-5 and figure 5-6.



parcel id	item B
1	b_1
2	b_2
3	b_4
4	b_3
5	b_1
6	b_6

Figure 5-6.

Spatial aggregation is a simple process if meet parcels can be easily determined and their common boundaries removed. The determination of meet parcels will depend on how they are represented. There are two general methods for polygon data represented in a vector format. The first, called the polygon method, ensures that the complete boundary which encloses a polygon is held as an object within the spatial data. Meet polygons may then be determined by checking for coincidence of certain portions of the boundary. This analysis and subsequent removal of coincident sections may be as complex as the parcel overlay process.

Polygons may also be defined by the segment method. A segment is simply a line or arc, hence a polygon may be made up of a number of segments. The advantage is that one segment may be used for two polygon descriptions. Hence meet polygons will share the same segment. Spatial aggregation is then a simple matter of comparing the polygon attributes for the comparison set on one side, with the polygon attributes on the other side, for each segment in the parcel layer, if the attribute values match then the segment is removed. After all possible segments are removed, new polygons are formed from the remaining segments. Representation of parcels will be examined in chapter 6.

It is worth noting that the layer produced in figure 5-5 still contains parcels with the same attribute. That is, parcels 1 and 7 share the same attribute a_1. It was not possible to combine these parcels because they are disjoint. Hence the spatial aggregation process does not guarantee unique attribute values.

The usefulness of this operation was illustrated by Zwart and Williamson [1988] who demonstrated how land use attribute items could be used to spatially aggregate a legal parcel layer to produce a land use layer.

> "As a result we have now transformed the base map consisting of [legal] parcel polygons identified by street address to a land use map wherein land use polygons are identified. If appropriate, this layer can now be stored and manipulated just like any other data set within the system."
>
> [Zwart and Williamson 1988]

Hence parcel subsets in layers which include hierarchical relations may be aggregated into higher level parcels by the aggregation process. This is particularly relevant to cultural parcels. Legal parcels may be aggregated to fiscal parcels given fiscal attributes to produce a fiscal layer. Likewise, municipal farm and census district layers may also be produced from the parcel layer. This is the solution to the amalgamation problems as sought by Palmer [1984] and discussed in section 3.4.

This operation does not require a hierarchical identifier system as espoused by Ziemann [1977] and Moyer and Fisher [1973]. It is based specifically on the topological relationships of the parcels and their attributes, thus providing greater flexibility. In fact a hierarchical identifier system may be detrimental to this process, as illustrated by the UPI in the Coal River Pilot GIS of chapter 9.

5.5 Textual Aggregation

Textual aggregation operates on a set of records and is useful for either summarising certain attributes or counting the number of occurrences of attributes in a list of records.

Consider the records listed in table 5-1. Each record belongs to a parcel in a legal parcel layer. The attribute items for each parcel are VACANT, AREA, TENURE AND PERIMETER. The operation requires a set of attribute items which are to be counted and an optional set of numerical attributes which may be summarised. Table 5-2 shows the result of textual aggregation on Table 5-1 using vacant as the count item and area as the summary item. The results indicate that there are three parcels of non vacant land with a total area of 3916 square metres and there are four parcels of vacant land with a total area of 3210 square metres.

PARCEL ID	VACANT	AREA	TENURE	PERIMETER
21063	no	2076	crown	240
21076	no	764	private	130
21054	yes	609	sec	120
21092	yes	856	crown	190
21002	no	1076	private	220
21004	yes	988	private	202
21009	yes	757	private	162

Table 5-1

COUNT	VACANT	AREA
3	no	3916
4	yes	3210

Table 5-2.

Table 5-3 illustrates a textual aggregation on the same original table but this time using VACANT and TENURE as the count items and AREA and PERIMETER as the summary items.

COUNT	VACANT	TENURE	AREA	PERIMETER
1	no	crown	2076	240
2	no	private	1840	350
1	yes	crown	856	190
2	yes	private	1745	364
1	yes	sec	609	120

Table 5-3.

Hence the result of this operation indicate that there are for example, two vacant private parcels with a total area of 1745 square metres and a total perimeter of 364 metres.

Textual aggregation is also useful for counting the number of disjoint parcels after a spatial aggregation. For example, after a spatial aggregation on item A, as shown by figure 5-4, a textual aggregation may be performed using the same item as a count item. The results would indicate that there are two disjoint parcels with the same attribute (a_1). This combination of spatial and textual aggregation is a very useful tool in the model that is developed in subsequent chapters. They were used effectively in the Coal River Pilot GIS to locate disjoint fragments of the Torrens title records of the study area.

5.6 Selection

Selection is a basic operation of Information systems. Parcels need to be selected on the basis of suitable criteria so that those which match the criteria may be displayed graphically or textually. Consequently selection is the first step in a query operation and is followed by some form of display.

The result of a selection on a parcel layer will produce a subset of the original layer which may be considered a new temporary layer. This temporary layer may be used for display purposes or form the source of new selection criteria. Hence selection may consist of a number of similar operations.

SUBSELECT allows the creation of a temporary parcel layer which is a subset of the original permanent parcel layer. The temporary layer lasts for the duration of the query operation. Each new subselect operates on the previous subset or temporary layer.

ADDSELECT allows the addition of parcels to the current subset. Hence addselect enables parcels to be added from the original parcel layer based on some criteria.

SWAPSELECT allows all those parcels not in the currently selected set to be included, and all those that were in the selected set to be discarded.

Each of these operations will require a layer as an argument and may either be based on the spatial or textual component

5.6.1. Spatial Selection

Spatial selection enables the selection of parcels based on location. A parcel may be selected by specifying a location, or a number of parcels may be selected within a certain distance of a specified location. Alternatively, parcels may be selected on the basis of whether they fall inside a user defined polygon. This polygon may be defined by a number of methods. It may be arbitrarily defined by entering boundary coordinates or it may be defined by a buffer distance from a point (as above), line (road or river) or existing parcel.

The determination of meet parcels is also an important spatial selection technique as it allows the determination of parcel neighbours. Meet parcels may be selected by buffering particular parcels to define a selection polygon or by determining which parcels share the same boundaries. Disjoint parcels may be selected by a composite of a SUBSELECT, using the meet criteria, and SWAPSELECT.

Figure 5-7 shows a number of parcels which have been SUBSELECTed within a distance of a specified point. The entire layer is shown by depicting parcel boundaries. The parcels of the temporary layer (selected set) are shaded. Figure 5-8 shows an ADDSELECT operation subsequent to the operation in Figure 5-7. All parcels in the user specified box are added to the temporary layer. Figure 5-9 shows the result of a SWAPSELECT on the previous example. Hence all parcels not in the circle, nor in the box, are shaded.

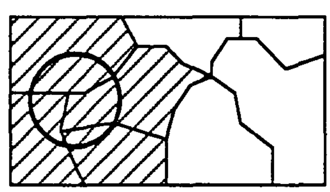


Figure 5-7

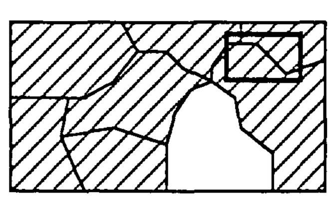


Figure 5-8.

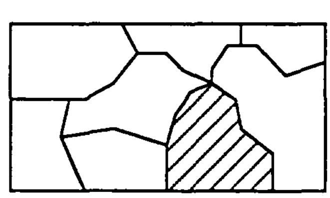


Figure 5-9.

5.6.2. Textual Selection

Textual selection allows parcels to be selected based on their attributes. For example, all parcels greater than a certain area may be chosen. This also results in a temporary parcel layer which may be used for further selection, both textual and spatial, or in other operations such as display.

A textual selection is based on a logical expression which may consist of operands, operators and connectors. The logical operands (attribute items and values) will depend on the data within the system. Operators and connectors will depend on the software, but will generally consist of the logical operators and connectors listed in table 5-4 and table 5-5. Connectors allow expressions to be made up of expressions. Table 5-6 illustrates examples of logical expressions based on the attribute items and values of table 5-1. Parcel records which satisfy an expression are placed in the temporary layer.

LOGICAL OPERATORS	
EXPRESSION	EVALUATES TO TRUE IF:
OP1 = OP2	OP1 is equal to OP2
OP1 <> OP2	OP1 is not equal to OP2
OP1 <= OP2	OP1 is less them or equal to OP2
OP1 >= OP2	OP1 is greater than or equal to OP2
OP1 > OP2	OP1 is greater than OP2
OP1 < OP2	OP1 is less than OP2

Table 5-4.

LOGICAL CONNECTORS	
EXPRESSION	EVALUATES TO TRUE IF
EXP1 **AND** EXP2	EXP1 and EXP2 are both true.
EXP1 **OR** EXP2	Either EXP1 or EXP2 evaluate to true, but both need not be true.
EXP1 **XOR** EXP2	EXP1 is true or EXP2 is true but not both.:

Table 5-5.

SAMPLE EXPRESSIONS	
EXPRESSION	SELECTED PARCELS
PARCEL-ID = 21076	21076
AREA >= 1000	21063 21002
AREA < 1000 AND TENURE = 'CROWN'	21092
VACANT = 'YES' OR TENURE = 'PRIVATE'	21054 21092 21004 21009 21076
PARCEL-ID = 21063 OR PARCEL-ID = 21004	21063 21004

Table 5-6.

5.7 Display

Information display is an important consequence of a parcel based system as it enables derived information to be communicated to the system users. The operations may apply to all the data in a layer or selected subsets depending on previous selection operations.

Spatial data may be displayed graphically via screen plots or paper maps. The capability of using a variety of symbols for both parcel shading and the drawing of boundaries and the variation of these symbols according to attributes must be available as well as scaling and windowing techniques. Display operations on textual data include screen listings of files and the creation of paper based reports.

Like selection techniques, graphical and textual display need not be treated separately. Maps may require the printing of various attributes inside each parcel, or files may need to be listed to a screen during the interactive plotting of parcel layers.

5.7.1 Display of Parcel Relationships.

Three display operations, which are logically similar to the spatial aggregation process of section 5.4, are useful for highlighting hierarchical relationships in parcel layers. They are based on the display of internal and external boundaries, for example, legal parcel boundaries within a municipality may be drawn with broken lines while the municipal boundaries are drawn with solid lines.

The shared boundaries of common_bounds parcels may be considered external boundaries while those that are not external are internal boundaries (figure 5-10).

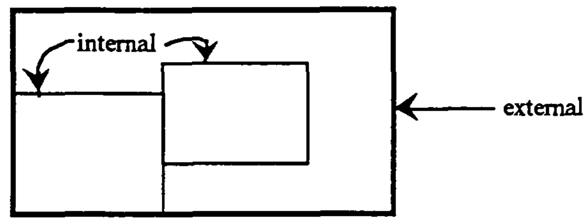


Figure 5-10.

All boundaries of parcels which concur with higher level parcels are internal. Conversely all boundaries of parcels which are equal with higher level parcels are external.

The drawing of external lines may be achieved by examining meet parcels. If the specified attribute set is the same for each side then an internal boundary has been found and is not drawn. If they are different, then an external boundary has been found and is drawn with the specified symbol. Internal boundaries may be highlighted in a similar manner. The ease with which these operations are performed will depend on how the parcels are represented.

The third display operation supplements the drawing of external lines by labelling only one sub parcel of all possible sub parcels of a higher level unit. If polygons are labelled in the usual way, then all sub parcels of higher level parcels are labelled. Consequently the higher level parcels, which may have been highlighted by their external boundaries, will contain a number of labels that are the same. Hence an aggregated labels operation is required which adds a label for only one sub parcel.

5.8. Summary

To summarise the fundamental operations described in this chapter, it is useful to use the language of data abstraction. The most significant abstract data type recognised so far is the parcel layer or simply layer. An abstract data type (ADT) is defined in terms of other data objects, together with basic operations which may be performed on these objects, and a set of rules describing the relationship and effect of the basic operations.

The following attempt at a formal definition of the abstract data type LAYER is not intended to be complete. It merely serves as a tool for summarising the fundamental operations required for representing and querying parcels and parcel relationships.

Parcel layers in general require many more fundamental operations, particularly in the general techniques of entry and editing but this is outside the scope of this thesis. Also, the following definition uses data objects, such as expression, item, parcel and symbol, which are not well defined and can themselves be considered as ADTs. These objects may be defined less formally as follows:

parcel	-	a polygon with associated textual data representing an area of land as discussed in previous chapters
item	-	a distinct column or set of data associated with a parcel. Parcel attributes may be categorised into one or more items. All parcels in a layer will have the same items. To represent groups of items the following symbology is used: [item] - one or more items or a set of items; $[\text{item}]_{\text{Layer}}$ - all possible items for a particular layer.
file	-	object containing textual data in relation to parcels of a layer or simply an object containing textual data
method	-	technique used for spatial selection, examples include: buffer - parcels inside a buffer zone; box - parcels inside a rectangular figure; circle - parcels inside a circle; polygon - parcels inside an arbitrary polygon; and arc - parcel containing a specified point. See section 5.6.1 for more details.
expression	-	a logical expression consisting of logical operands, operators and connectors as discussed in section 5.6.2.
symbol	-	an object defining a graphic symbol for either line representation or polygon shading

To facilitate the formal declaration, the generalised operation of creation has been separated into two operations. CREATE produces a new empty layer which is ready for the loading of parcels, and LOAD represents the actual data entry operations of digitizing, editing, polygon formation and attributing. These operations are data representation dependent. Two other operations, EMPTY and NUMBER, have also been included for the purposes of the declaration.

Type Layer

declare
Create( ) → layer.
Load(parcel, layer) → layer.
Empty(layer) → boolean.
Number(layer) → integer.
Overlay(layer, layer) → layer.
SpatialAg(layer, [item]) → layer.
TextualAg(file, [item]) → file.
SubSelect_spatial(layer, method) → layer.
SubSelect_textual(layer, expression) → layer.
AddSelect_spatial(layer, method) → layer.
AddSelect_textual(layer, expression) → layer.
SwapSelect(layer) → layer.
Shade(Layer, symbol) → output.
Boundary(layer, symbol) → output.
Label(layer, item) → output.
Internal(layer, [item], symbol) → output.
External(layer, [item], symbol) → output.
Aggregate_Label(layer, item) → output.
List(file, [item]) → output.

for all L, L1, L2 ε layer, P ε parcel, I [I] $[I]_L$ $[I]_{L2}$ ε item, and S ε symbol.

Empty(Load(L,P)) = false.
Empty(Create) = true.
SpatialAg(Overlay(L1,L2), $[I]_{L2}$) = L2.
SpatialAg(L, $[I]_L$) = L.
Boundary(spatialag(L, [I]), s) = External(L, [I], s).
Overlay(L1, L1) = L1.
Overlay(Create, L) = undefined.
Overlay(L, Create) = undefined.
SpatialAg(Create, [I]) = undefined.

end.

end layer.

Note, output indicates that some form of output will result from the operation.

5.9 Conclusion

This chapter has examined the fundamental operations on parcels and parcel layers, particular emphasis has been placed on those operations which allow queries based on parcel relationships and therefore the integration of parcel data.

Many operations on parcel data are for the purpose of queries which may be considered a combination of selection and display. Textual or spatial selections which satisfy a particular query are made first and are followed by some form of display which may take the form of a plot or listing. However selections may also be made purely for data extraction purposes so that the chosen data may be utilised in other applications. In this case a new layer is created and consequently display may not be required initially. One example of an alternative operation is textual aggregation which may be used to summarise parcel data. The two fundamental query operations apply to a single layer, if selections based on one or more layers are required then they must be combined or integrated into one layer.

The overlay process allows two separate layers to be integrated and the results depend on the parcel relationships. If the layers are statistically dependent such that only relations which can be expressed in terms of containment are found, then the spatial component does not change significantly and the textual data linked to each of these layers are integrated. However, if the overlap relation occurs between the two layers, then new sub parcels are created and each new parcel obtains the attributes of the parent parcels. Hence overlay orders parcels by inclusion so that queries based on their integrated attributes may be performed.

It is often useful to illustrate parcels ordered by inclusion or to display higher level boundaries without their internal boundaries. These operations may be performed if it is possible to differentiate between internal boundaries and external boundaries so that they can be displayed separately. An extension of this interactive amalgamation process is to create a new permanent layer of specialised parcels with internal boundaries removed.

The determination of meet parcels is fundamental to this and other operations based on parcel relationships. Disjoint parcels within a simple parcel layer are those that are not meet. Furthermore, meet parcels that have the same attributes represent a common_bounds or concur relation with a higher order parcel, similarly, parcels that have different attributes to all other meet parcels represent an equal relation.

A parcel data representation which will support these fundamental operations must now be defined.

6. PARCEL REPRESENTATION

6.1 Introduction

The aim of this chapter is to define a data structure for the representation of parcel data which will allow the performance of the fundamental parcel operations described in chapter 5. Of primary concern is the overlay process as well as the representation of meet parcels because their evaluation is basic to many operations based on parcel relationships. Both these processes require the representation of polygon topology.

The structure must also efficiently represent textual data which is structurally different to the spatial component of parcels.

6.2 Hybrid Model

Parcel boundaries were traditionally represented on maps and their attributes in paper files or books. This tendency to separate the spatial and textual components of parcel data reflects their dissimilarity. Attributes are often too detailed to present adequately on a map and spatial data is not easily represented in a descriptive format.

The developers of data structures for representing parcels in a digital form have followed the lead set by their manual system counterparts. Different data structures are required for both digital spatial data and digital textual data, if these components are to be manipulated effectively. As in manual systems these components are linked by an identifier.

This hybrid approach to digital parcel representation is gaining increasing acceptance in LIS and GIS [Love and Zwart 1983] and is supported by Bullock [1984], Schuller [1985] and Burrough [1988]. Nevertheless some systems combine attribute and spatial data and even symbology in the one structure leading to increased complexity and confusion. These structures are typical of pure mapping and Computer Aided Drafting (CAD) systems.

The discussion on the digital representation of parcel data is divided into the textual and spatial components.

6.3 Textual Data

6.3.1 Introduction

Of the commonly known data structures, hierarchical, network and relational, the latter is gaining wide acceptance.

> "The future for data base systems undoubtedly lies with the relational model, a relatively new and still developing architecture. Its most important feature is the degree of data independence it offers the data base and hence its ability to respond to new user requirements."
>
> [Love and Zwart 1983]

The disadvantage of network and hierarchical structures is there inflexibility. Queries on the data must be along lines embedded into their structure. Hence all possible queries must be conceived at the design stage. The formation of logical expressions to ask questions of the data, as discussed in section 5.6.2, is not possible. Ad-hoc queries are an important data management consideration.

> "Flexibility must be built into the system to accommodate unforeseen applications and inquiries, which inevitably arise as the system expands to meet user demands."
>
> [Dale and M^cLaughlin, 1988]

6.3.2 The Relational Model

6.3.2.1 Structure

The relational model is simple in concept. Data is held in one or more two dimensional tables which consist of rows and columns. Columns represent a field or attribute name and may be referred to as items, they increase or decrease depending on the attribute classes to be represented. Rows represent single records which describe a distinct object in the system, such as a parcel.

Hence each column may represent an attribute item and each record will have only one attribute value for that item. An example is provided in Table 6-1.

County-id	Name	Population	Avg-Income
101	Bass	108 500	6 315.23
102	Flinders	161 683	6 700.50
103	Burke	2 951 377	7 251.75
104	Wills	23 255	5 493.12
105	Sturt	1 316 888	5 991.23

RECORD → (row 103); *ITEM* ↑ (Name column); *VALUE* ↖ (Burke)

Table 6-1

6.3.2.2 Relates and Joins

An operation that is fundamental to a relational database is a relate. A relate operates on two tables, each of which include a common item. Each record in a table A may be related to a record in a second table B if they share a common item. The relate operation is also simple in concept and is illustrated in figure 6-1.

TABLE A

BLDG	APT	NAME
C	1B	SWEENEY
A	3	JENNINGS
C	2A	STUBBLEFIELD
B	1	MOYNIHAN
B	5	COHEN
B	2	BENNETT
B	3A	POLANSKI
A	1	TALESE
B	4B	RODRIGUEZ

TABLE B

BLDG	STREET
A	270 CHESTNUT LANE
B	417 OCEAN VIEW DRIVE
C	311 HARBOR STREET

Figure 6-1.

Sometimes it is convenient to permanently join two related tables. This operation is called a JOIN and produces a new third table.

These operations permit the efficient organisation of data. Records about one subject may be placed in one table, while records for other subjects are placed in different tables. This improves data efficiency by minimising duplication. The relate operation allows files to be related together for the purposes of queries, listings and reports so that all the data appears to be in the one table.

The relate operator is fundamental to parcel based systems with a hybrid data structure. If the spatial component of parcels is kept in a different system to the attributes then the two may only work together effectively if the two components appear to be in unison. This is achieved by the relate operation and the common item is usually a parcel identification number.

6.3.2.3 Relationship Types

The relation illustrated in figure 6-1 is a typical *many to one* relationship. That is, a value in the relate item of table A is repeated many times, however there is only one occurrence of the same value in table B. Various other relationships between a table A and a related table B may occur.

One to one	Arises when each value for the relate item in table A is unique and corresponds with exactly one value in table B.
One to many	Arises when a number of records in table B correspond to one record in table A. That is, a value for the relate item in table A is repeated in several records for the relate item of table B.
One to none	Arises when a value in Table A does not have a corresponding value for the relate item in table B.
None to one	Arises when a value in the related table B does not have a corresponding value in table A.

These relationships are of particular interest when they occur between parcels and parcel records. A parcel may have many attributes values for an item, for example, visits to a farm. Also many disjoint parcels may share the same attribute, for example, a number of soil parcels may have the same soil type.

6.3.2.4 Summary

The advantages of a relational data structure for the representation of parcel attributes may be summarised as follows:

- addition or deletion of parcel records are easily implemented;
- changes to parcel attributes are easily implemented;
- facilitates a query language based on logical expressions so that combinations of attribute items with particular values may be selected and manipulated, and so ad-hoc queries can be made, and;
- selections and reports may be made across various related tables, hence parcel data may be linked to data which is not directly related to the parcel as a spatial entity.

6.4 Spatial Data

6.4.1 Introduction

The spatial representation of parcels falls into two broad categories: raster and vector. Raster systems perform most of the operations described in chapter 5 with relative ease. However they are totally inappropriate for cultural data, in particular legal and cadastral parcels [Bennett 1982].

Hence the vector data representation is considered more appropriate and must include the spatial topology of the represented features so that the operations of overlay and continuity determination may be efficiently performed.

Bennett [1982] described four models for representing vector data, namely optical centre, cartographic, areal and encoding. These were rejected on the basis that spatial topology was not adequately represented or the display operations were cartographically unacceptable. As a result a polygon network structure was designed which is similar to a number of other topological models now in existence.

6.4.2 Polygon Network Model

6.4.2.1 Description

Parcels are defined in terms of segments which in turn are defined in terms of points (figure 6-2). Segments meet at points which are called nodes. Segments have a start node and a finish node and may consist of any number of points between them [Chan 1984].

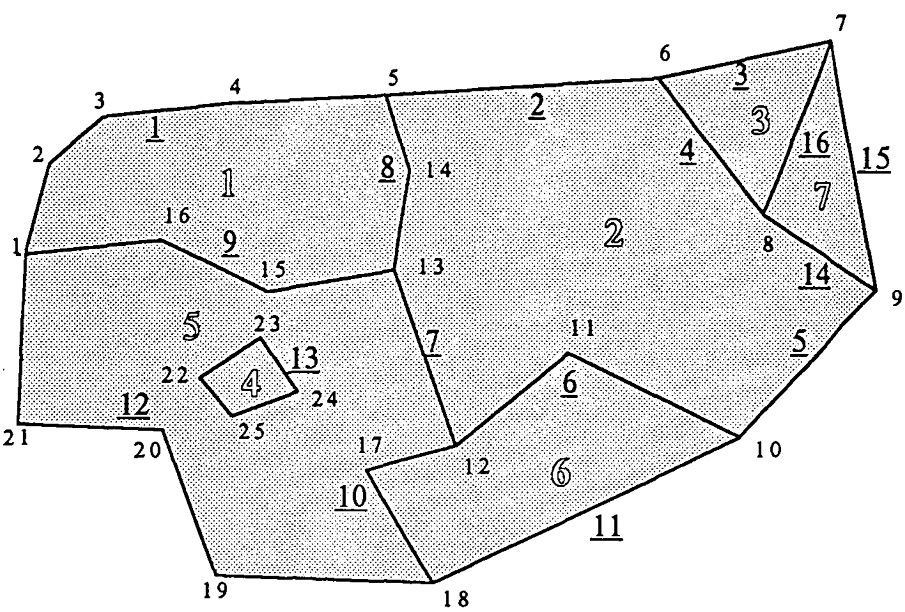


Figure 6-2.

PARCEL FILE	
Parcel number	Segment number
1	1, 8, 9
2	2, 4, 14, 5, 6, 7, 8
3	3, 16, 4
4	13
5	9, 7, 10, 12, 13
6	6, 11, 10
7	15, 14, 16

Table 6-3.

SEGMENT FILE	
Segment number	Point numbers
1	1, 2, 3, 4, 5
2	5, 6
3	6, 7
4	6, 8
5	9, 10
6	10, 11, 12
7	12, 13
8	13, 14, 5
9	13, 15, 16, 1
10	12, 17, 18
11	10, 18
12	18, 19, 20, 21, 1
13	22, 23, 24, 25, 22
14	8, 9
15	7, 9
16	7, 8

Table 6-4.

POINT FILE		
Point number	X coordinate	Y coordinate
1	526200.00	5248011.65
2	526205.68	5248120.79
3	526286.43	5248209.68
4	526401.94	5248228.32
5	526613.15	5248235.53
6	.	.
7	.	.
.	.	.
.	.	.
.		

Table 6-5.

POLYGON SUMMARY FILE							
Parcel number	Centroid X	Centroid Y	Min X	Min Y	Max X	Max Y	Area
1	val	val	val	val	val	val	val
2	val	val	val	val	val	val	val
3	val	val	val	val	val	val	val
4	val	val	val	val	val	val	val
5	val	val	val	val	val	val	val
6	val	val	val	val	val	val	val
7	val	val	val	val	val	val	val

val indicates a REAL value.

Table 6-6.

SEGMENT SUMMARY FILE					
Segment number	Start point number	End point number	Left parcel number	Right parcel number	length
1	1	5	0	1	val
2	5	6	0	2	val
3	6	7	0	3	val
4	6	8	3	2	val
5	9	10	0	2	val
6	10	12	6	2	val
7	12	13	5	2	val
8	13	5	1	2	val
9	13	1	5	1	val
10	12	18	6	5	val
11	10	18	0	6	val
12	18	1	0	5	val
13	22	22	5	4	val
14	8	9	7	2	val
15	7	9	0	7	val
16	7	8	7	3	val

Table 6-7.

The parcel file (table 6-3) and segment file (table 6-4) require variable length records. A parcel may consist of any number of segments and a segment may consist of any number of points. Hence it is inappropriate to implement this structure in a relational database. The summary files (tables 6-6 and 6-7) are normalised however, and may be represented in a relational structure with the advantage that items for parcel or segment attributes may be added to the table.

This polygon network representation of parcels is typically implemented as a collection of files. The key to the files are the feature (point, segment and parcel) identification numbers or master index pointers. The files are usually sequential which causes problems when features are edited. They also have a tendency to become very large as do most spatial structures.

The discussion above is a simplified description of the polygon network model, often a number of other files are required for the efficient management of spatial data.

This model has developed a variety of names:

- fully topological polygon network structure [Burrough 1988];
- universal spatial topological model [Bennett 1982];
- topological model [ESRI 1987]

6.4.2.2 Advantages

1. Allows cartographically acceptable display operations given certain implementation procedures and operations.

2. Formation of parcels and coding of segments may be performed automatically [Burrough 1988] (this capability makes it suitable for polygon formation in the overlay process).

3. Includes complete topology including segment continuity and node parcel relationships.

4. Fundamental topological relations can be implemented.

5. Eliminates redundant data.

6. Allows direct access to coordinates which facilitates display operations and import and export between grid systems.

7. Provides data access flexibility, features may be selectively extracted as points, line strings or parcels as required.

8. Internal and external boundaries are easy to determine.

9. Parcels are represented as an entity.

6.4.2.3 Disadvantages

1. Complex data structure.

2. Computing overhead in formation of parcels and line coding.

6.5 Parcel Data Structure

The most advantageous structure for representing parcel data is a hybrid of the relational model for attributes and the polygon network structure for the spatial component. The complexity of this structure introduces a limitation but this is surpassed by the flexibility that it provides for both spatial and textual queries. The most distinct advantage is that the model handles all six fundamental topological relations between parcels.

> "Topologically structured vector data are essential in the creation of large digital map files."
>
> [National Research Council 1983]

Hence a parcel layer may be represented by a network of logically connected line strings, the relationships between the parcels, lines and points is defined in a number of files. Each map feature has a unique number which may be represented in a relational database. This number is included in a table (parcel summary file or segment summary file) which may also include the attributes of the map features. Attribute data may also be held in any other relational table provided that there is a suitable common item to link the necessary tables.

6.6 Layers

It is not convenient to hold all possible parcel themes in one layer. Parcels of different themes may be held in separate layers within a database. This provides greater access flexibility and speed, it also allows the logical separation of themes to be preserved so that data can be managed effectively.

Hence the groups of files of the polygon network structure may be repeated numerously. There will be a group of files for each layer and each will have associated tables in the relational data base which maybe linked to any of the layers.

This layer structure is possible if all coordinates, held in the structure are based on a common map grid so that maps may be overlayed or simply drawn in coincidence. Therefore separate layers are linked or related spatially via a common location using coordinates and each layer is linked to the textual data via the feature identifiers. This structure is illustrated conceptually in figure 6-3.

6.7 Conclusion

Parcels and parcel layers may be represented digitally in an information system by means of a hybrid structure which incorporates a polygon network model for the spatial component and a relational model for the textual component. The separate models, which are related via an identification number, appear to be in unison to the user.

The model defines a layer via a number of files which include a definition of the topological relationships of the parcels and the parcel constituents represented in the layer. Parcels are defined by one or more segments which in turn may be composed of two or more points. Consequently, meet polygons share a common boundary and their evaluation may be performed by examining the left and right polygons on either side of a segment. Given this basic operation, others based on disjoint, common_bounds, concur and equal relations may also be implemented. Furthermore, algorithms are available which allow the automatic definition of the topological relationships which is an important criteria for the overlay process. Therefore this structure will facilitate the manipulation of overlap parcels.

Each parcel in a layer has a unique identification number which may be represented in one or more tables in a relational data base. Relational data bases provide a simple, easy to understand structure for textual data. They also allow ad-hoc queries in the form of logical expressions, in terms of attribute items and values, which provides greater flexibility.

Parcel themes are separated into layers which provides a logical means of separating data. The number of layers is conceptually unlimited, however each must be on the same coordinate system. Layers are integrated via a common spatial location through the overlay process.

Therefore the hybrid data model with components as described above provides flexibility, efficiency and full spatial topology which, more importantly, permits the performance of the fundamental operations as discussed in chapter 5. The cost of this ability is a complex spatial data structure.

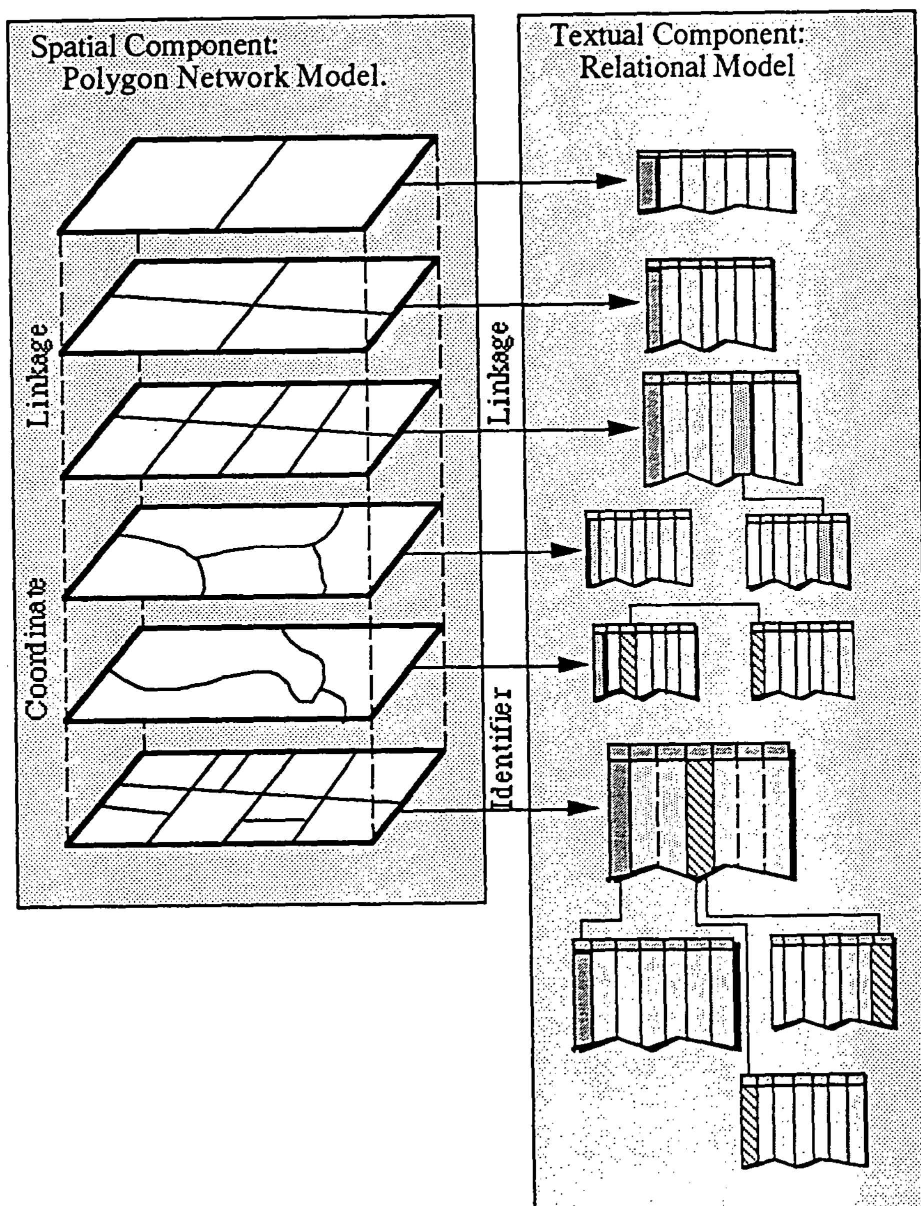


Figure 6-3.

7. REPRESENTATION OF PARCEL TYPES

7.1 Introduction

Chapter 6 introduced one method for representing various parcel types which required the creation of a separate layer for each theme. This approach may seem the most obvious, particularly since it allows the logical separation of data that is normally held in different systems within different organisations. However this representation of parcels appears inefficient, particularly for statistically dependent parcel types consisting of conterminous boundaries, each of which may be repeated in a number of layers. This repetition results in the duplication of collection and maintenance as well as storage.

This chapter evaluates a number of alternate models for representing a variety of themes of parcel based data given the ideal representation of a parcel layer as defined in chapter 6 and the operations performed on and within layers as discussed in chapter 5.

The initial approach is the separate layers model. Two further models, the combined layers model and the structurally enhanced combined layers model, are then introduced to overcome the limitations of the preceding methodology. The latter two models are particularly appropriate for cultural parcels and therefore will be discussed mainly from that perspective.

7.2 Separate Layers - Model I

7.2.1. Description

A new layer is produced for each parcel type. For example, the model may include legal, fiscal, farm, soil, municipal, vegetation and grant parcel layers, as shown in figure 7-1. Each of these layers is a primary layer and is maintained by their respective trustees. These layers consist of only meet and disjoint relations as each parcel in the layers will be linked to only one identifier.

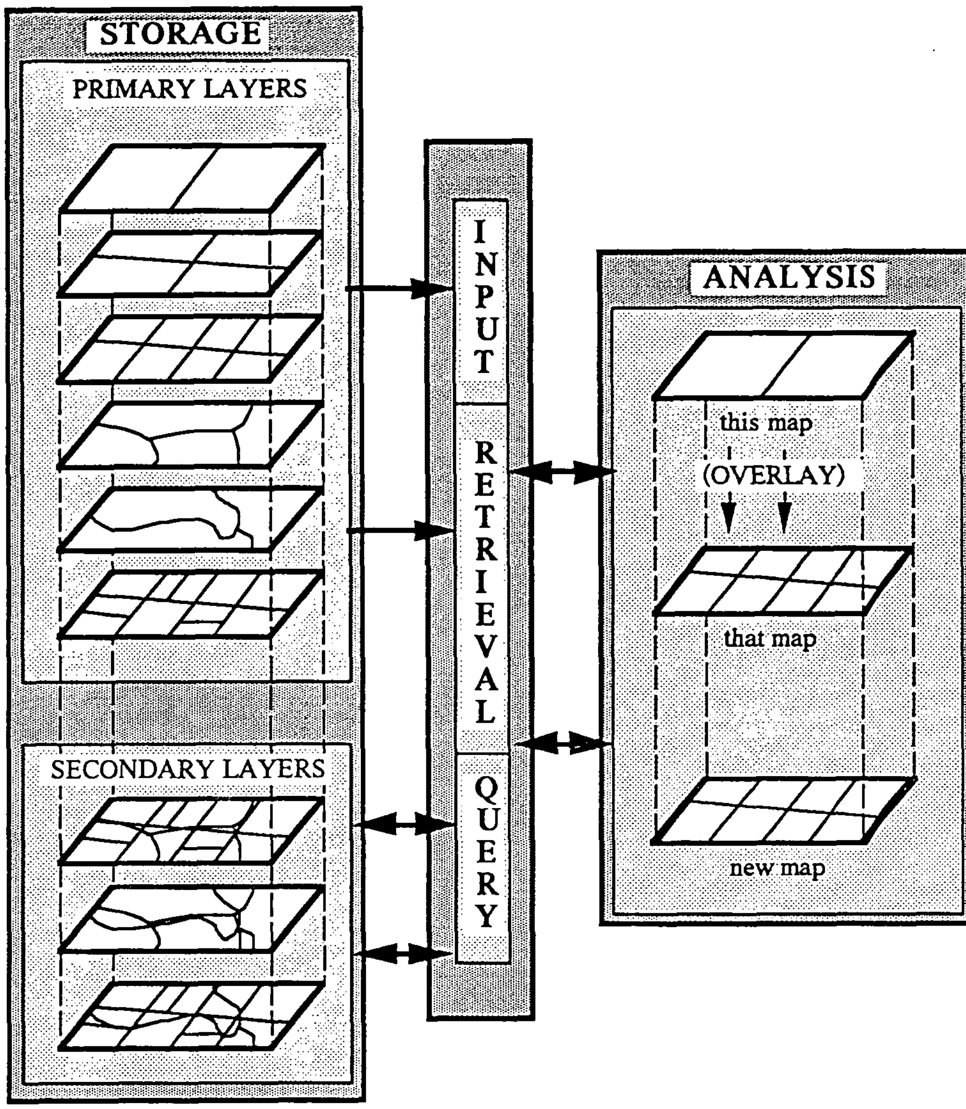


Figure 7-1

Parcel relationships such as common_bounds, concur, equal and overlap are established by overlay. Hence an overlay must be performed to determine the names of legal owners of a farm. Secondary layers that are produced to resolve such queries may or may not be maintained in the system.

7.2.2. Advantages

1. Simple, layers are logically separated into distinct themes.

2. Each layer allows a parcel to be treated as a unit. Hence queries are answered quickly and efficiently.

3. Trustees may develop and maintain their layers as they desire, without interference from other organisations.

4. Custodianship is well defined.

5. Meet and disjoint relations may be evaluated within a parcel layer.

6. Relationships between layers may be found by overlay to produce a secondary layer.

7.2.3. Disadvantages

1. Does not utilise hierarchical relations. Hence common segments are repeated several times throughout the layers of the model.

2. Storage overhead.

3. Layers are maintained independently of the other statistically dependent layers. Hence update operations must be repeated several times for common segments.

4. Individual maintenance of common segments leads to inconsistencies which cause spurious polygons such as silvers and gaps during overlay.

5. Trusteeship of secondary layers is poorly defined and as a result they may have a short life expectancy. Hence the same overlay is performed repeatedly.

7.2.4. Conclusion

The individual maintenance of common boundaries is clearly undesirable. Should a parcel be subdivided in this model, then an update is performed on the legal or cadastral layer. However, the trustees of the fiscal layer or the farm layer may not be interested in this update until the new parcel is sold. At the time of sale the new boundaries are added to these layers as a separate exercise. Hence there is a duplication of the same update process at different times. If different techniques are used to update the affected parcel then more complications are created.

Also, the primary layers whose maintenance is assured, may be queried less often than secondary layers whose currency is in doubt. For example, valuers always query soil information, hence a soil/fiscal layer will be in demand perhaps more than the primary fiscal layer. These layers are statistically independent, consequently there is little advantage in maintaining a composite soil/fiscal layer. It is more appropriate to maintain the two primary layers and update the secondary layer by performing the overlay at regular intervals in a batch environment. The maintenance of secondary layers produced from statistically independent primary layers tend to pose management problems. However if there is a strong statistical dependence between layers then there is merit in maintaining a composite layer of the two primary layers as a primary layer.

The logical separation of themes into layers may provide database simplicity in terms of organisation, however such a structure hinders mainstream queries which require the evaluation of parcel relationships. Although the relationships can be established by overlay, the repeated performance of this operation is inefficient. Hence the model for representing parcel relationships must take into account the intended use of the data and storage efficiency.

7.3 Combined Layers - Model II

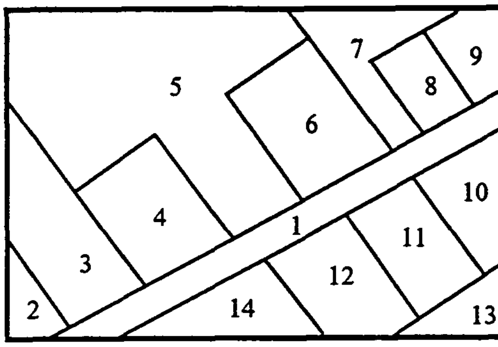
7.3.1 Description

7.3.1.1 General

The combined layers approach attempts to take advantage of common_bounds, concur, equal and, to some extent, overlap relations. This model is primarily designed for statistically dependent layers such as those of cultural themes. It is essentially the same as the multipurpose cadastre model in that cultural parcels are represented by the one layer linked to various files via a family of identifiers such as a central cross reference index. However the cadastral parcel need not be the basic parcel.

Conceptually the multipurpose cadastre model may be seen as the product of a series of overlays. When two layers are overlayed and all the boundaries of layer A are already represented in layer B then the composite layer that is produced is spatially the same as layer B. However the new layer has combined attributes for each parcel. This is shown in figure 7-2 where cadastral and fiscal layers are overlayed. This new composite layer can be successively combined with other statistically dependent layers, such as farm or county layers, until a multipurpose cadastre model is produced (figure 7-3).

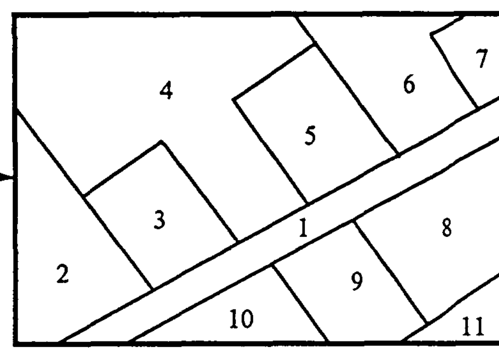
LEGAL LAYER



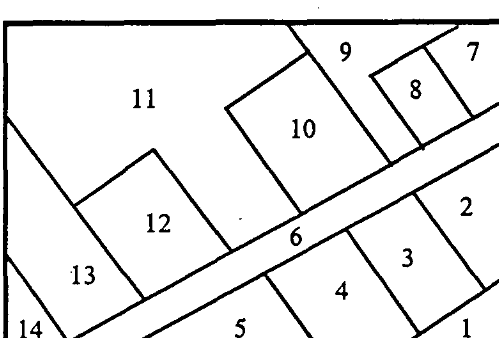
Parcel id	Legal id
1	RD
2	L01
3	L02
4	L03
5	L04
6	L05
7	L06
8	L07
9	L08
10	L09
11	L10
12	L11
13	L12
14	L03

Parcel id	Fiscal id
1	RD
2	F02
3	F03
4	F04
5	F05
6	F06
7	F07
8	F08
9	F09
10	F03
11	F10

FISCAL LAYER



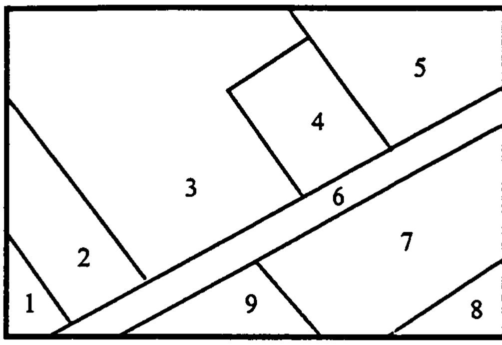
LEGAL/FISCAL LAYER



Parcel id	Legal id	Fiscal id
1	L12	F10
2	L09	F08
3	L10	F08
4	L11	F09
5	L03	F03
6	RD	RD
7	L08	F07
8	L07	F06
9	L06	F06
10	L05	F05
11	L04	F04
12	L03	F03
13	L02	F02
14	L01	F02

Figure 7-2.

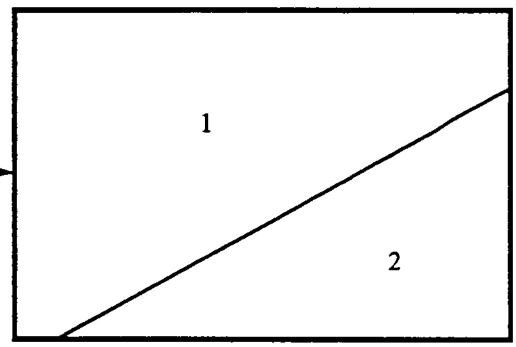
FARM LAYER



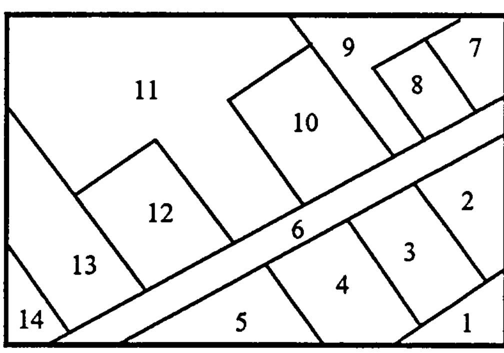
Parcel id	Farm id
1	A01
2	A02
3	A03
4	A04
5	A05
6	RD
7	A06
8	A07
9	A03

COUNTY LAYER

Parcel id	County id
1	C01
2	C02



LEGAL/FISCAL/FARM/COUNTY LAYER



Parcel id	Legal id	Fiscal id	Farm id	County id
1	L12	F10	A07	C02
2	L09	F08	A06	C02
3	L10	F08	A06	C02
4	L11	F09	A06	C02
5	L03	F03	A03	C02
6	RD	RD	RD	C02
7	L08	F07	A05	C01
8	L07	F06	A05	C01
9	L06	F06	A05	C01
10	L05	F05	A04	C01
11	L04	F04	A03	C01
12	L03	F03	A03	C01
13	L02	F02	A02	C01
14	L01	F02	A01	C01

Figure 7-3.

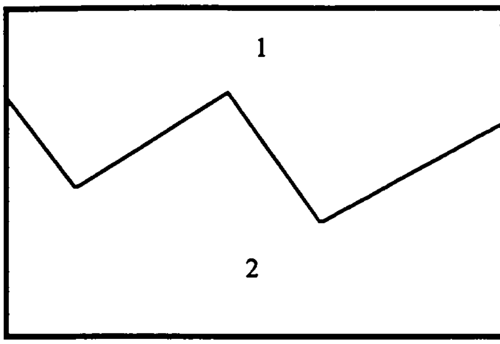
In practice, a model is not created in this manner. Instead a cadastral layer or DCDB is produced and identifiers are linked to each parcel. This can be performed by various manual or semi automatic methods. The resulting cadastral layer with combined identifiers becomes the primary layer.

Utilising the operations described in chapter 5 the layer can be queried as a function of the represented units. Also, specialised layers based on amalgamated units can be produced using the spatial aggregation process should the need arise.

However the multipurpose cadastre model does not effectively handle the low incidence of overlap parcels (section 3.3.2). A solution is available if one is prepared to accept that the legal or cadastral parcel need not be the basic spatial unit.

Layers such as the municipal layer in figure 7-4 can be overlayed on the cadastral layer. The legal parcels subject to the overlap relation are split in two and each of the portions are assigned the relevant municipal codes. This operation can be repeated for the census district parcels as shown in figure 7-5.

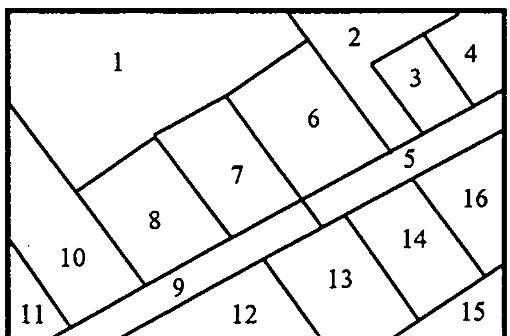
Likewise, this model need not be created by overlay. The cadastral layer can be used as a base and codes can then be added by identifier linking. Whenever an anomaly arises, the affected parcels can be split into sub cadastral parcels by adding the necessary boundaries. Each sub parcel retains all the original parent identifiers but separate identifiers from the parcels which caused the subdivisions.



MUNICIPAL LAYER

Parcel id	Municipal id
1	M01
2	M02

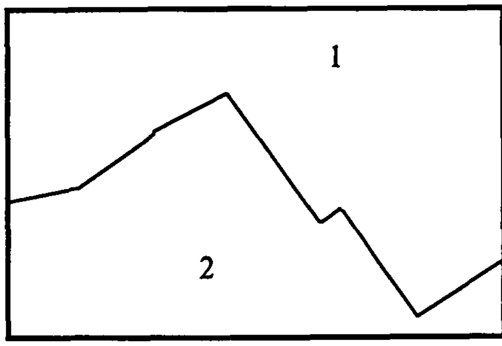
LEGAL/FISCAL/FARM/COUNTY/MUNICIPAL LAYER



Parcel id	Legal id	Fiscal id	Farm id	County id	Municipal id
1	L04	F04	A03	C01	M01
2	L06	F06	A05	C01	M01
3	L07	F06	A05	C01	M01
4	L08	F07	A05	C01	M01
5	RD	RD	RD	C02	M01
6	LO5	F05	A04	C01	M01
7	L04	F04	A03	C01	M02
8	L03	F03	A03	C01	M02
9	RD	RD	RD	C02	M02
10	L02	F02	A02	C01	M02
11	L01	F02	A01	C01	M02
12	L03	F03	A03	C02	M02
13	L11	F09	A06	C02	M02
14	L10	F08	A06	C02	M02
15	L12	F10	A07	C02	M02
16	L09	F08	A06	C02	M02

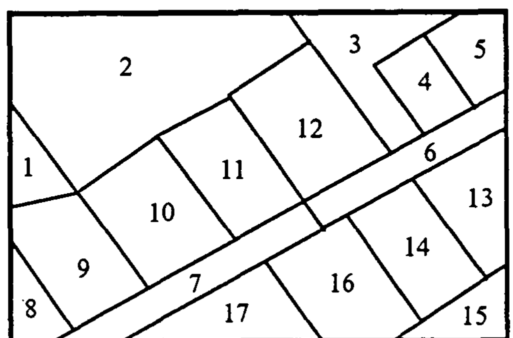
Figure 7-4.

CENSUS LAYER



Parcel id	Census id
1 2	CD1 CD2

COMBINED LAYER



Parcel id	Legal id	Fiscal id	Farm id	County id	Municipal id	Census id
1	L02	F02	A02	C01	M02	CD1
2	L04	F04	A03	C01	M01	CD1
3	L06	F06	A05	C01	M01	CD1
4	L07	F06	A05	C01	M01	CD1
5	L08	F07	A05	C01	M01	CD1
6	RD	RD	RD	C01	M01	CD1
7	RD	RD	RD	C01	M02	CD2
8	L01	F02	A01	C01	M02	CD2
9	L02	F02	A02	C01	M02	CD2
10	L03	F03	A03	C01	M02	CD2
11	L04	F04	A03	C01	M02	CD2
12	L05	F05	A04	C01	M01	CD1
13	L09	F08	A06	C02	M02	CD1
14	L10	F08	A06	C02	M02	CD1
15	L12	F10	A07	C02	M02	CD2
16	L11	F09	A06	C02	M02	CD2
17	L03	F03	A03	C02	M02	CD2

Figure 7-5.

Figures 7-2 through to 7-5 illustrate how the central index changes as cultural parcel definitions are added to the layer. Hence there is a set of identifier values (item) in the central index for each parcel layer represented by the model. This identifier provides the spatial definition of the parcel in terms of the basic unit and serves as a key to various other files linked to the central index. The model is illustrated conceptually in figure 7-6. The combined layer is added to the data base as a primary layer (figure 8-1).

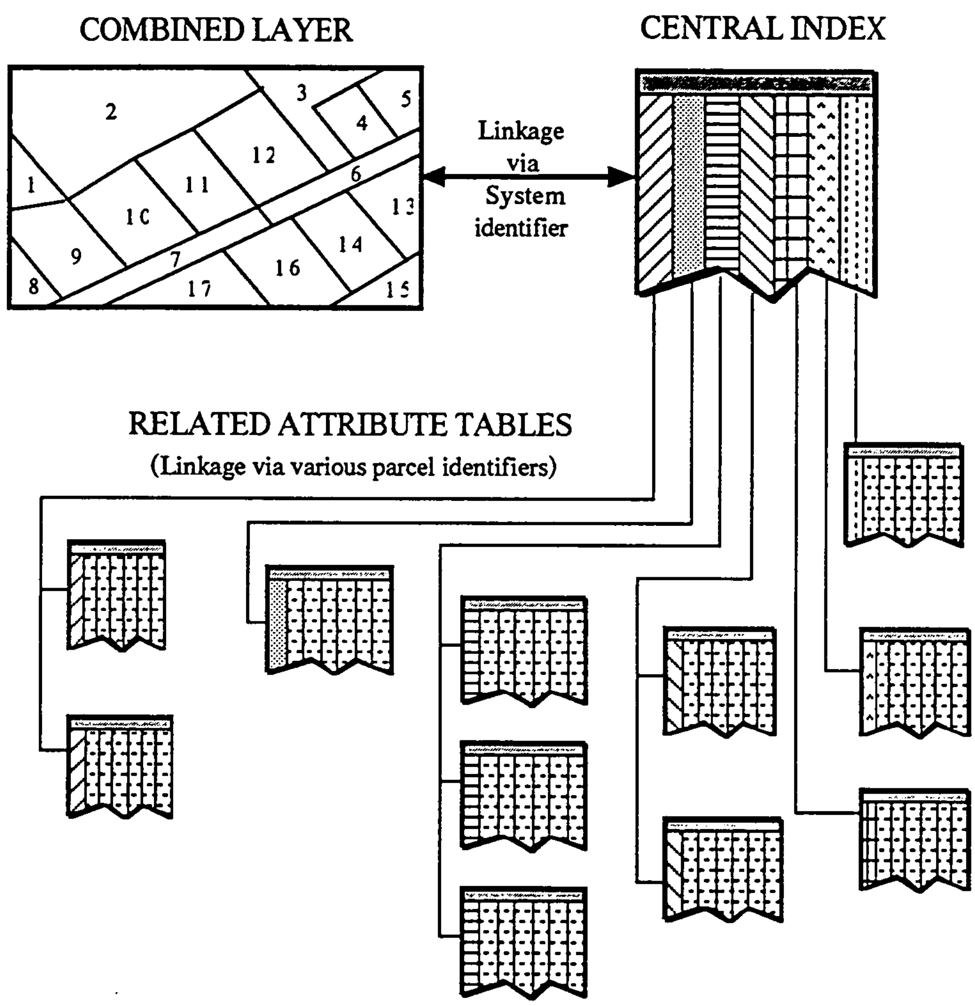


Figure 7-6.

The combined layer model is not unlike the model espoused by Bullock [1984] which is illustrated in figure 7-7. The main difference is that the ownership (cadastral) parcel is not the basic unit and an existing identifier is used to link the spatial component with the central index. The combined layers model provides greater flexibility by allowing sub parcels of the cadastral parcel to be the basic unit. However, in most situations these subdivisions of the cadastral parcel are rare.

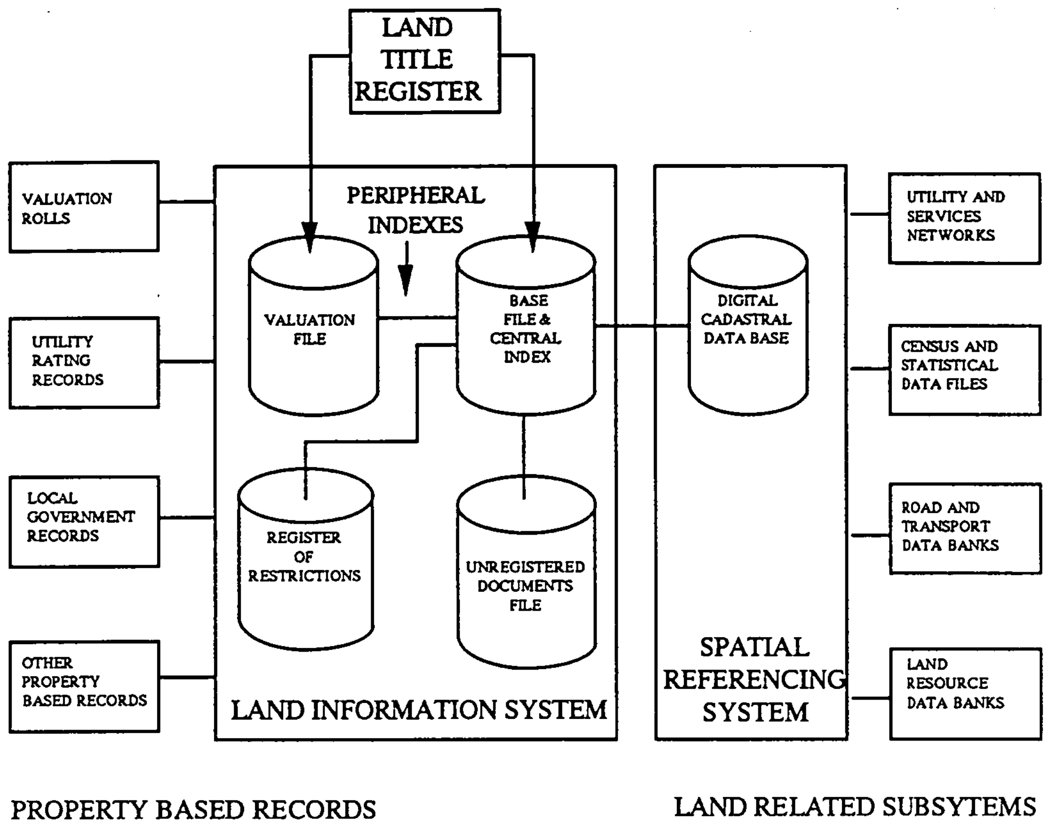


Figure 7-7.

7.3.1.2 Basic Parcel

The basic parcel of the resulting cultural layer is not a distinct entity and is therefore more appropriately defined in terms of the identifiers represented in the central index. Each parcel represents a particular combination of central index identifiers, boundaries occur wherever there is a change in any one of the identifiers. Therefore a spatial aggregation using all identifiers in the central index should not change the layer. That is,

SpatialAg(Combined_Layer,[Central_Index_Items]) → Combined_Layer.

7.3.1.3 Identifiers

The central index of this model may consist of a large number of identifiers, one identifier item is required for each parcel definition that is represented in the layer. It is the identifier that provides the parcel definition and so allows the parcel to be treated as a unit. A number of basic parcels, both meet and disjoint, represent a higher level parcel if they share the same identifier for that unit. However, many believe that an efficient system has only one identifier set and therefore seem unable to grasp this notion. This is evidenced in the past by the studies of Moyer and Fisher [1973] and Ziemann [1976].

Previous studies have also encouraged the creation of identifiers with embedded meaning such as hierarchies and coordinates. The problems of hierarchical identifiers were introduced in chapter 4. These identifiers also cause some conflict in this model since a higher level identifier may not match the code embedded in the lower level identifier. This is examined in more detail in chapter 9 under the discussion of the Coal River Pilot GIS.

It seems that the most appropriate identifiers are those which have no embedded meaning. This becomes a valid alternative in a computer system where the identifier which links the parcel with the attributes is hidden from the user. The speed of computers allows users to determine with ease, centroid coordinates, common addresses and other attributes for parcels and vice versa. Hence there is no need to clutter the identifier with information.

The important identifier of this model is the one that links the spatial feature (parcel) with the corresponding record in the central index. The only characteristic required of this identifier is uniqueness, a condition not satisfied by existing identifiers. There are three reasons for this: human error; common_bound parcels and; disjoint units. The first and third are unavoidable and are closely related. The second is a feature of the combined layers model since a higher level parcel is defined as a number of adjoining basic parcels with the same identifier for that particular parcel.

A new, machine generated sequential numbering system is recommended for the identifier which links the spatial component with the central index. This number should not be allowed to have any significance outside the model.

7.3.1.4 The Many To One Problem.

A many to one relationship often exists between basic parcels and attributes within this model. Common_bounds and concur parcels consist of many basic parcels which are linked to one record in various attribute tables. Two problems stem from this situation as a result of spatial selections.

When a spatial selection is made on the basis of a circle, box or single point, only some of the sub parcels may be chosen. The remaining fragments may fall outside the search criteria. If the selected unit is to be displayed, then only the selected portions are highlighted. This problem is overcome by performing an ADDSELECT after each spatial selection to ensure the selection of all fragments with the same identifier values as the currently selected sub parcels.

Secondly, there may be many occurrences of the same record when the parcel data is listed. Although a parcel may only have one record associated with it in the tables, all sub parcels are linked to that record and so it is repeated for each selected sub parcel. This may be resolved by filtering the data before it is listed using textual aggregation.

If necessary both these problems may also be overcome by producing a specialised layer using spatial aggregation. A specialised layer will generally contain one to one relationships between the subject unit and the attributes except where units consist of areal discontinuities.

The decision on whether to produce a specialised parcel layer or to use the combined layer for queries will depend on the individual organisation. If an organisations' queries are generally independent of other themes, then it may be beneficial to produce a specialised layer. However if parcel relationship determination is an important basis for most queries, then the combined layer may be used as a function of all of the units

7.3.1.5 Quantitative Attributes

The difficulties which result from the distribution of quantitative attributes to sub parcels is closely related to the many to one problem. The combined layers model allows quantitative values, associated with higher level units in the various tables, to be linked to sub parcels. This may create misleading situations since quantitative attributes do not apply to portions of parcels. For example, the population of a municipality may be listed in relation to a census district or fiscal parcel valuations may be assigned to individual legal parcels.

The model requires a mechanism to restrict the access of these quantitative values via parcels other than the ones to which they apply. These restrictions may be implemented by representing quantitative values in tables which are read protected from unauthorised use. Alternatively a menu driven query package may be built on the model which does not allow unauthorised access. Clearly such mechanisms are data specific and will depend on the rules and procedures of particular organisations. Nevertheless they must be considered in the implementation of a model which allows data integration.

7.3.1.6 Disjoint Units

This model adequately copes with the problem of disjoint fragments of a unit of record as introduced in chapter 2. Since a unit is defined by the areas of land with the same identifiers, then any disjoint parcels with the same identifier must belong to the same unit. However if a spatial selection is performed then all units with the same identifier values must be selected before a display is performed, as discussed in section 7.3.1.4. This typical many to one problem is not solved by spatial aggregation.

7.3.1.7 Anomalous Parcels

Most disjoint fragments are caused by roads, double sided rivers and other anomalies. These are parcels in their own right and cannot be avoided. They arise in both the separate and combined layers models.

These parcels generally do not have identifiers due to their anomalous characteristic, hence they would be normally assigned an identifier to indicate this non conformity. Likewise, many legal parcels in an urban area, for example, are not of interest to an Agricultural organisation, hence do not have farm identifier values. These may be assigned the same value (for example 'N/A') to reflect this situation.

However, anomalous parcels which sever other parcels may be assigned the identifier of the enclosing parcels. For example the road illustrated in figure 7-8 may be utilised by the farm as a whole for most practical purposes, hence the road may be assigned the identifier of the farm. Nevertheless if a legal identifier exists it should be assigned to the road so that the actual ownership can be determined.

This procedure is typically performed for many of the higher level units such as municipalities. The adoption of this principle may necessitate the subdivision of roads into smaller units as advised by the Cook definition of chapter 2. The subdivision of these very long narrow parcels into more manageable areas is often an advantage.

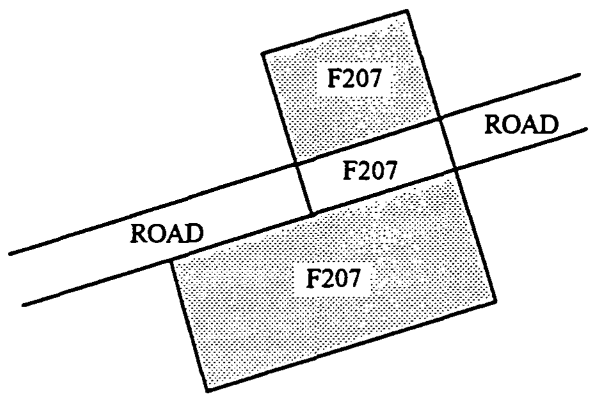


Figure 7-8

7.3.1.8 Creation

Creation is best implemented by the manual mutation of a cadastral layer as this avoids the development of inconsistencies such as silvers and spurious polygons. If the cadastral layer is used as a template, then the overlay process is not required. The advantage of this is that the vagaries of fuzzy creep are avoided, hence the spatial location of cadastral boundaries in the primary combined layer will not be in doubt.

7.3.1.9 Updates

If specialised layers are produced, organisations must guard against performing updates or modifications on this derived layer. Any spatial changes must be performed in the combined layer so that the source is kept updated. Should an update to the source occur, then the secondary layer may need to be redetermined by spatial aggregation.

Some updates to the combined layer may not have an effect on derived layers. Most modifications to higher level parcels will be a result of legal parcels changing attributes, which may perhaps be caused by a sale. Hence this will only require an update in the central index which will reflect a change in the spatial extent of the higher level parcels. That is, a change of ownership, depending on the circumstances, is reflected in the fiscal and farm parcels when the appropriate identifiers are modified.

Subdivisions of the legal parcel will actually require a spatial modification to the combined layer with corresponding changes to the central index. Spatial changes to the combined layer may also be caused by mutations to parcels at a level lower than the legal parcel, for example, land use and paddocks. High level parcels such as municipalities and counties rarely experience changes in their spatial extent. However should this occur, they usually conform to existing boundaries which would only require modifications to the identifiers in the central index. Nevertheless, this model will cater for the changes which sever existing basic parcels in the combined layer.

7.3.2 Advantages

1. Simple, one layer for cultural parcels linked to physically separated textual data.

2. Display and query operations described in chapter 5 allow the various hierarchical parcels to be treated as separate units.

3. Common_bounds, concur and equal, as well as meet and disjoint relations are represented in the primary layer.

4. Minimal duplication in storage and update since the combined layer is the primary layer.

5. The low incidence of the overlap relation is catered for by the cultural layer.

6. Secondary layers which consist of specialised parcels may be produced quickly and simply if required by spatial aggregation.

7. Reflects the true situation.

7.3.3 Disadvantages

1. Slow, not as fast and efficient as the separate layers model when used for queries and display of individual definitions. Particularly for higher level parcels.

2. Difficult to create conceptually. Complex situations may cause digitising and attribute linking problems.

3. The legal parcel is no longer the basic unit.

4. Trusteeship of the combined layer is not clear.

5. There is an overhead in identifiers for one layer.

6. Many to one problem.

7.3.4 Conclusion

In summary, the combined layers model consists of a spatial layer linked to a wide range of relational tables via a central index (figure 7-6).

The layer may be thought of as an overlay of separate layers of themes represented in the central index. Each parcel in the index consists of an identifier set for each parcel definition represented in the combined layer. The relational tables hold the parcel attributes for the represented parcels and are keyed to one or more of the identifiers in the central index. Ideally some restrictions are required in the linking mechanism so that quantitative attributes of high level units cannot be construed as belonging to sub parcels.

The main improvement of this model over the separate layers model is that the combined layer is primary and any specialised one parcel definition layers are secondary. Hence source updates, as defined by Mullins [1988], are restricted to one layer. Also, queries which require the evaluation of common_bounds, concur, and equal relations, may be readily performed between the various parcel definitions represented in the combined layer.

7.4 Structurally Enhanced Combined Layers - Model III

7.4.1 Description

The combined layers model determined higher level parcels by grouping together basic parcels with the same parcel identifier. The speed of this operation may be improved if the polygon network structure is enhanced to more efficiently cater for common_bounds and concur parcels.

Spatially the model is the same as the combined layers model but instead a parcel file (table 6-3) is created for each parcel definition represented in the layer. Figure 7-9 and table 7-1 illustrates a combined layer and central index for a small area. Figure 7-10 illustrates the same data after the structural enhancement. the segment and point files are similar to those for the polygon network files described in section 6.4.2

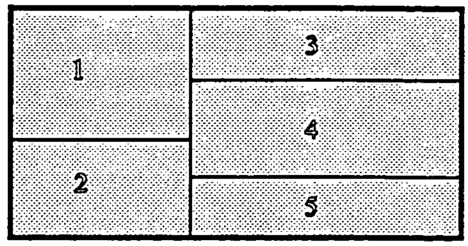


Figure 7-9

Parcel id	Legal id	Fiscal id	Farm id
1	L1	F1	A1
2	L2	F1	A1
3	L3	F2	A2
4	L4	F2	A2
5	L5	F3	A2

Table 7-1

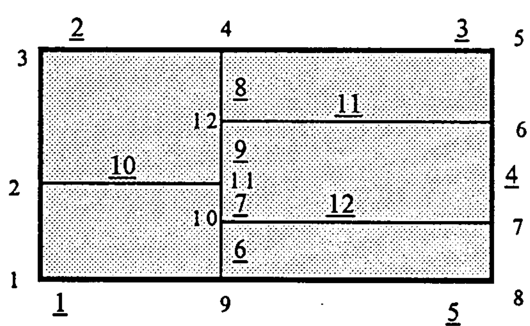


Figure 7-10.

LEGAL PARCEL FILE	
Parcel id	Segment numbers
1	2, 8, 9, 10
2	1, 10, 7, 6
3	3, 11, 8
4	11, 4, 12, 7, 9
5	6, 12, 5

Table 7-2.

FISCAL PARCEL FILE	
Parcel id	Segment numbers
1 2 3	1, 2, 8, 9, 7, 6 3, 4, 12, 7, 9, 8 6, 12, 5

Table 7-3.

FARM PARCEL FILE	
Parcel id	Segment numbers
1 2	1, 2, 8, 9, 7, 6 3, 4, 5, 6, 7, 9, 8

Table 7-4.

In practice, this model is very similar to the separate layers model except that the segments referred to in the polygon files are in the one file. The points referred to in the segment file are also in one file. The model is therefore a hybrid of the separate and combined layers models.

This structure is similar to the one described by Gerald Temple following a presentation of the system used in Cape Coral, Florida [Temple and Jenkins 1988].

7.4.2 Advantages

1. Allows the represented parcels to be treated as a unit.

2. External boundaries of higher level parcels may be quickly established.

3. Minimal duplication in boundary storage and update.

4. Caters for the low incidence of overlap relations (although not demonstrated in example).

7.4.3 Disadvantages

1. Complex, the polygon network model is further complicated. Special operations are required to query the data.

2. Decreases functionality of generic polygon network data structure.

3. Internal boundaries are difficult to determine and therefore display.

4. Determination of parcel segments may be faster but segment and point files are still large and so require the same amount of search time to find desired features as the combined layers model.

5. Although it maybe possible to display hierarchical relations, but it is is still difficult to query them as the attribute files are not linked.

7.4.4 Conclusion

The structurally enhanced model provides the advantages and disadvantages of both previous models. Consequently it is a compromise model which provides no distinct advantages. The main disadvantage is the complexity of the data structure which provides only a limited degree of efficiency. It may be useful for some combined layers but the overheads are too much for the average layer to carry.

It is not possible to query attributes for sub parcels unless the structure is complicated further by including their identifiers in the parcel files. This adds to the complexity and is not recommended. Although parcel segments are quickly established in the model, the same amount of time is required to establish the coordinates, as it does for the combined layers model.

Hence the speed and efficiency of the model do not match that of a specialised layer. The model also does not satisfactorily allow queries based on hierarchical relations.

7.5 Conclusion

This chapter examined the representation of a variety of parcel types and their relationships. Three models were introduced which are all equally capable of representing parcels and the six basic parcel relations discussed in chapter 4. However they differed in the way statistically dependent data is represented, which has implications on the storage, collection and maintenance activities.

All parcel data may be conveniently represented by a number of separate layers, where each layer corresponds to a particular theme. The textual data for each theme is linked to the spatial component via an identifier and the layers are linked to each other via their spatial location. Each layer will consist of the two principle relations of meet and disjoint, however the other relations are represented amongst the layers rather than within them. Consequently a separate layer is created for parcels that can be defined in terms of other parcels held within different layers in the model. Each layer will be a primary layer linked only to textual data that is relevant to the particular theme. If these themes are to be integrated, then the overlay process must be performed.

The main disadvantage of this separate layers model is that it ignores the benefits provided by the common_bounds, concur and equal relations. The combined layers model overcomes this limitation by efficiently representing in one layer a number of parcel types which produce this relation. It is particularly useful for cultural parcels where high level units are defined in terms of the basic cultural unit. Higher level units are represented by an identifier which is assigned to each base parcel. Base parcels with the same value for a particular identifier constitute a particular unit which may be displayed or aggregated when necessary. The advantages of this approach are in maintenance, since a modification to a parcel boundary will be reflected in all other themes that are represented in the model.

To a large extent statistically independent data must still be represented in separate layers as it is difficult to represent the overlap relation in a single layer. Nevertheless, it is still efficient to represent small occurrences of the overlap relation in the combined layer by expressing them in terms of the common_bounds or concur relations. However, this implies that the basic unit is not a distinct entity but a sub parcel of all units represented in the model.

The multipurpose cadastre model is a limited version of the combined layers model where the base unit in the legal parcel and higher level units, if they are to be represented, must consist of an integral number of these base units. Consequently the small incidence of overlap relation found in cultural themes cannot be adequately represented by the multipurpose cadastre. However the model is made more flexible if sub parcels of the legal parcel can be implemented as the base unit.

The following chapters attempt to demonstrate the benefits of the combined layers model by implementing it within an actual GIS using both theoretical and real data.

8. THEORETICAL DATA IMPLEMENTATION

8.1 Introduction

The aim of this chapter is to implement the combined layers model on a small theoretical data set. The data set was created specifically to test the model and included a number of the typical problems encountered with cultural data. Consequently the many problems were concentrated in one small area which was an advantage from the point of view of testing, but by no means realistic. For this reason, and to ensure that the discussion remained as general as possible, theoretical data was used during the initial implementation. However the model was also tested on a number of real data sets and this is covered in chapter 9.

The model was implemented using the ARC/INFO GIS software which is a commercially available package developed and marketed by the Environmental Systems Research Institute, Redlands, California [ESRI 1987]. Version 4 of the software was used on a Prime 9955 model II.

The implementation was to be judged successful if the theoretical data could be manipulated in ARC/INFO using the operations described in chapter 5 given the data structure and model proposed in chapters 6 and 7. The overriding objectives were: to efficiently handle a number of parcel definitions as individual units and; establish and query relationships between these units.

Before an examination of the implementation can proceed, the discussions of chapters 5 and 6 need to be placed in the context of ARC/INFO. The data structure will be discussed first and then the operations.

8.2 ARC/INFO

8.2.1 Introduction

ARC/INFO is a commercially available GIS software package which provided the functionality to manipulate large volumes of geographical data in a digital form. The system uses the parcel network model described in chapter 6 to handle spatial data and a relational data base management system called INFO to handle textual data. The basic data structure is called a coverage which is synonymous with a layer or choropleth map. Coverages consist of map features such as polygons, points, segments, or nodes.

A number of operations are provided for the manipulation of coverages. Two of these are UNION and DISSOLVE. A number of modules are also provided to perform operations on coverage features including ARCEDIT and ARCPLOT. The former is used for editing coverage features, and the latter is used for query and display. Most operations described in chapter 5 are represented in ARCPLOT.

Operations within ARC/INFO are at a very basic level and provide users with a tool box of geo-processing capabilities, this ensures maximum flexibility. The system can be considered as a high level GIS programming language. ARC/INFO operations and functions can be written into a programming language provided by the system called Arc Macro Language (AML). Hence the operations of chapter 5 that were not included with the software at the command level, were conveniently added to the system.

8.2.2 Parcel Representation

Parcels are represented in ARC/INFO coverages as polygons. A polygon network structure, similar to the one described in chapter 6, was used to represent polygons. Segments are called arcs in ARC/INFO and consisted of start points and end points (nodes) and a series of intermediate points called vertices. Hence closed polygons are defined in terms of arcs containing a label. The label is the object which represents the polygon as a unit. Hence polygon attributes are linked to this label.

The polygon summary file (table 6-6) is called a polygon attribute table (PAT) and consist of the items listed in table 8-1. The segment summary file (table 6-7) is called an arc attribute table (AAT) and consists of the items listed in table 8-2. These tables are represented in the INFO data base which handles coverage attributes. The model is similar to the one discussed in section 6.3.2, however not all the operations of a relational data base are provided within INFO. Extra relational operations are provided within ARC/INFO by ESRI so that attribute items can be added to attribute tables or other attribute tables can be related to the basic PAT and AAT tables via a common item.

POLYGON ATTRIBUTE TABLE (PAT) TEMPLATE

DATAFILE NAME: name.PAT
4 ITEMS: STARTING IN POSITION 1

COLUMN	ITEM NAME	WIDTH	OUTPUT WIDTH	TYPE	NUMBER OF DECIMALS
1	AREA	4	12	F	3
5	PERIMETER	4	12	F	3
9	name#	4	5	B	-
13	name-ID	4	5	B	-

TABLE 8-1

ARC (SEGEMENT) ATTRIBUTE TABLE (AAT) TEMPLATE

DATAFILE NAME: name.AAT
7 ITEMS: STARTING IN POSITION 1

COLUMN	ITEM NAME	WIDTH	OUTPUT WIDTH	TYPE	NUMBER OF DECIMALS
1	FNODE#	4	5	B	-
5	TNODE#	4	5	B	-
9	LPOLY#	4	5	B	-
13	RPOLY#	4	5	B	-
17	LENGTH	4	12	F	3
21	name#	4	5	B	-
25	name-ID	4	5	B	-

TABLE 8-2

NOTE

For types
F indicates internal floating point;
B indicates binary;
C indicates character.

For item names
name# indicates internal record number;
name-ID indicates feature identification number (user-id) (name corresponds to the coverage or layer name);
FNODE# indicates from node number;
TNODE# indicates to node number;
LPOLY# indicates left polygon internal number;
RPOLY# indicates right polygon internal number.

All features in ARC/INFO have two identification numbers. The internal number (cover#) is simply a record number and is used to ensure that features in the AAT and PAT remain in the correct order. In some operations it was necessary to sort the attribute tables on some other key. However the data needs to be sorted on the internal number for general ARC/INFO operations because attributes are linked to coverage features by the order in which they appear in the attribute table. The internal number allows the records to be sorted back to the correct order.

The user number (cover-ID) is a user assigned number which can also be assigned automatically to ensure its uniqueness. Some operations in ARC/INFO change the order of coverage features, thus their positions in the attribute tables are variable. Consequently the internal number of features is typically variable, however the user number is assured of its correct association with features. The user number is used by the system to ensure that the links between the coverage attributes and features are maintained. The user-number is the important linkage identifier discussed in section 7.3.1.3.

The central index, which is an important component of the combined layers model, is structured within the polygon attribute table. Items were added for each parcel type represented in the layer and the identifiers were added as values within their respective fields. Attribute tables can be queried via the spatial component of the system provided they are keyed to one of the identifiers in the polygon attribute table.

At the time of implementation, the ARC/INFO system did not support one to many relationships between polygons and attributes. Consequently, if a parcel is represented by a number of records in an attribute table, only the first record can be queried. Hence it is difficult to efficiently model situations like stratums (one parcel many owners), telephone services (one parcel many telephones) and farm visits (one parcel many visits). However, there is a cumbersome solution which is discussed in Appendix A. This solution was used in the real data application in chapter 9.

8.2.3 Parcel Operations

8.2.3.1. Creation

There are a number of operations for polygon creation in ARC/INFO. CREATE is the command used to make a coverage template. ARCEDIT, ADS or GENERATE can then be used to add labels or segments. Topology such as left and right polygon are created automatically using the BUILD operation. Some digitising errors are also resolved automatically using CLEAN.

Parcel attributes are loaded into tables using ADD or GET in INFO. The table templates are created using DEFINE. Parcel Attributes can also be added using a graphical selection technique in ARCEDIT. This is the most convenient way of manually performing the identifier linking operation. Attribute linking can also be executed by performing relates or joins.

8.2.3.2 Overlay

There are a number of operations in ARC/INFO which can be grouped into the overlay category. Some of these operations allow point on polygon and line on polygon as well as polygon on polygon overlays. Different polygon on polygon overlays are used depending on the required extent of the output coverage. That is, INTERSECT produces a coverage which only has polygons in areas common to both input coverages.

The operation most similar to the one described in section 5.3 is UNION. Each overlay operation allows the user to enter a fuzzy tolerance as an argument.

All items of the attribute table for the parent layers are represented in the attribute table which results from the overlay process, including quantitative attributes. Nevertheless the overlay commands can be extended (using macros) to drop both the invalid and unwanted items from the new attribute table.

8.2.3.3 Spatial Aggregation

This operation is called DISSOLVE in ARC/INFO and it performs generally as described in section 5.4. The command operates on an existing coverage and produces a new coverage as a result.

DISSOLVE only accepts one attribute item as an argument, or all the items after the user-ID in the PAT. A group of items can be used as DISSOLVE arguments by utilising two methods. The most convenient is to use the ALL option after dropping unwanted items from the PAT. Alternatively the INFO command REDEFINE can be used to group a number of items into one item which can then be used as the DISSOLVE argument.

8.2.3.4 Textual Aggregation

This operation is called FREQUENCY in ARC/INFO. The table upon which the command operates and the table to be produced are entered as arguments. The count and summary items are entered via a dialogue with the system.

8.2.3.5 Relates and Joins

These two important operations of a relational data base were discussed in section 6.3.2.2. Two files can be related using a common item at any level in ARC/INFO using the command called RELATE. RELATE at the ARC level also allows files, located in various data bases, to be related. INFO also provides a RELATE command which allows two files to be linked for the duration of the INFO session.

A join is implemented by the JOINITEM command at the ARC level and allows two INFO files to be joined to create a third file.

8.2.3.6 Selection

Feature selection, for the purposes of query as described in section 5.6, can be performed using two methods in ARC/INFO. Selections at the ARC level operate on coverages as a whole, but at the level of the display and query module (ARCPLOT) selections operate within many coverages. The operations in ARCPLOT correspond to the general discussion in section 5.6. However the ARC level operations also provide useful applications.

Like most ARC level commands the selection operations apply to coverages and produce coverages. The RESELECT commands allows a new coverage to be produced based on logical expressions in terms of attributes. Spatial Selections are performed using operations such as CLIP and ERASE, however the polygon used to define the selection criteria is entered into a separate coverage.

The queries in ARCPLOT also operate on coverages but produce temporary coverages which only last as long as the ARCPLOT session. The temporary coverage produced by a selection has the same name as the source coverage. Hence if a selection is made from the source coverage, then further operations on that coverage has effect only on the selected subset, not the entire set. An operation called CLEARSELECT is used to reset all coverages back to their original set. The command used to perform selections is called RESELECT which is similar to the subselect operation described in section 5.6. The ARC/INFO commands ASELECT and NSELECT are equivalent to addselect and swapselect respectively.

These three basic selection commands use coverage name and feature type as arguments. The latter is essential since polygons, segments or points can be selected from a coverage. These are the only two arguments for NSELECT, however RESELECT and ASELECT have further arguments. If a textual selection is performed, then the third argument is a logical expression. Spatial Selections are performed by using a key word as a third argument. The keywords can be either *circle*, *box* or *polygon*. The coordinates, which define these shapes, can be entered after the keywords or interactively using some hardware device.

Spatial selection methods such as *buffer* and *one* are not supported in ARCPLOT. *Buffer* is to be available in subsequent versions of ARC/INFO, however it can be performed as an ARC level operation. Option *one* is implemented by using the *circle* keyword with a small radius, alternatively, a slightly different command called IDENTIFY can be used. This does not reduce the selected set, but allows a user to point to a feature and list the attributes.

Spatial selections only select basic polygons, not higher level units. This is the many to one problem which was also discussed in section 7.3.1.4. In many instances only sub polygons of higher level parcels are selected by the spatial selection operation, other polygons of the higher level units can fall outside the spatial selection criteria. An aml called GETREST.AML was written to overcome this problem, it ensured that all polygons with selected identifiers were in the selected set. This operation was particularly useful for units of record which consisted of disjoint fragments such as some legal records and the Australian Bureau of Statistics farm unit.

8.2.3.7 Display

Display operations are also performed in ARCPLOT. They operate on coverages or the selected subset of coverages. Both spatial and textual displays can be performed in this module, however purely textual operations, such as listings and report generation, can also be performed in INFO.

Relevant display operations are summarised below.

Boundaries/Polygon Outlines

ARCLINES or ARCS are the commands used to draw the selected polygon segments (ARCS) of a coverage. To ensure that only the arcs of selected polygons are displayed, all arcs for these polygons have to be selected first. This operation was built into an AML called GETBOUNDS.AML which is listed in Appendix B. Alternatively the POLYGONS command can be used but this does not provide the same line symbol flexibility as ARCLINES which can be used to draw lines according to attributes.

Shading

POLYGONSHADES is used to shade selected polygons. They can be shaded by the one specified symbol or according to attributes.

Labelling

POLYGONTEXT is used to label selected polygons with specified attributes.

External boundaries

DROPLINE is used to draw external boundaries of polygons with the same attributes. This command also incorporates the aggregated labelling operation. The user can specify whether the higher level polygon is to be labelled with the attribute used to perform the operation. For convenience, this command was divided into the two operations as described in section 5.7.1 using AMLs. They were called AGGREGATE_LABEL.AML and EXTERNAL.AML and are listed in Appendix B.

Aggregate labelling

The DROPLINE command can be used for this operation with the line symbol set to 0. A special AML was written to perform this operation called AGGREGATE_LABEL.AML which is listed in Appendix B. Also see External boundaries above.

Internal Boundaries

A specific command to perform this operation is not supported in ARC/INFO. Hence an AML was written to display the internal boundaries of polygons. See Internal.AML in Appendix B. The implementation of this command at the AML level was inefficient, particularly for large coverages. The procedure uses RELATE to establish links that are already embedded in the data structure. Hence this operation is best implemented at the command or code level. At the time of implementation it was not possible to do this because of the unavailability of subroutines.

Attribute listing

LIST is used to list the attributes of all or selected features of a coverage. The items to be listed can be specified, otherwise all the items in the PAT are listed. The ITEMS command is useful for listing the items of a particular attribute file. INFOFILE is useful for writing selected records to another file. Reports are generated in INFO using REPORT. INFO also has LIST and ITEMS commands.

8.2.3.8 Display Enhancement

There are a number of graphic primitive commands in ARCPLOT which can be used to enhance cartographic output. These commands included LINE, BOX, CIRCLE, PATCH TEXT, and TEXTFILE.

8.2.3.9 Other operations

Various other commands are useful for queries and the presentation of output, the important ones are summarised below.

MAPEXTENT - used to specify the portion of a coverage to be viewed.

DISPLAY - used to specify the presentation medium. This can be either a graphics screen or plot file. Plot files are used to produce hard copy output.

MAPLIMITS - used to specify where on a page a coverage, or coverage portion, is drawn.

MAPSCALE - used to scale output.

COORDINATE - used to specify the coordinate input device, that is, either mouse, cursor, or digitiser can be specified.

MEASURE - allows locations, areas and lengths to be measured interactively.

The ARC/INFO commands mentioned above are only a small subset of the total commands. However, they are the most important in terms of representing and querying parcels and parcel relationships.

8.3 Implementation and Testing

The theoretical data used to test the model is illustrated in figure 8-1. The central index which defines the parcel relationships is listed in table 8-3. Various attribute tables are illustrated in tables 8-4 through to tables 8-11. These attribute tables were over simplified for the purposes of the exercise. In practice many more tables, consisting of a wide range of items, would be represented. The theoretical model contains a number of situations where the legal or cadastral parcel is severed by a higher order parcel boundary. The wide variety of anomalies would not normally be found in such a small area. It is also acknowledged that one hectare is much smaller than the size of the average sheep farm.

A statistically independent layer was also required to test the model and so the soil layer illustrated in figure 8-2 was created. SOIL_CODE was the only soil attribute and the values are labelled within the corresponding polygon.

Testing was performed in terms of the general operations of the preceding chapter.

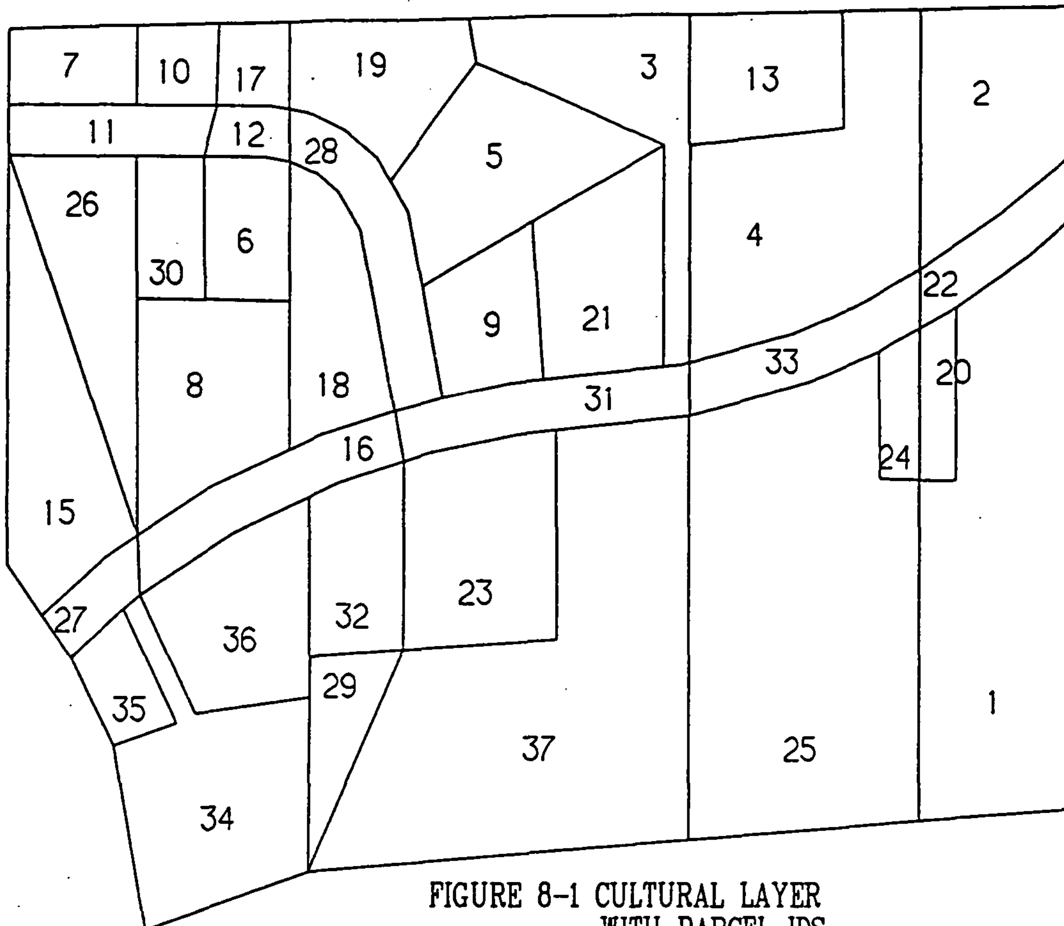


FIGURE 8-1 CULTURAL LAYER WITH PARCEL IDS

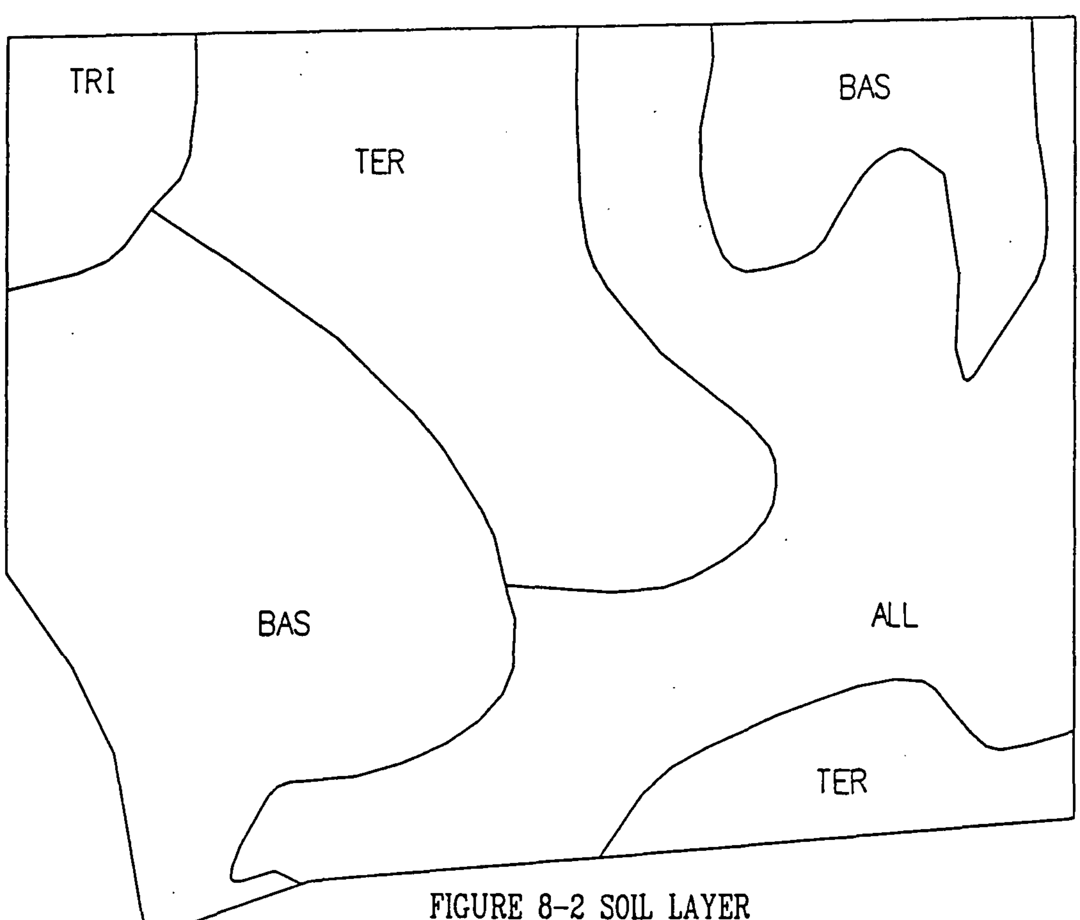


FIGURE 8-2 SOIL LAYER WITH SOIL CODES

CENTRAL INDEX
(DEFINES CULTURAL PARCEL RELATIONSHIPS FOR FIGURE 8-1)

PARCEL NUMBER	LEGAL IDENTIFIER	FISCAL IDENTIFIER	FARM IDENTIFIER	GRANT IDENTIFIER	MUNICIPAL IDENTIFIER	CENSUS IDENTIFIER
1	L23	F1	A13	G2	M1	C2
2	L20	F1	A13	G3	M2	C2
3	L18	F4	A9	G5	M2	C2
4	L19	F3	A12	G4	M2	C2
5	L16	F7	A9	G5	M2	C2
6	L1	F16	A3	G8	M2	C1
7	L3	F18	N/A	G8	M2	C1
8	L7	F14	A3	G8	M2	C1
9	L14	F6	N/A	G5	M2	C2
10	L2	F17	N/A	G8	M2	C1
11	ROAD	ROAD	ROAD	G8	M2	C1
12	ROAD	ROAD	ROAD	G8	M2	C2
13	L18	F4	A9	G4	M2	C2
15	L4	F13	A4	G8	M1	C1
16	ROAD	ROAD	ROAD	G0	M2	C1
17	L1	F16	A3	G8	M2	C2
18	L6	F15	A3	G5	M2	C1
19	L17	F8	A9	G5	M2	C2
20	L21	F2	A13	G2	M1	C2
21	L15	F5	A11	G5	M2	C2
22	ROAD	ROAD	ROAD	G0	M1	C2
23	L13	F9	A8	G6	M2	C2
24	L21	F2	A13	G1	M1	C2
25	L22	F1	A13	G1	M1	C2
26	L4	F13	A4	G8	M2	C1
27	ROAD	ROAD	ROAD	G0	M1	C1
28	ROAD	ROAD	ROAD	G5	M2	C2
29	L12	F9	A8	G6	M2	C1
30	L5	F16	A3	G8	M2	C1
31	ROAD	ROAD	ROAD	G0	M2	C2
32	L11	F10	A7	G6	M2	C1
33	ROAD	ROAD	ROAD	G0	M1	C2
34	L10	F12	A5	G7	M1	C1
35	L8	F12	A5	G7	M1	C1
36	L9	F11	A6	G7	M2	C1
37	L12	F9	A8	G6	M2	C2

TABLE 8-3

TITLE DETAILS

LEGAL-ID	TITLE REFERENCE	OWNER'S NAME	ADDRESS OF PARCEL	AREA SQU. M.
L1	CT7912/34	P BACON	20 STAFFORD DRIVE UTOPIA	1,380
L2	CT7789/32	G BUSH	15 STAFFORD DRIVE UTOPIA	500
L3	CT5248/95	F LEWIS	31 STAFFORD DRIVE UTOPIA	770
L4	CT4589/92	J E KERRY	51 MARGARET RD UTOPIA	4,210
L5	CT6023/43	P BACON	22 STAFFORD DRIVE UTOPIA	730
L6	CT5879/56	MRS. P BACON	4 STAFFORD DRIVE UTOPIA	1,610
L7	CT2546/65	P BACON JUN.	55 MARGARET RD UTOPIA	2,200
L8	CT8952/42	F DODGEY	80 MARGARET RD UTOPIA	570
L9	CT8952/44	B DAVISON	90 MARGARET RD UTOPIA	1,880
L10	CT8952/43	A DODGEY	88 MARGARET RD UTOPIA	2,800
L11	CT6512/23	FIRST UTOPIA BANK	100 MARGARET RD UTOPIA	1,270
L12	DO4789/12	S HIGHSPACE	110 MARGARET RD UTOPIA	8,280
L13	CT6512/25	D HIGHSPACE	106 MARGARET RD UTOPIA	2,330
L14	CT2287/31	A COLEMAN	63 MARGARET RD UTOPIA	1,110
L15	CT2287/31	T KING	65 MARGARET RD UTOPIA	1,840
L16	CT5110/09	G SAINSBURY	5 STAFFORD DRIVE UTOPIA	2,220
L17	CT5110/09	FIRST UTOPIA BANK	10 STAFFORD DRIVE UTOPIA	1,540
L18	CT9001/34	FIRST UTOPIA BANK	113 MARGARET RD UTOPIA	3,410
L19	DO3011/98	H CARTWRIGHT	115 MARGARET RD UTOPIA	4,080
L20	DO1209/42	R J DAVIS	119 MARAGARET RD UTOPIA	2,370
L21	CT1987/56	FIRST UTOPIA BANK	120 MARGARET RD UTOPIA	880
L22	DO6734/23	B KING	116 MARGARET RD UTOPIA	7,570
L23	DO9856/23	J OSBORN	122 MARGARET RD UTOPIA	5,710
ROAD	N/A	NOT APPLICABLE		6,750

INFO DATAFILE: TITLE
TABLE 8-4

RATEPAYER DETAILS

FISCAL-ID	NAME	ADDRESS	AREA SQU. MET.	AAV *1000
F1	FUNNY FARMS INC	120 MARGARET RD UTOPIA	15670	500
F2	T SPRENT	120 MARGARET RD UTOPIA	880	60
F3	H CARTWRIGHT	115 MARGARET RD UTOPIA	4,080	420
F4	F SAINSBURY	300 LIVERPOOL ST NUBEENA	3,410	124
F5	T KING	65 MARGARET RD UTOPIA	1,840	110
F6	A COLEMAN	63 MARGARET RD UTOPIA	1,110	90
F7	G SAINSBURY	300 LIVERPOOL ST NUBEENA	2,220	123
F8	A SAINSBURY	10 STAFFORD DRIVE UTOPIA	1,540	236
F9	NATURAL FARMS INC	5 WESTLAND AVE BLANDSFORDIA	10620	289
F10	J DERMOUDY	100 MARGARET RD UTOPIA	1,270	176
F11	B DAVISON	90 MARGARET RD UTOPIA	1,880	150
F12	DODGEY BROS.	20 MURRAY ST STOWPORT	3,380	78
F13	J E KERRY	51 MARGARET RD UTOPIA	4,210	213
F14	P BACON JUN.	20 STAFFORD DRIVE UTOPIA	2,200	50
F15	MRS. P BACON	20 STAFFORD DRIVE UTOPIA	1,610	120
F16	P BACON	20 STAFFORD DRIVE UTOPIA	2,120	300
F17	G BUSH	5 WASHINGTON BLVD BALFOUR	500	212
F18	F LEWIS	31 STAFFORD DRIVE UTOPIA	770	101
ROAD	NOT APPLICABLE	NOT APPLICABLE	6,750	

INFO DATAFILE: RATEPAYER
TABLE 8-5

BUILDING DETAILS FOR FISCAL PROPERTIES

FISCAL-ID	NUMBER	TYPE	ROOMS
F1	3	WB	6
F2	1	BR	5
F3	2	SS	15
F4	1	BR	7
F5	1	WB	6
F6	1	WB	5
F7	0	N/A	0
F8	1	SS	9
F9	1	WB	1
F10	1	BR	8
F11	1	BR	5
F12	1	WB	3
F13	1	BR	7
F14	0	N/A	0
F15	1	WB	3
F16	3	BR	7
F17	1	BR	9
F18	1	BR	5
ROAD	0	N/A	0

INFO DATAFILE: BUILDINGS
TABLE 8-6

FARM TENURE DETAILS

FARM-ID	NAME	ADDRESS
A11	T KING	65 MARGARET RD UTOPIA
A12	PONDEROSA PTY LTD	12 LAKE RD MIENA
A13	FUNNY FARMS INC	120 MARGARET RD UTOPIA
A3	P BACON	20 STAFFORD DRIVE UTOPIA
A4	J E KERRY	51 MARGARET ST UTOPIA
A5	DODGEY SHEEP AND GOATS	20 MURRAY ST STOWPORT
A6	B DAVISON	90 MARGARET RD UTOPIA
A7	J DERMOUDY	100 MARGARET RD UTOPIA
A8	HOMEGROWN ENTERPRISES	5 WESTLAND AVE BLANDSFORDIA
A9	G SAINSBURY	300 LIVERPOOL ST NUBEENA
N/A	NOT APPLICABLE	NOT APPLICABLE
ROAD	ROAD RESERVE	NOT APPLICABLE

INFO DATAFILE: FARMER
TABLE 8-7

FARM QUANTITY DETAILS

FARM-ID	MAJOR_ENTERPRISE	FARM_AREA_HA	QUANTITY-CODE
A11	FRUIT	0.2	2
A12	CATTLE	0.4	1
A13	SHEEP	1.7	3
A3	PIGS	0.6	5
A4	GOATS	0.4	3
A5	GOATS	0.3	2
A6	FRUIT	0.2	1
A7	FRUIT	0.1	1
A8	GOATS	1.1	5
A9	WOOL	0.7	3
N/A	NOT APPLICABLE	0.2	0
ROAD	NOT APPLICABLE	0.7	0

INFO DATAFILE: FARM_QUANTITIES
TABLE 8-8

MUNICIPALITY DETAILS

MUN-ID	NAME	CENTRE
M1	KINGBOROUGH	MITCHELL
M2	OSBOROUGH	UTOPIA

INFO DATAFILE: MUNICIPALITIES
TABLE 8-9

CENSUS DISTRICT DETAILS

CD-ID	CODE	POPULATION	AVERAGE_INCOME	AREA_HA
C1	102030	1,045	25000	2,987
C2	102040	2,056	18790	4,780

INFO DATAFILE: CENSUS_DETAILS
TABLE 8-10

ORIGINAL GRANT DETAILS

GRANT-ID	GRANTEE	LO-REF	AREA_A-R-P
G0	RESRVED ROAD	15/26R	1-0-14
G1	JOHN LUCAS SEN.	12/15 UTOP	1-3-37
G2	WILLIAM HORTIN	12/23 UTOP	1-2-3
G3	JAMES THORPE	12/43 UTOP	0-2-13
G4	GEORGE WHITE	12/42 UTOP	1-1-19
G5	CHARLES STURT	19/28 UTOP	2-3-15
G6	THOMAS RANKIN	23/11 UTOP	2-3-30
G7	JOHN BLACKWELL	23/12 UTOP	1-1-8
G8	FRANK HELLYER	19/29 UTOP	2-2-32

INFO DATAFILE: GRANT_DETAILS
TABLE 8-11

8.3.1. Creation

The following procedure was used to enter the data represented in figures 8-1 and 8-2 and tables 8-3 to 8-11.

SOIL LAYER (SOILS)

1. ARCEDIT was used to digitise all line segments shown in figure 8-2.
2. Polygon topology was created using BUILD.
3. Labels were added using CREATELABELS.
4. Polygon topology was updated using BUILD.
5. SOIL item was added to SOILS.PAT using ADDITEM.
6. Soil parcels were attributed using MOVEITEM in ARCEDIT, that is, MOVEITEM (value) to SOIL.

CULTURAL LAYER (CULTURAL)

1. ARCEDIT was used to digitise all segments shown in figure 8-1.
2. Polygon topology was created using BUILD.
3. Labels were added using CREATELABELS.
4. Polygon topology was updated using BUILD.
5. ARCEDIT was used to update Polygon user-IDs to match figure 8-1. Graphical selection was used to choose labels and values were assigned using the following ARCEDIT command line: Calculate $ID = nn
6. An INFO file called CENTRAL-INDEX was created using DEFINE in INFO.
7. Data as per table 8-3 was added to CENTRAL-INDEX using ADD in INFO.
8. CENTRAL-INDEX was joined to CULTURAL.PAT using CULTURAL-ID as the relate item. (This file is listed in table 8-12).
9. The data in tables 8-4 to 8-11 were added to separate INFO data files in a similar manner to steps 6 and 7

Note that if any of the above data were already in a digital format, then it could have been added in a similar fashion in batch mode.

ITEMS FOR CULTURAL.PAT (CENTRAL INDEX)

10 ITEMS: STARTING IN POSITION 1

COLUMN	ITEM NAME	WIDTH	OUTPUT WIDTH	TYPE	NUMBER OF DECIMALS	HEADINGS AS PER LISTING BELOW
1	AREA	4	12	F	0	[1]
5	PERIMETER	4	12	F	0	[2]
9	CULTURAL#	4	5	B	-	[3]
13	CULTURAL-ID	4	5	B	-	[4]
17	LEGAL-ID	4	4	C	-	[5]
21	GRANT-ID	4	4	C	-	[6]
25	FISCAL-ID	4	4	C	-	[7]
29	FARM-ID	4	4	C	-	[8]
33	MUN-ID	4	4	C	-	[9]
37	CD-ID	4	4	C	-	[10]

LISTING OF CULTURAL.PAT
(See items listing for explanation of headings)

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]
2377	206	2	2	L20	F1	A13	G3	M2	C2
4087	298	3	4	L19	F3	A12	G4	M2	C2
1461	154	4	13	L18	F4	A9	G4	M2	C2
1952	294	5	3	L18	F4	A9	G5	M2	C2
1542	163	6	19	L17	F8	A9	G5	M2	C2
459	86	7	17	L1	F16	A3	G8	M2	C2
502	89	8	10	L2	F17	N/A	G8	M2	C1
772	115	9	7	L3	F18	N/A	G8	M2	C1
2221	205	10	5	L16	F7	A9	G5	M2	C2
795	141	11	11	ROAD	ROAD	ROAD	G8	M2	C1
312	73	12	12	ROAD	ROAD	ROAD	G8	M2	C2
1231	204	13	28	ROAD	ROAD	ROAD	G5	M2	C2
1845	180	14	21	L15	F5	A11	G5	M2	C2
2348	274	15	15	L4	F13	A4	G8	M1	C1
1870	250	16	26	L4	F13	A4	G8	M2	C1
727	138	17	22	ROAD	ROAD	ROAD	G0	M1	C2
739	115	18	30	L5	F16	A3	G8	M2	C1
928	124	19	6	L1	F16	A3	G8	M2	C1
1610	188	20	18	L6	F15	A3	G5	M2	C1
1117	137	21	9	L14	F6	N/A	G5	M2	C2
979	170	22	33	ROAD	ROAD	ROAD	G0	M1	C2
2200	196	23	8	L7	F14	A3	G8	M2	C1
441	110	24	20	L21	F2	A13	G2	M1	C2
444	101	25	24	L21	F2	A13	G1	M1	C2
1145	192	26	31	ROAD	ROAD	ROAD	G0	M2	C2
1140	193	27	16	ROAD	ROAD	ROAD	G0	M2	C1
2335	194	28	23	L13	F9	A8	G6	M2	C2
1274	149	29	32	L11	F10	A7	G6	M2	C1
1883	176	30	36	L9	F11	A6	G7	M2	C1
423	90	31	27	ROAD	ROAD	ROAD	G0	M1	C1
2807	274	32	34	L10	F12	A5	G7	M1	C1
577	99	33	35	L8	F12	A5	G7	M1	C1
774	151	34	29	L12	F9	A8	G6	M2	C1
5717	394	35	1	L23	F1	A13	G2	M1	C2
7561	376	36	25	L22	F1	A13	G1	M1	C2
7514	426	37	37	L12	F9	A8	G6	M2	C2

TABLE 8-12

8.3.2 Spatial Aggregation

A legal layer was derived from the cultural layer as an example of spatial aggregation. The following command and arguments were used:

DISSOLVE CULTURAL LEGAL_LAYER LEGAL-ID.

The legal layer produced by this operation is shown in figure 8-3. The resulting attribute table, LEGAL.PAT, is shown in table 8-13.

This new layer was quick to produce (see section 8.3.6, Performance and Storage). It could then be used for efficient queries of a legal nature or it could be used in a number of other ARC/INFO processes (see section 8.3.3 below).

8.3.3 Overlay

The new legal layer, produced in section 8.3.2, was combined with the soil layer to produce a new layer called LEGAL_SOIL. This new layer could be used for determining the types of soils within certain parcels. The UNION command was used as follows:

UNION LEGAL_LAYER SOIL LEGAL_SOIL.

A default fuzzy tolerance was determined by the system since a value was not specified in the command line. The resulting layer and attribute table are shown in figure 8-4 and table 8-14 respectively.

8.3.4. Textual Aggregation

A close examination of table 8-13 revealed that the legal identifier was still not unique after spatial aggregation. The main reason for this was the areal discontinuity of the legal units. In the situation shown, the legal unit of record was severed by a road. Textual Aggregation was useful in this situation for locating fragmented portions of units. The FREQUENCY operation was performed on table 8-13, the dialogue and a portion of the resulting datafile are listed in table 8-15.

The textual aggregation operation was also useful for filtering out data which resulted from the many to one relationships (parcels to record) which were common in the combined layers model. For example, when a conventional listing was performed, the one record, which was linked to many sub parcels of the selected higher level parcel, was repeated once for for each sub parcel. A better approach was to write the selected record to a file using INFOFILE and then perform a FREQUENCY on this file using all items in the file. This summarised file could then be listed.

There were a number of other practical applications for textual aggregation.

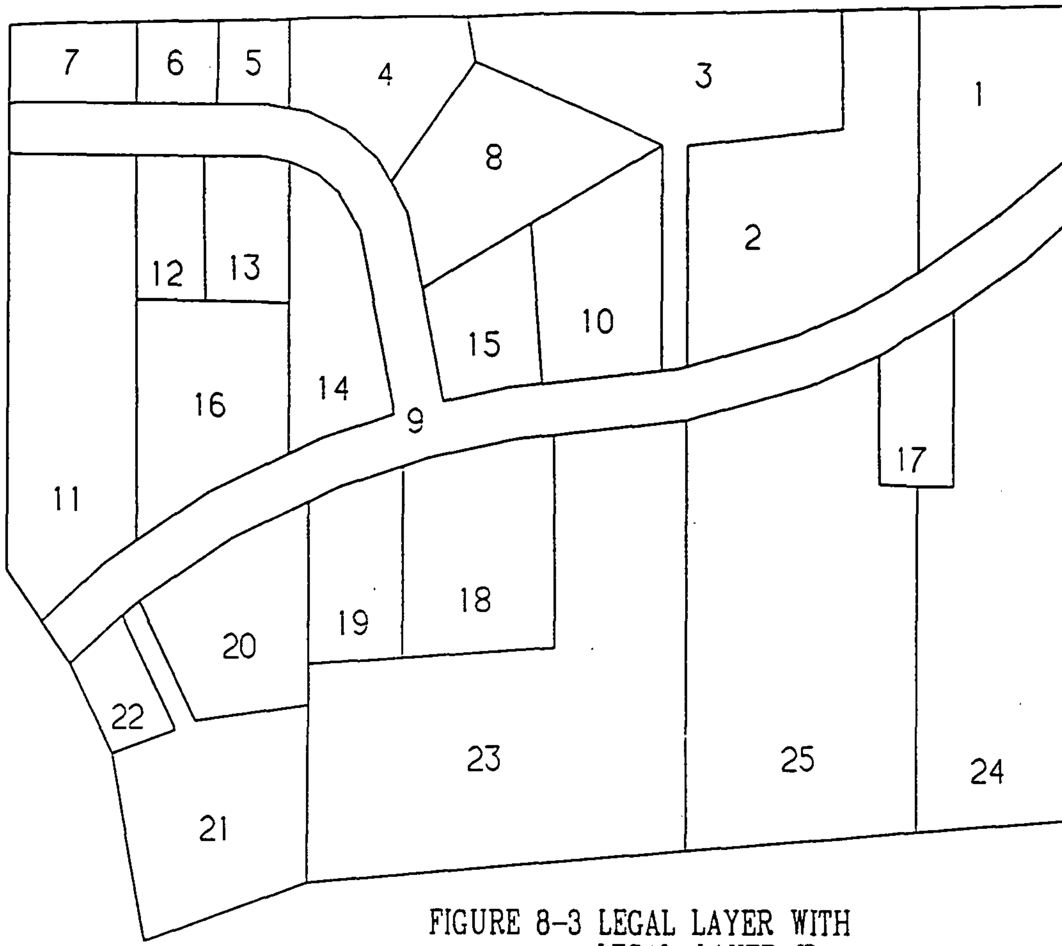


FIGURE 8-3 LEGAL LAYER WITH LEGAL_LAYER-IDs

AREA	PERIMETER	LEGAL_LAYER#	LEGAL_LAYER-ID	LEGAL-ID
-66,128	1,036	1	0	(WORLD POLYGON)
2,377	206	2	1	L20
4,087	299	3	2	L19
3,414	377	4	3	L18
1,543	163	5	4	L17
459	87	6	5	L1
503	90	7	6	L2
773	115	8	7	L3
2,221	205	9	8	L16
6,757	998	10	9	ROAD
1,846	180	11	10	L15
4,219	304	12	11	L4
739	116	13	12	L5
929	125	14	13	L1
1,610	189	15	14	L6
1,118	138	16	15	L14
2,201	197	17	16	L7
886	128	18	17	L21
2,336	194	19	18	L13
1,274	150	20	19	L11
1,883	177	21	20	L9
2,808	274	22	21	L10
578	100	23	22	L8
8,289	445	24	23	L12
5,718	394	25	24	L23
7,561	376	26	25	L22

INFO DATAFILE: LEGAL_LAYER.PAT
TABLE 8-13

AREA	PERIMETER	LEGAL_SOIL#	LEGAL_SOIL-ID	LEGAL-ID	SOIL_CODE
-66140	1036	1	0	(WORLD POLYGON)	
470	109	2	1	L20	ALL
1683	176	3	2	L20	BAS
2010	234	4	3	L19	BAS
1296	146	5	4	L18	BAS
1576	251	6	5	L18	ALL
523	97	7	6	L18	TER
1543	163	8	7	L17	TER
459	87	9	8	L1	TER
133	57	10	9	L2	TER
369	77	11	10	L2	TRI
773	115	12	11	L3	TRI
1925	175	13	12	L16	TER
720	130	14	13	ROAD	TRI
2699	430	15	14	ROAD	TER
297	79	16	15	L16	ALL
2077	267	17	16	L19	ALL
795	131	18	17	L15	ALL
224	75	19	18	L20	ALL
1042	129	20	19	L4	TRI
137	57	21	20	ROAD	ALL
181	60	23	22	L5	TER
695	111	24	23	L1	TER
875	143	25	24	L6	TER
426	96	26	25	ROAD	BAS
1051	147	27	26	L15	TER
434	83	28	27	L5	BAS
4350	347	29	28	L23	ALL
3177	257	30	29	L4	BAS
1118	138	31	30	L14	TER
234	72	32	31	L1	BAS
286	89	33	32	L23	BAS
1055	185	34	33	ROAD	ALL
735	119	35	34	L6	BAS
2201	197	36	35	L7	BAS
882	128	38	37	L21	ALL
4417	319	40	39	L22	ALL
1719	284	41	40	ROAD	BAS
795	115	42	41	L22	TER
1568	157	43	42	L12	TER
796	123	44	43	L13	TER
1312	151	45	44	L13	BAS
1274	150	46	45	L11	BAS
1883	177	47	46	L9	BAS
4919	335	48	47	L12	ALL
227	63	49	48	L13	ALL
2379	304	50	49	L10	BAS
578	100	51	50	L8	BAS
1402	160	52	51	L12	BAS
2349	201	53	52	L22	TER
1081	157	54	53	L23	TER
400	90	55	54	L12	TER
429	89	56	55	L10	ALL

INFO DATAFILE: LEGAL_SOIL.PAT (some small areas not listed)

TABLE 8-14

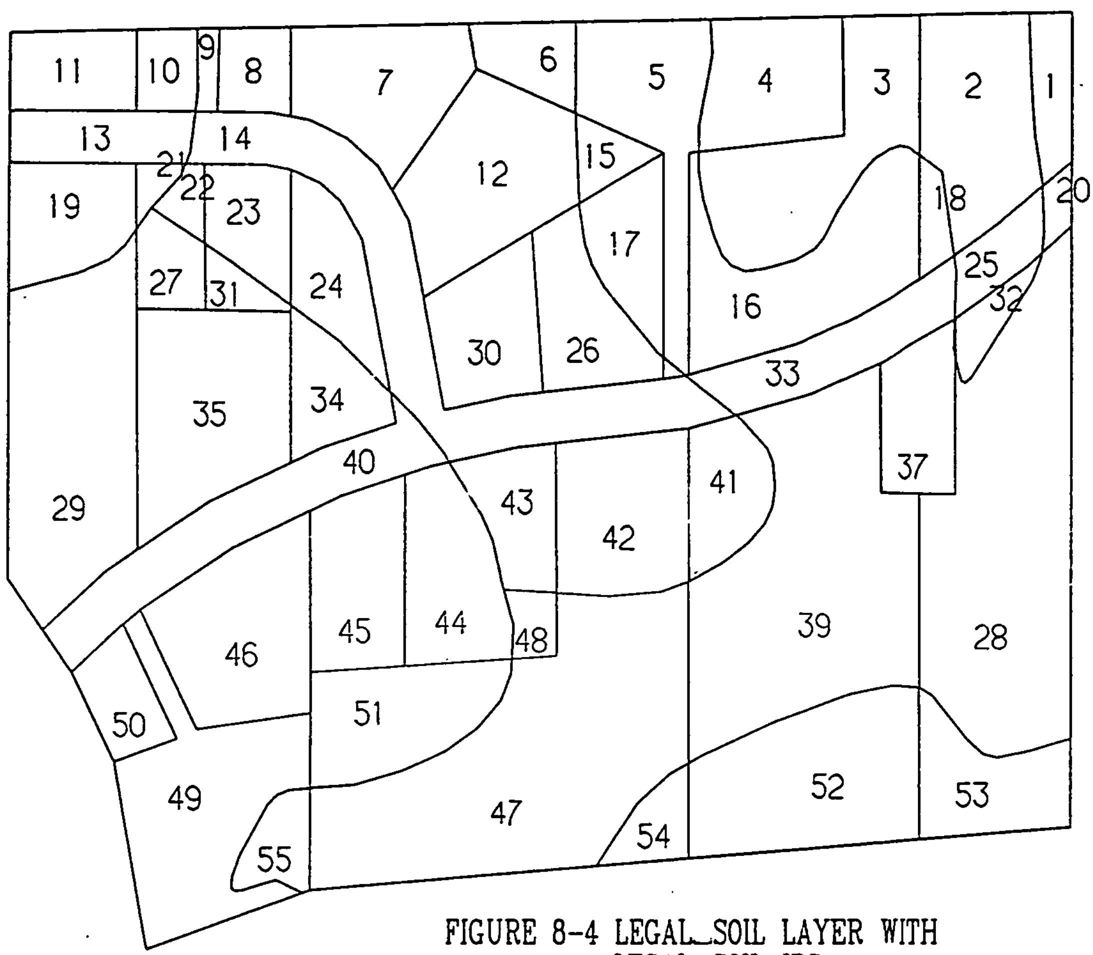


FIGURE 8-4 LEGAL_SOIL LAYER WITH LEGAL_SOIL-IDS

DIALOG USED TO PRODUCE LEGAL-SOILS

```
Arc: FREQUENCY LEGAL_SOIL.PAT LEGAL-SOILS

Enter Frequency item names (type END or a blank line when done):
================================================================
Enter the 1st item: LEGAL-ID
Enter the 2nd item: SOIL_CODE
Enter the 3rd item: END

Enter Summary item names (type END or a blank line when done):
==============================================================
Enter the 1st item: AREA
Enter the 2nd item: END          (END OF DIALOG)
```

CASE#	FREQUENCY	LEGAL-ID	SOIL_CODE	AREA(sq m.)
3	1	L1	BAS	234
4	2	L1	TER	1154
5	1	L10	ALL	429
6	1	L10	BAS	2379
7	1	L11	BAS	1274
8	1	L12	ALL	4919
9	1	L12	BAS	1402
10	2	L12	TER	1968
11	1	L13	ALL	227
12	1	L13	BAS	1312
13	1	L13	TER	796
14	1	L14	TER	1118
15	1	L15	ALL	795
16	1	L15	TER	1051
17	1	L16	ALL	297
18	1	L16	TER	1925
19	1	L17	TER	1543
20	1	L18	ALL	1576
21	1	L18	BAS	1296
22	2	L18	TER	542
23	1	L19	ALL	2077
24	1	L19	BAS	2010
.				
.				
.				
38	1	L4	TRI	1042
39	1	L5	BAS	434
40	1	L5	TER	181
41	1	L5	TRI	124
42	1	L6	BAS	735
43	1	L6	TER	875
44	1	L7	BAS	2201
45	1	L8	BAS	578
46	1	L9	BAS	1883
47	2	ROAD	ALL	1192
48	2	ROAD	BAS	2145
49	1	ROAD	TER	2699
50	1	ROAD	TRI	720

INFO DATAFILE: LEGAL-SOILS
TABLE 8-15

8.3.5. Selection and Display

Many selection and display operations were intrinsically interactive and were therefore difficult to illustrate on paper. Nevertheless, an attempt is made below to present some of the selection and display operations that were performed on the model. A number of figures were used to illustrate the results of the query operations. These results were in the form of a plot, a listing, or both.

The operations below were performed using a keyboard since keyboard commands were more convenient for the purpose of presentation. However, ARC/INFO also supported a pull down menu environment which allowed all these operations to be performed with speed , since they did not require the typing of long command lines. It was not possible to present the use of these pull down menus in this static environment. Also full command lines were presented so that readers, if required, would be able to repeat the operations given a similar database.

The main advantage of a menu environment is that access to the system may be tailored for specific groups of users once their requirements are known. This is particularly useful in terms of quantitative attributes since the menu system can be designed so that their linkage to sub parcels is not supported. This does not mean that data access is restricted since the model still supports ad-hoc queries performed by knowledgeable users, however, general users are restricted to valid operations.

The queries, commands used to execute them, and comments, are listed below. Most queries were performed on the cultural layer, however the last two were performed on the legal_layer and legal_soil coverages. To perform these queries, the relates listed in table 8-16 were created.

The following commands were used to initialise the ARCPLOT environment. A Tektronix 4111 series terminal was used.

ARCPLOT: *DISPLAY 4111*
ARCPLOT: *COORDINATE TABLET*
ARCPLOT: *MAPEXTENT CULTURAL*
ARCPLOT: *MAPPOSITION CEN CEN*

CLEARSELECT was used before each separate query.

LIST OF RELATES FOR CULTURAL QUERIES					
RELATION	TABLE-ID	DATA BASE	ITEM	COLUMN	TYPE
TITLE	TITLE	INFO	LEGAL-ID	LEGAL-ID	ORDERED
RATEPAYER	RATEPAYER	INFO	FISCAL-ID	FISCAL-ID	ORDERED
BUILDINGS	BUILDINGS	INFO	FISCAL-ID	FISCAL-ID	ORDERED
FARMER	FARMER	INFO	FARM-ID	FARM-ID	ORDERED
QUANTITIES	FARM_QUANTITIES	INFO	FARM-ID	FARM-ID	ORDERED
GRANT	GRANT_DETAILS	INFO	GRANT-ID	GRANT-ID	ORDERED
MUN	MUNICIPALITIES	INFO	MUN-ID	MUN-ID	ORDERED
CD	CENSUS_DETAILS	INFO	CD-ID	CD-ID	ORDERED

Table 8-16.

1. (Figure 8-5)

Query

Show legal parcels using cultural layer.

Commands

ARCPLOT: *EXTERNAL CULTURAL LEGAL-ID 1*

ARCPLOT: *AGGREGATE_LABEL CULTURAL LEGAL-ID*

Comments

Demonstrated how the cultural layer based on an arbitrary land parcel smaller than the legal parcel, could be used to show just legal parcels. Similar operations were performed to show how municipal parcels and grant parcels could be displayed using the cultural layer. These are shown in figures 8-6 and 8-7 respectively.

2. (Figure 8-8)

Query

Show external and internal boundaries of farm parcels. Label farm parcels with identifiers.

Commands

ARCPLOT: *EXTERNAL CULTURAL FARM-ID 5*

ARCPLOT: *AGGREGATE_LABEL CULTURAL FARM-ID*

ARCPLOT: *INTERNAL CULTURAL FARM-ID 17*

Comments

Demonstrated how cultural layer may be used to display higher level parcels and show their relationship with lower order parcels.

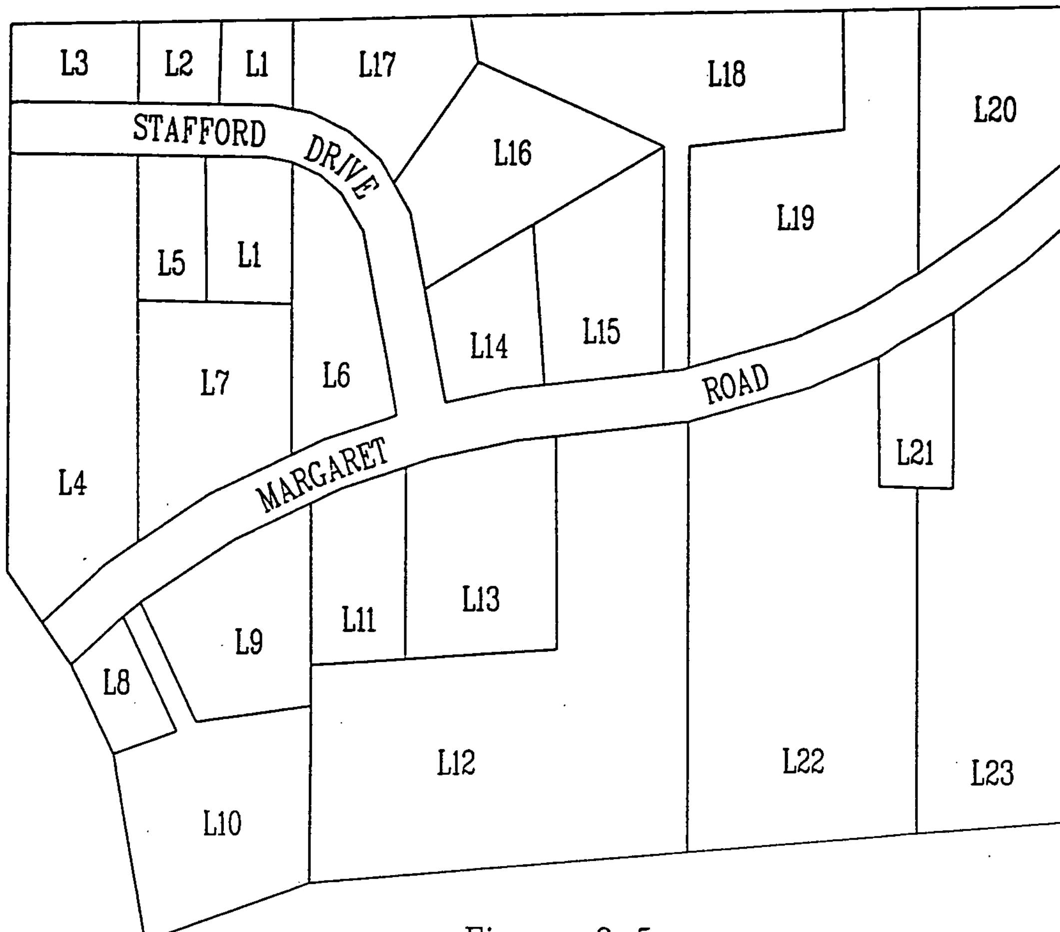


Figure 8-5

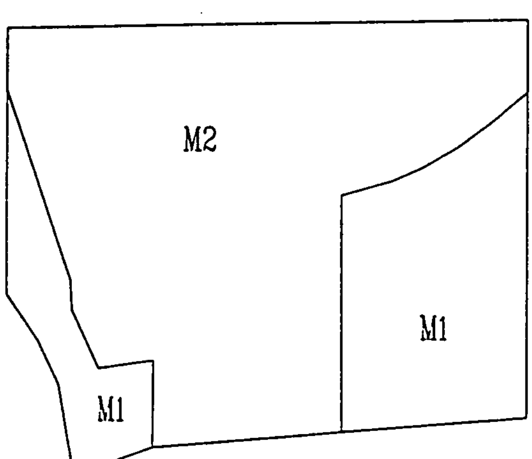


Figure 8-6

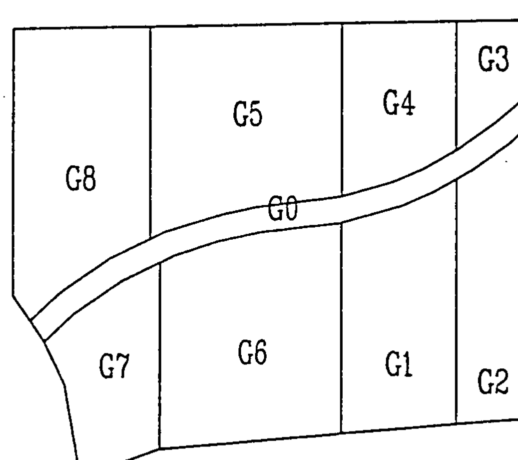


Figure 8-7

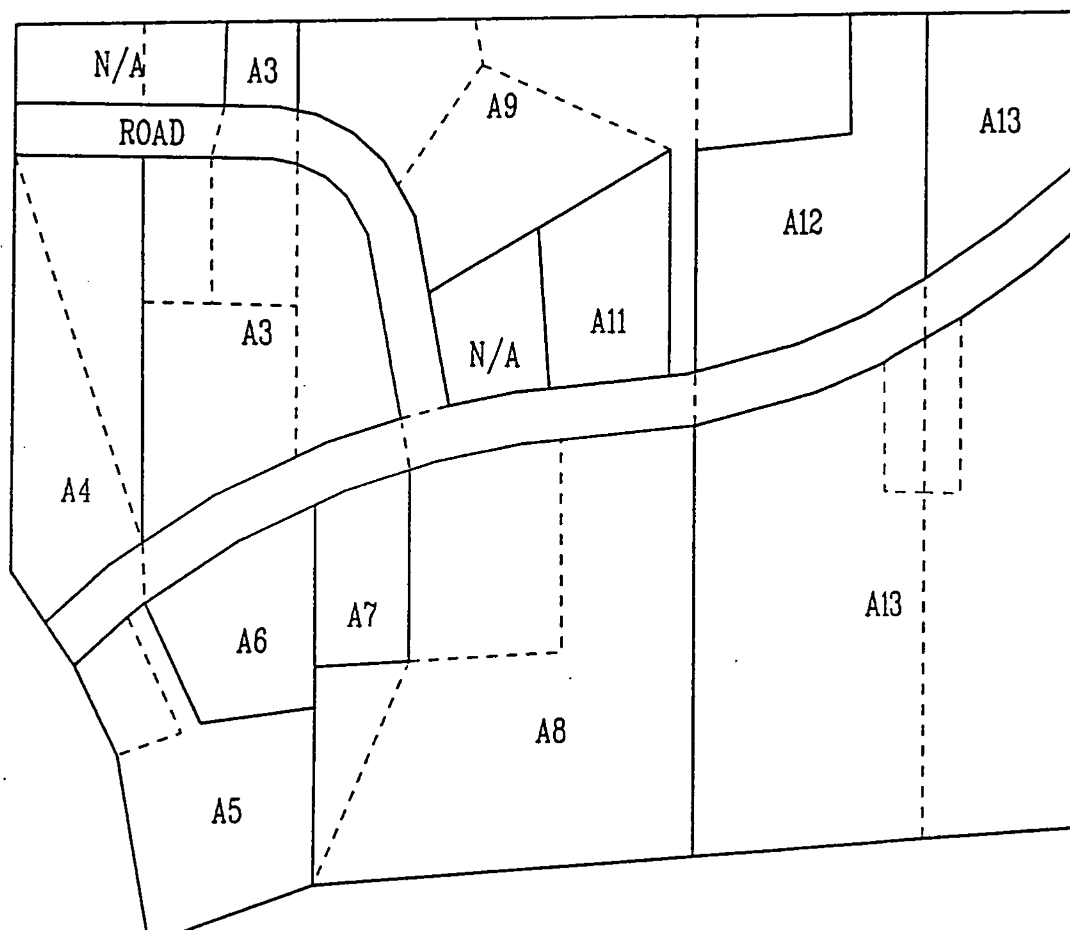


Figure 8-8

3. (Figure 8-9)

Query

List owners of legal parcels within unit farmed by P BACON. Also list farm details.

Commands

ARCPLOT: *EXTERNAL CULTURAL LEGAL-ID 1*
ARCPLOT: *RESELECT CULTURAL POLY* ~
- *FARMER//NAME = 'P BACON'*
ARCPLOT: *LIST CULTURAL POLY FARMER//NAME* ~
FARMER//ADDRESS QUANTITIES//MAJOR-ENTERPRISE
ARCPLOT: *POLYGONSHADE CULTURAL 42*
ARCPLOT: *AGGREGATE_LABEL CULTURAL LEGAL-ID*
ARCPLOT: *LIST CULTURAL POLY LEGAL-ID* ~
TITLE//NAME TITLE//ADDRESS

Comments

Demonstrated how legal and farm data could be related and queried together. The full extent of the selected farm was highlighted and details were listed. Also the internal legal boundaries were shown as were legal ownership details. Also illustrated the many to one problem in the first listing. Textual aggregation could have been used to thin this listing down to one record if necessary.

4. (Figure 8-10)

Query

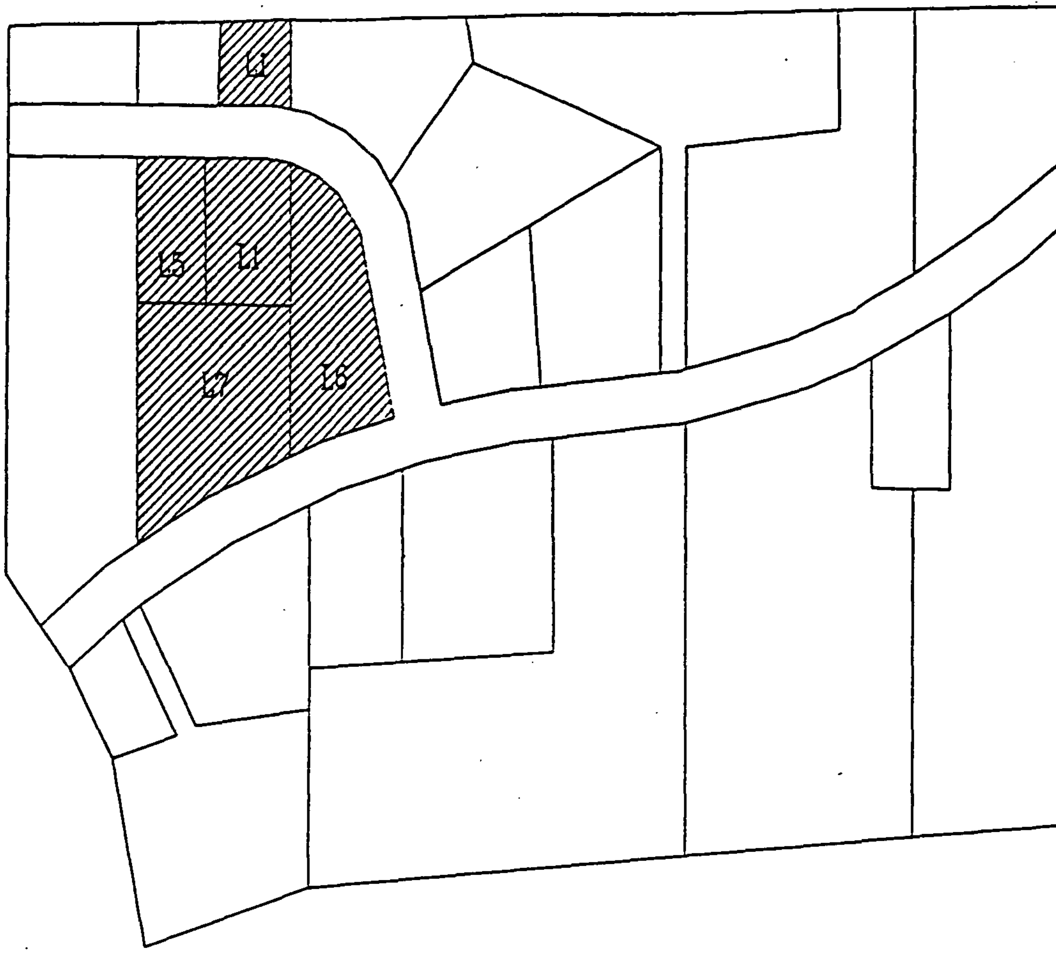
Show all fiscal parcels within 50m of Margaret St and Stafford Drive intersection, and list ratepayers and values.

Commands

ARCPLOT: *EXTERNAL CULTURAL FISCAL-ID 5*
ARCPLOT: *RESELECT CULTURAL POLY CIRCLE * 50*
ARCPLOT: *GETREST CULTURAL POLY FISCAL-ID*
ARCPLOT: *RESELECT CULTURAL POLY FISCAL-ID <> ROAD'*
ARCPLOT: *POLYGONSHADES CULTURAL 42*
ARCPLOT: *AGGREGATE_LABEL CULTURAL FISCAL-ID*
ARCPLOT: *LIST CULTURAL POLY FISCAL-ID*
RATEPAYER//NAME RATEPAYER//AAV

Comments

Demonstrated spatial selection using a circle centred on a user specified point. The centre was located using a cursor. Getrest was used to ensure all fiscal sub units for the selected identifier were selected. The listing that resulted could have been tidied using textual aggregation.



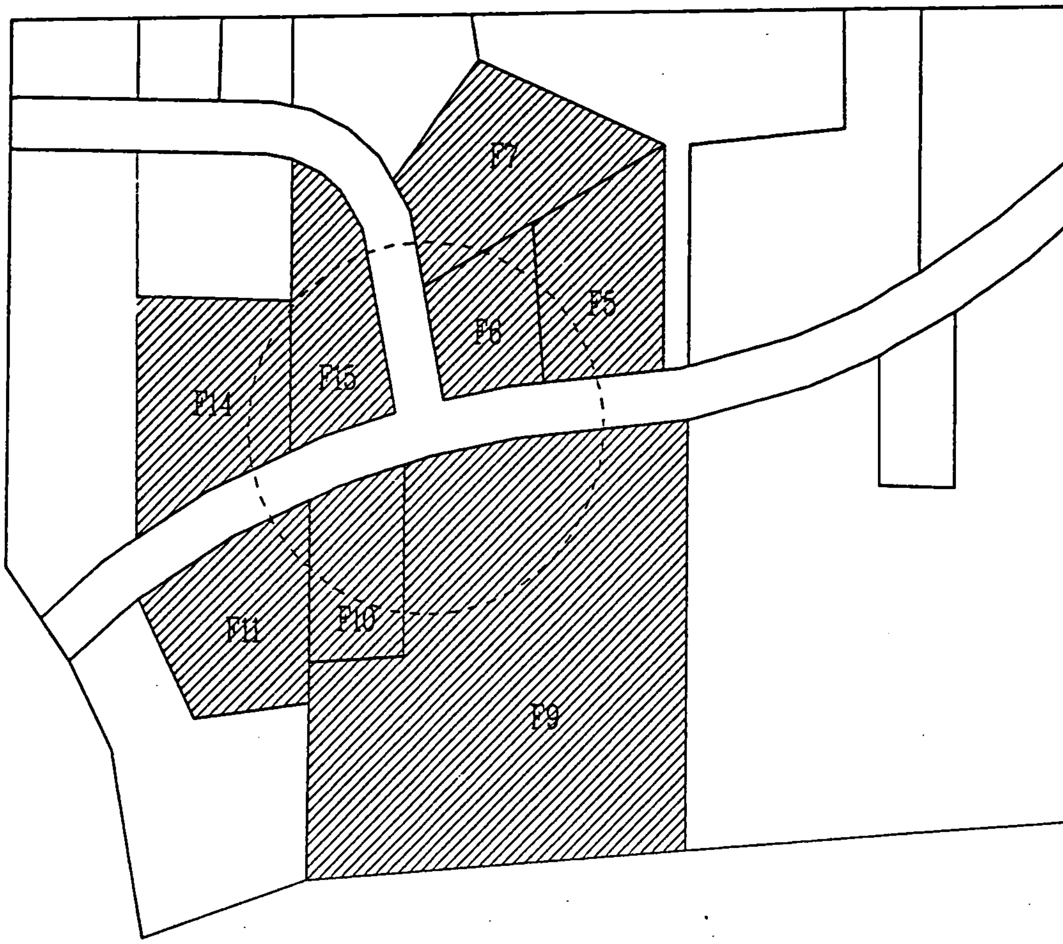
First listing (farm details) :

NAME	ADDRESS	MAJOR ENTERPRISE
P BACON	20 STAFFORD DRIVE UTOPIA	PIGS
P BACON	20 STAFFORD DRIVE UTOPIA	PIGS
P BACON	20 STAFFORD DRIVE UTOPIA	PIGS
P BACON	20 STAFFORD DRIVE UTOPIA	PIGS
P BACON	20 STAFFORD DRIVE UTOPIA	PIGS

Second listing (ownership details) :

LEGAL-ID	NAME	ADDRESS
L1	P BACON	20 STAFFORD DRIVE UTOPIA
L5	P BACON	22 STAFFORD DRIVE UTOPIA
L1	P BACON	20 STAFFORD DRIVE UTOPIA
L6	MRS. P BACON	4 STAFFORD DRIVE UTOPIA
L7	P BACON JUN.	55 MARGARET RD UTOPIA

Figure 8-9



Listing :

FISCAL-ID	NAME	AAV($)
F7	G SAINSBURY	123000
F5	T KING	110000
F15	MRS. P BACON	120000
F6	A COLEMAN	90,000
F14	P BACON JUN.	50,000
F9	NATURAL FARMS INC	289000
F10	J DERMOUDY	176000
F11	B DAVISON	150000
F9	NATURAL FARMS INC	289000
F9	NATURAL FARMS INC	289000

Figure 8-10

5. (Figure 8-11)

Query

Show farm at user specified location and list farmer and address.

Commands

ARCPLOT: *EXTERNAL CULTURAL FARM-ID 5*

ARCPLOT: *RESELECT CULTURAL POLY CIRCLE * 0.1*

ARCPLOT: *LIST CULTURAL POLY ~*
FARMER//NAME FARMER//ADDRESS

ARCPLOT: *GETREST CULTURAL POLY FARM-ID*

ARCPLOT: *POLYGONSHADES CULTURAL 42*

ARCPLOT: *INTERNAL CULTURAL FARM-ID 17*

Comments

Demonstrated how a farm parcel could be selected given a user specified location. The polygon which enclosed the point was first identified, selected, and listed. GETREST was used to select other farm polygons associated with the chosen polygon. These polygons were then highlighted as the farm unit. The last command displayed the internal boundaries for the selected farm.

6. (Figure 8-12)

Query

Show major enterprises for all farms.

Commands

ARCPLOT: *EXTERNAL CULTURAL FARM-ID 5*

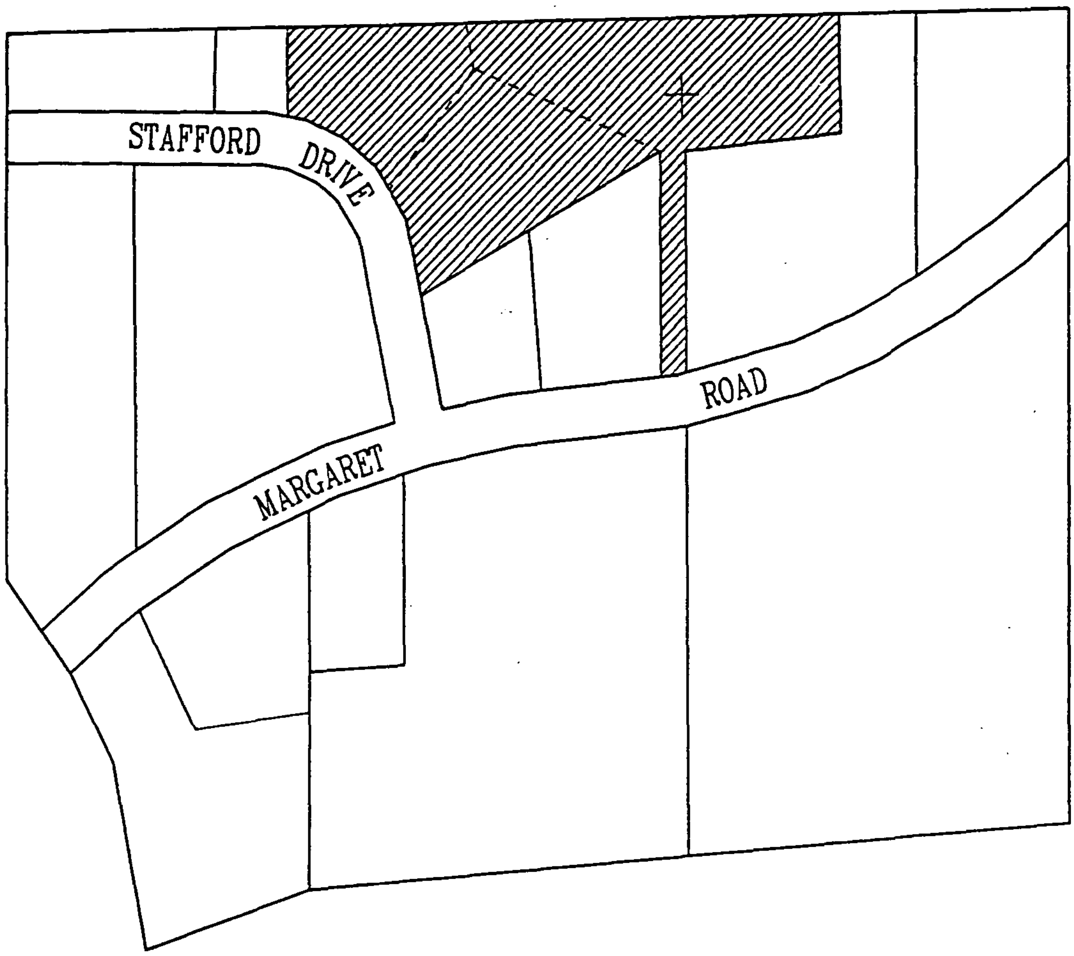
ARCPLOT: *AGGREGATE-LABEL CULTURAL ~*
QUANTITIES//MAJOR-ENTERPRISE

ARCPLOT: *POLYGONSHADES CULTURAL QUANTITIES//MAJOR ~*
ENTERPRISE ENTERPRISE.LU

ARCPLOT: *KEYSHADE ENTERPRISE.KEY*

Comments

Demonstrated how farm parcels could be labelled according to an attribute. Only one of the polygons inside the farm was labelled. Also showed how farm parcels could be shaded according to attributes. A lookup table called enterprise.lu was used to perform this operation. KEYSHADE was a command which enabled the legend to be drawn as shown in the figure. Keyshade uses parameters as specified in the ASCII file enterprise.key.



┼ indicates user specified location.

```
Listing:

NAME       =G SAINSBURY
ADDRESS    =300 LIVERPOOL ST NUBEENA
```

Figure 8-11

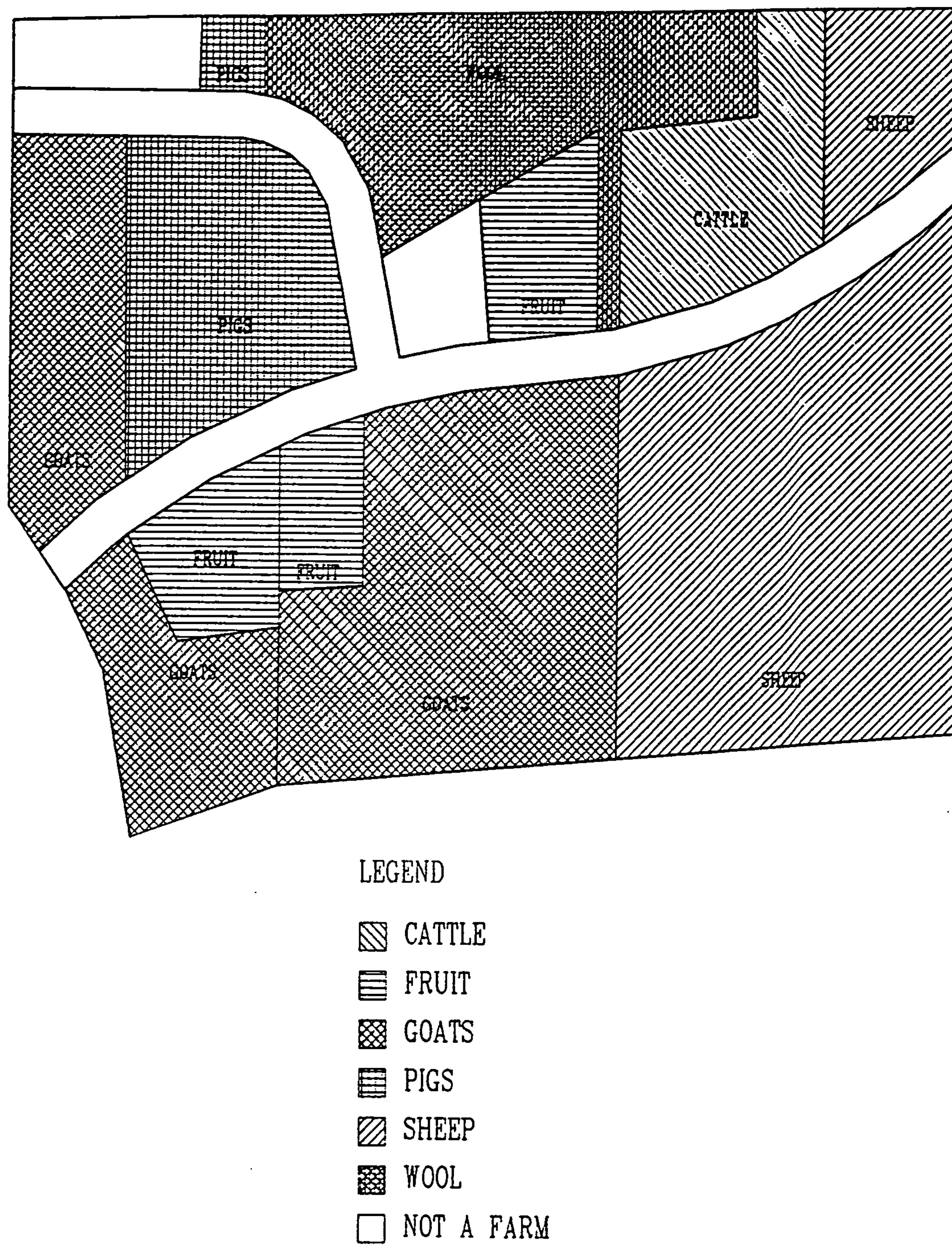

PIGS
WOOL
SHEEP
CATTLE
FRUIT
PIGS
GOATS
FRUIT
FRUIT
GOATS
GOATS
SHEEP
LEGEND
CATTLE
FRUIT
GOATS
PIGS
SHEEP
WOOL
NOT A FARM

Figure 8-12

7. (Figure 8-13)

Query

Show legal parcels owned by B King

Commands

ARCPLOT: *ARCLINES LEGAL_LAYER 1*
ARCPLOT: *RESELECT LEGAL_LAYER POLY ~*
TITLE//NAME = 'B KING'
ARCPLOT: *POLYGONSHADES LEGAL_LAYER 42*

Comments

Demonstrated a typical query on a specialised layer. The commands were similar in execution to those for the cultural layer.

8. (Figure 8-14)

Query

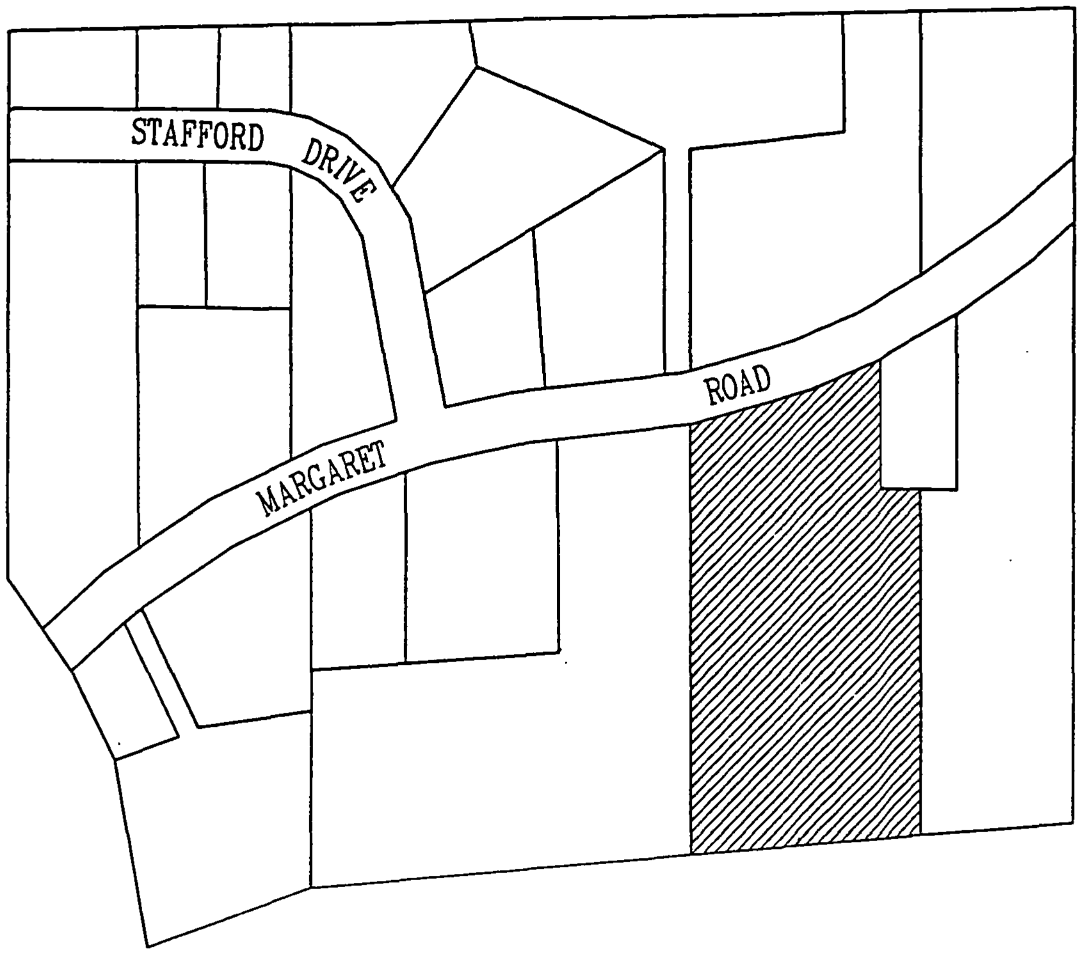
List soil types on B KING's legal parcels

Commands

ARCPLOT: *RESELECT LEGAL_SOIL POLY TITLE//NAME = 'B KING'*
ARCPLOT: *LIST LEGAL_SOIL POLY ~*
LEGAL-ID TITLE//NAME SOIL_CODE AREA

Comments

This was a typical query which required the overlay of two statistically independent layers. (The actual overlay was performed in section 8-3-3.) There were two disjoint soil parcels of tertiary sediments (TER) and one soil parcel of alluvial soil within the legal parcel. The query could have been extended by showing soil parcel boundaries within the legal parcel by labelling these parcels with the soil code.



▨ Legal parcel owned by B King

Figure 8-13

Listing:

LEGAL-ID	NAME	SOIL-CODE	AREA(sq. met.)
L22	B KING	ALL	4,417
L22	B KING	TER	795
L22	B KING	TER	2,349

Figure 8-14

9. (Figure 8-15)

Query

Show legal parcels within municipality of OSBOROUGH

Commands

ARCPLOT: *RESELECT CULTURAL POLY*
MUN//NAME = 'OSBOROUGH'

ARCPLOT: *EXTERNAL CULTURAL LEGAL-ID 5*

ARCPLOT: *AGGREGATE_LABEL CULTURAL LEGAL-ID*

Comments

Demonstrated the selection of lower level parcels based on their containment within a high level parcel. Details of the legal parcels, or any other unit, could also be listed.

Figure 8-16 shows the full extent of legal parcels not entirely contained within the chosen municipality. This was made possible by executing the command

GETREST CULTURAL POLY LEGAL-ID

after the initial RESELECT. The municipal boundaries are highlighted.

Figure 8-17 shows a similar operation performed on farms and census districts. The CD boundary is highlighted.

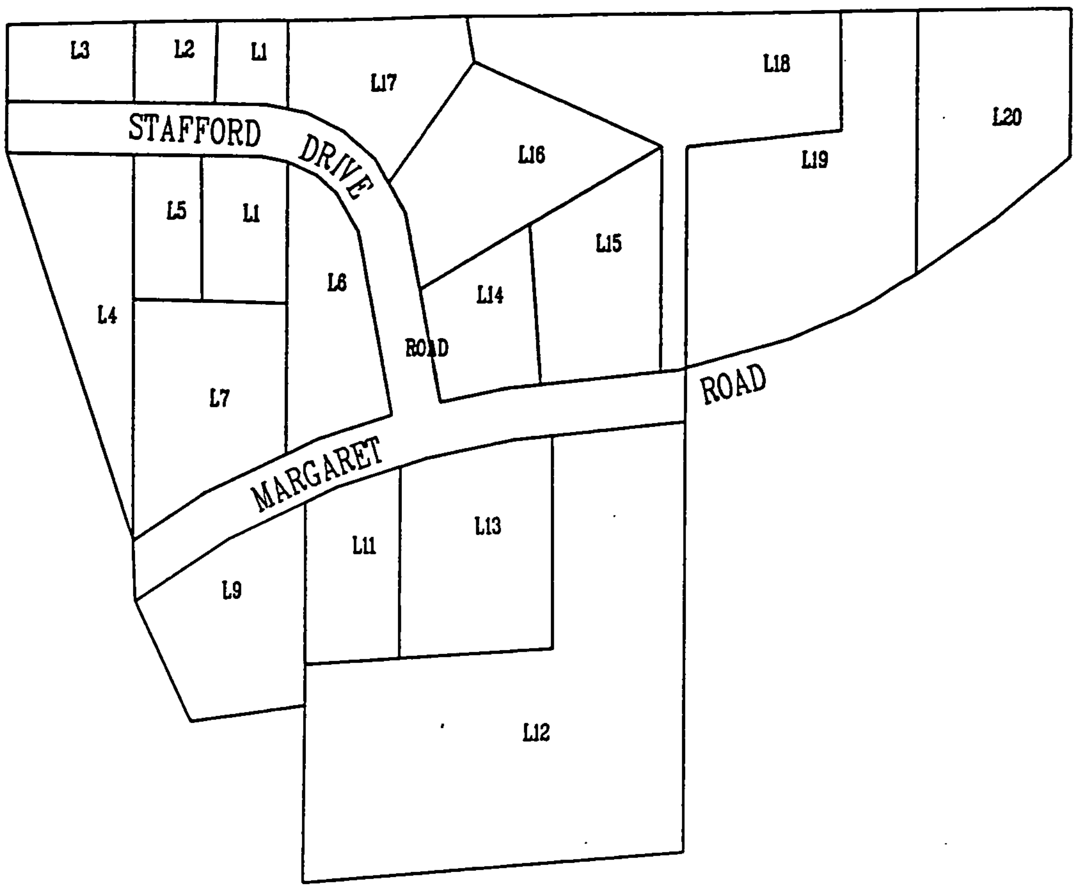


Figure 8-15

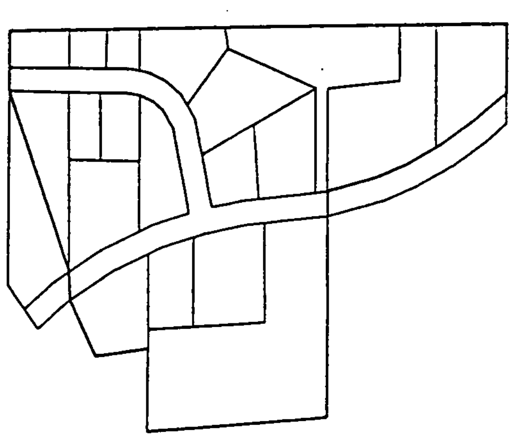


Figure 8-16

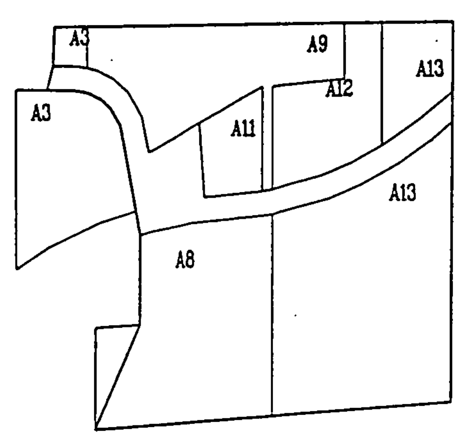


Figure 8-17

8.3.6 Performance and Storage

To judge the performance and storage characteristics on such a small data set was unrealistic. However, a number of comparisons could be made between the storage requirements and query times of the various layers.

Table 8-17 lists the sizes of the combined spatial files of each of the layers. The units are in kilobytes and represent the storage requirements on the Prime 9955II. An empty coverage which did not contain point, line or polygon features required 12 kilobytes.

COVERAGE	SIZE(Kbytes)
CULTURAL	59
LEGAL_LAYER	57
FISCAL_LAYER	57
FARM_LAYER	55
GRANT_LAYER	53
CD_LAYER	53
MUN_LAYER	53
SOIL	57
LEGAL_SOIL	76

Table 8-17

The coverages legal_layer through to mun_layer were all derived from the cultural layer using DISSOLVE. The total storage required for these 6 coverages was 328 kilobytes. However, due to their high statistical dependence all these parcels could be represented in the combined layer which required only 59 kilobytes.

In contrast, two independent coverages such as legal_layer and soil, when combined, produced a coverage which required 76 kilobytes.

The time taken to perform a spatial aggregation and an overlay was also measured. The operations timed were those discussed in section 8.3.2 and 8.3.3 respectively. The results are listed in table 8-18. The times were in CPU seconds on the Prime 9955II. The last command was timed so that the two operations could be compared using the same data

COMMAND	TIME (CPU secs)
DISSOLVE CULTURAL LEGAL_LAYER LEGAL-ID	10
UNION LEGAL_LAYER SOIL LEGAL_SOIL	17
DISSOLVE LEGAL_SOIL LEGAL-ID LEGAL_TEST	11

Table 8-18.

The time taken to perform a general selection on the combined layer and the same selection on specialised layers were also measured. As most selections are performed within a second, they were repeated 100 times to give a query time per hundred, this was considered more reliable. The results are listed in table 8-19. Again the times were in CPU seconds on the Prime 9955II.

COMMAND	TIME (CPU secs/100)
RESELECT CULTURAL POLY TITLE//ADDRESS CN 'MARGARET'	70
RESELECT LEGAL_LAYER POLY TITLE//ADDRESS CN 'MARGARET'	68
RESELECT CULTURAL POLY ~ QUANTITIES//MAJOR-ENTERPRISE = 'SHEEP'	70
RESELECT FARM_LAYER POLY ~ QUANTITIES//MAJOR-ENTERPRISE = 'SHEEP'	65
RESELECT CULTURAL POLY MUN//CENTRE = 'MITCHELL'	70
RESELECT MUN_LAYER POLY MUN//CENTRE = 'MITCHELL'	64

Table 8-19.

Similar comparisons were performed on the draw times as shown in table 8-20. The connect times were more significant in this test as they reflect the time required to produce the output on the screen. For this reason the test was performed when there were no other active users on the system. The display operations were repeated 10 times. The communication baudrate was 9600 bytes per second.

COMMAND	TIME (CONNECT secs/10)	TIME (CPU secs/10)
EXTERNAL CULTURAL LEGAL-ID 1	37	9
ARCLINES LEGAL_LAYER 1	32	3
EXTERNAL CULTURAL FARM-ID 1	34	9
ARCLINES FARM_LAYER 1	24	3
EXTERNAL CULTURAL MUN-ID 1	22	8
ARCLINES MUN_LAYER 1	12	2

Table 8-20.

8.4 Conclusion

This chapter implemented and tested a small theoretical data set using the combined layers model of section 7.3. The combined layer consisted of legal, fiscal, farm, grant, census and municipal parcels. All six of the possible parcel relations of chapter 3 could be found in this model including overlap. Storing the above parcel definitions in the one layer provided significant reductions in storage due to the high statistical dependence of these layers. Statistically independent soil layer was also included as a separate layer in the test data set, however its inclusion in the combined layer did not result in such a significant storage advantage.

Queries on the combined layer, using any of the represented parcel definitions, could be performed adequately. Extra operations were required, such as GETREST and AGGREGATE_LABEL, to ensure that higher order parcels appeared as units rather than a collection of smaller polygons. The many to one relationship between these sub polygons and the parcel attributes posed some problems when data was listed. However, the listing could be thinned using textual aggregation at the expense of time. GETREST was particularly useful for ensuring that all fragmented portions of units of records were included after spatial selections.

The AMLs INTERNAL and EXTERNAL were useful for illustrating relationships between parcels. Queries based on the relationships between the textual data of the various parcel definitions could also be implemented.

The operation of drawing internal boundaries could have been made more efficient by implementing it at the core level rather than as a macro. The information determined by the relate operation within INTERNAL.AML was most likely stored within the coverage data structure. Hence an ARCPLOT command to draw just internal boundaries, in contrast to DROPLINE, would have been an advantage.

It must be emphasised that the cumbersome command lines used in this chapter can be avoided, particularly with the creation of pull down menus in specialised environments.

Specialised layers consisting of any one of the parcel definitions of the combined layer could be produced when necessary. The difference between selection times indicated that there was no significant advantage for producing a specialised layer on that basis. However, display times were improved by utilising a specialised layer particularly for higher order units.

The time taken to perform a spatial aggregation was two thirds that of the reverse operation of overlay. Furthermore, spatial aggregation was not subject to a fuzzy tolerance, hence a boundary in the coverage derived using spatial aggregation was in the same location as the same boundary in the parent coverage. Also, necessary modifications to any of the parcels represented in the cultural layer were made on that layer and new specialised layers were then quickly produced. Hence only one source update was required. These updates could have been in the form of a modification to the central index or a boundary

On the basis of the theoretical data set, the test results were successful. It was possible to represent all the cultural land parcels within the combined layer as distinct units, yet it was also possible to perform queries based on the parcel relationships. The advantages of holding statistically dependent layers in one combined layer were adequately demonstrated. However, specialised layers could be easily produced when necessary. Also, layers held separately could be overlayed when their integration was required.

9. REAL DATA IMPLEMENTATIONS

9.1 Introduction

To enhance the credibility of the combined layers model, this section examines its implementation on a number of different cultural data sets compiled for the purposes of pilot studies. The three prototype Land Information Systems resulted from the Coal River, Hobart City Council and Telecom pilot studies. The two former pilots were performed by the School of Surveying, University of Tasmania. The University's Prime 9955 model II computer was used for both these pilot studies. The Telecom pilot was performed by Telecom Research Laboratories on a VAX computer with the assistance of the School of Surveying.

All studies utilised ARC/INFO Version 4, so the implementation of the model within the polygon network/relational structure was similar to that described in section 8.

The two main identifiers in the Tasmanian pilot studies were the property identifier (PID) and the unique parcel identifier (UPI).

The UPI was assigned to each legal parcel that was outlined on a cadastral map and capable of being separately conveyed. The maps and UPIs were created by the mapping division of the Department of Lands, Parks and Wildlife. UPI values were shown inside their corresponding parcel on the maps. They did not have legal status, however they were being linked with parcel centroids and legal identifiers such as title and deeds references. Their popularity as an identifier was increasing because of their availability.

The PID was the key identifier of the fiscal system, called Valtax. The Valtax database was purely textual and was designed by personnel at the Tasmania State Computer Centre. The file structure was hierarchical with links between the various record types [AURISA 1985]. The structure is illustrated in fig.9-1.

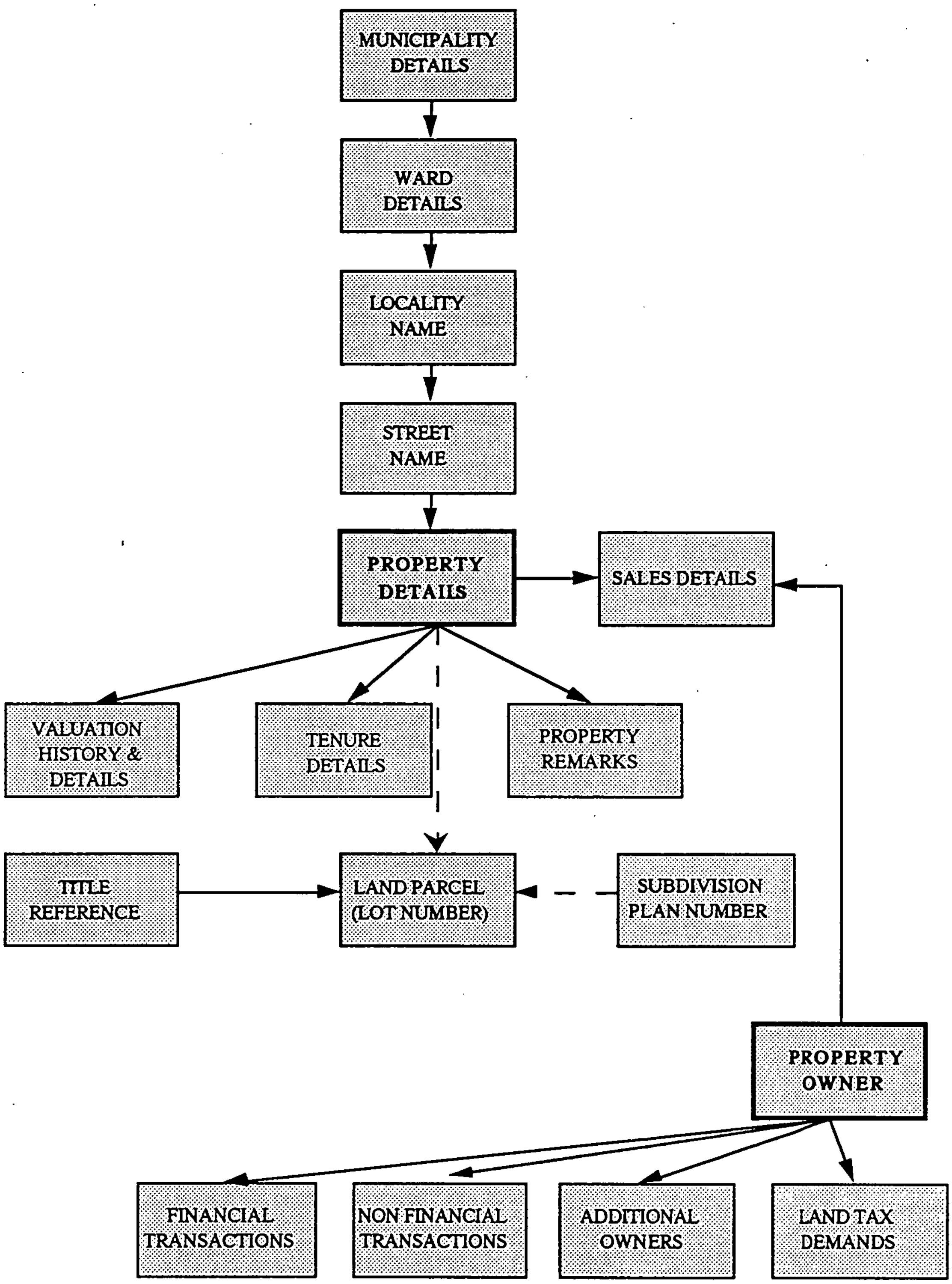


DIAGRAM OF SIMPLIFIED STRUCTURE

OF

TASMANIAN VALUATION AND LAND TAX DATA

Figure 9-1.

9.2 Hobart City Council Pilot Study

9.2.1. Introduction

In 1986 a pilot study was instigated to study the problems of putting the detail sheets maintained by the Engineering Department of the Hobart City Council into a digital form. These sheets included information on property boundaries and services, such as water, sewerage, storm water and road pavements. Hence the system developed was predominantly facilities based, however there was a strong cultural parcel component. For a full report on the pilot study see Driessen [1987].

This section examines the implementation and operation of the fiscal zoning and census parcels of the urban pilot study.

9.2.2. Implementation

Approximately 480 fiscal parcels were represented on the detail sheets. Fifteen of these consisted of more than one legal parcel. Nine of the fifteen were legal parcels subject to stratum subdivisions. The internal boundaries of the fiscal parcels were shown by a broken line as opposed to a continuous line for the external boundaries. All boundaries indicated on the detail sheets were digitised so that the legal parcel became the base unit. However, the internal fiscal boundaries were tagged to distinguish them from the external boundaries.

Each legal parcel was assigned an address as shown on the detail sheets and a unique parcel identifier (UPI) as shown on the 1:5000 maps produced by the Department of Lands, Parks and Wildlife. The UPI and address were assigned interactively by a graphical selection technique as discussed in the pilot study report. The UPI was the only legal reference assigned to the parcel as the title references were not available in a digital form.

The fiscal identifier (PID) from Valtax (see table 9-1) was linked into the pilot system via the address. Approximately 80% of parcels were linked automatically, the remainder were linked manually. A major cause was that the PID was linked to only one of the legal parcels when more than one was possible. Fortunately the PID could be automatically transferred across the flagged internal boundaries. A number of Valtax files comprising ratepayer details, building details and valuation details were loaded into INFO. These were related via the fiscal identifier in the PAT.

Census district and planning zone codes were also assigned to the cadastral parcels. This was also performed using an interactive graphical selection technique. The only cadastral parcels that these parcels severed were roads. Hence the roads were subdivided where necessary so that each portion could be assigned the correct code.

Most census boundaries were along road centre lines. Strictly, the boundaries should have been added to the legal parcel layer so that the road parcels were split into two sub units. Each new road portion could then receive a distinct census identifier but the same legal identifier as shown in figure 9-5. However, there was no practical advantage in doing this, particularly since roads are anomalous parcels. Hence census boundaries were adjusted to road boundaries. However, internal road boundaries were added where census boundaries crossed road intersections. For example, the situation depicted in figure 9-2 was resolved as illustrated in figure 9-3. This was a valid approach because the census boundaries were defined by road centre lines as a result of the scale of the original source maps. Furthermore, census information is not collected in relation to roads.

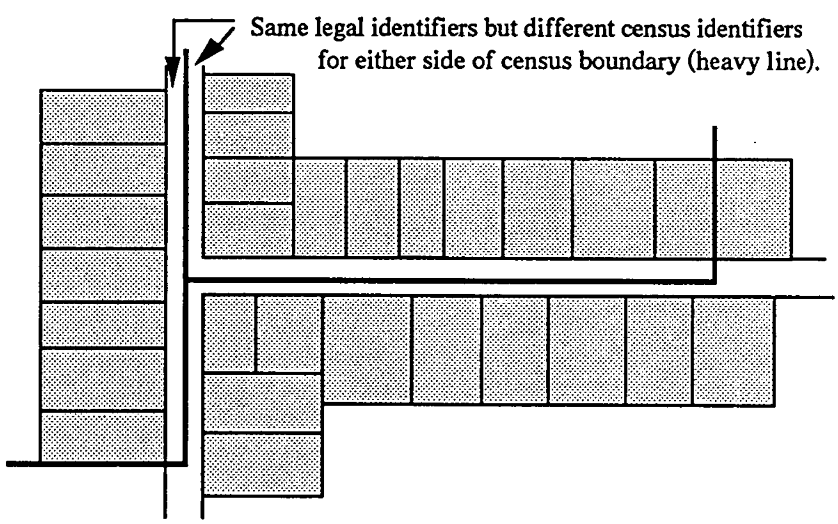


Figure 9-2.

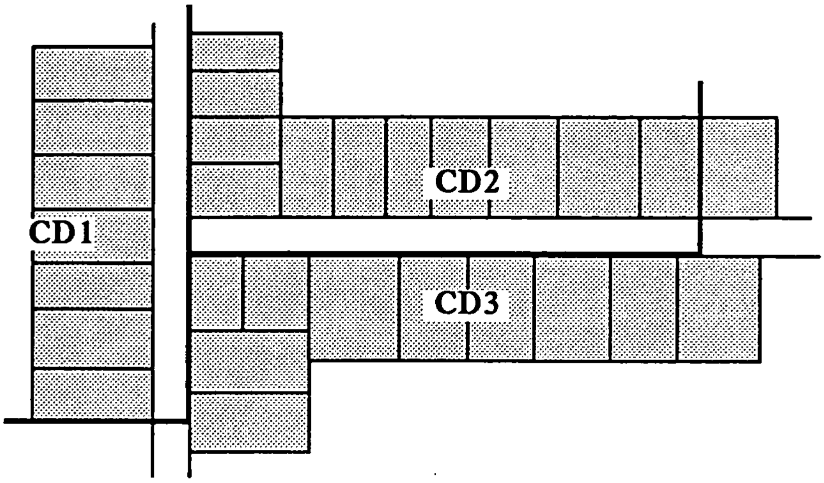


Figure 9-3.

The pilot area also included some stratum subdivisions. All were single level stratums and hence they were not subdivided along horizontal lines, however their boundaries were not shown on the detail sheets. The most appropriate solution for representing stratum subdivisions in a two dimensional system was to treat them as attributes of their parent legal parcel. Despite the fact that a majority could have been treated as a cadastral parcel in their own right, there were other areas, not covered by the pilot study, that included classic stratum subdivisions. The makeshift solution for handling one to many (legal parcel to owners) relationships in ARC/INFO is discussed in appendix A.

9.2.3. Operation

The cultural parcels described above were represented in the one combined layer. Most boundaries in the layer were cadastral except for the odd internal boundaries caused by the census and planning zone boundaries. The planning and census identifiers, UPI, PID and common address were represented in a central index within the PAT. The PAT is shown in Table 9-1. Note that planning and census details were not included in the initial pilot study report [Driessen 1987] as only the digital entry of data on the detail sheets was considered.

Planning zone and census parcel layers were produced by spatial aggregation (DISSOLVE), however they were used mainly as convenient display devices. Queries on census districts and planning zones were performed mainly within the combined (cadastral) layer. A fiscal layer was not created as most fiscal and legal parcels were equal. Fiscal queries were performed adequately on the cadastral layer.

```
DATAFILE NAME: CULTURAL.PAT
  10 ITEMS: STARTING IN POSITION     1
COL   ITEM NAME          WDTH OPUT TYP N.DEC  ALTERNATE NAME
   1  AREA                  4   12  F     3
   5  PERIMETER             4   12  F     3
   9  CULTURAL#             4    5  B     -
  13  CULTURAL-ID           4    5  B     -
  17  HSE#                  8    9  C     -
  25  ROAD                 20   21  C     -
  45  PID                  11   12  C     -
  56  UPI                   4    7  B     -
  60  CD                    8    9  C     -
  68  ZONE                 15   16  C     -
```

Table 9-1.

The combined layer showing all boundaries is displayed in figure 9-4.

Typical queries based on parcel relationships are listed below.

1. Show all vacant parcels with area greater than 1000 square metres and zoned industrial.
2. List owner, ratepayer, value, and zoning for a particular cadastral parcel.
3. List the names and addresses of the owners of all legal parcels within a particular census district.
4. Select legal parcels that have a commercial business in an area zoned residential and list the names and addresses of the associated ratepayers.
5. Show the parcels that are vacant and priced under $30,000 in areas zoned residential and list the owners' names and addresses

9.2.4 Conclusion

The combined layers model was implemented effectively on the cultural data of the Hobart City Council Pilot Study. There was no real need to separate the data into separate layers since many queries required their combination. The overhead of carrying the extra identifiers and the small number of internal boundaries in the cadastral layer was negligible.

Figure 9-4.

9.3 Coal River GIS Pilot Study

9.3.1. Introduction

This land resource pilot study was instigated during 1987 by various Tasmanian Government agencies. The pilot study resulted from concerns expressed by the agencies over the monitoring and planning of developments in the Coal River catchment area. The Coal River Valley is a region with a political centre at Richmond, approximately 20 kilometres from Hobart.

One of the objectives of the study was to examine the methodology for collecting, storing and manipulating land resource data. Cultural data played an important part in the study and included legal, fiscal, agricultural, census and municipal themes. This section examines the implementation and operation of these themes based on the combined layer model.

More complete details for the pilot study may be found in the report by Driessen and Zwart [1989].

9.3.2. Implementation

9.3.2.1. Legal Parcels

The cultural layer for the pilot study was based on the 1:25,000 topographic/cadastral maps prepared by the Department of Lands, Parks and Wildlife. These maps represented the best available source for continuous spatial cadastral data. However, there were a number of limitations in using such a map as a source for a DCDB:

1. Parcels smaller than 2 hectares were not represented on the 1:25000 map sheets. Consequently many parcels were not shown, especially those inside town areas.

2. Roads and Rivers were shown as topographic features, not cadastral features. Consequently unmade legal roads were not represented and those that were shown were represented as linear features. For similar reasons, river boundaries were also difficult to determine.

As a result of the second limitation, legal parcels were digitised as opposed to cadastral parcels. Roads which created areal discontinuities in legal parcels were not represented. Hence the anomalous parcel problem was avoided. However, double sided rivers were digitised as such and the anomalous parcels produced formed areal discontinuities in some situations. Double sided rivers usually occurred between separate parcels.

A total of 1058 parcels were digitised from the Tea Tree and Richmond map sheets. 200 of these were anomalous parcels. Figure 9-5 show the legal parcel boundaries inside the Richmond Municipality parcel for the two map sheets.

Each valid legal parcel was assigned a unique parcel identifier (UPI). This was an automatic process as the UPI data, which was provided in a digital ASCII file by the Department of Lands Parks and Wildlife, included centroid coordinates. Anomalous legal parcels, such as those formed by rivers and towns, were also assigned a UPI by the pilot study team so that all polygons in the legal layer had a unique parcel identifier.

A parcel as determined by the mapping division did not strictly correspond to a legal unit of record. Section 9.3.2.3 provides one example, where two parcels had been created from a legal parcel divided by municipal boundaries.

Another exception occurred as a result of an unusual policy adopted by the Titles Office who had combined some legal parcels in the pilot region into one legal unit of record for taxation purposes. However, they been assigned separate UPIs by the Mapping Division because they were still capable of being separately conveyed. Fragmented portions of general law land were also assigned distinct unique parcel identifiers.

Consequently the unit adopted for the pilot study suffered some inconsistencies. It was neither a cadastral parcel nor a legal parcel but something in between, and its definition varied with the size of the parcel in question. For the purposes of this exercise it was considered a convenient legal parcel.

The actual legal identifier was in the form of either a deeds office or titles office reference. These identifiers were linked to the UPI by the mapping division and were included with the coordinates in the file mentioned above. Titles office identifiers were prefixed with a CT and deeds office identifiers with a DO so that both identifiers could be conveniently represented in the one item.

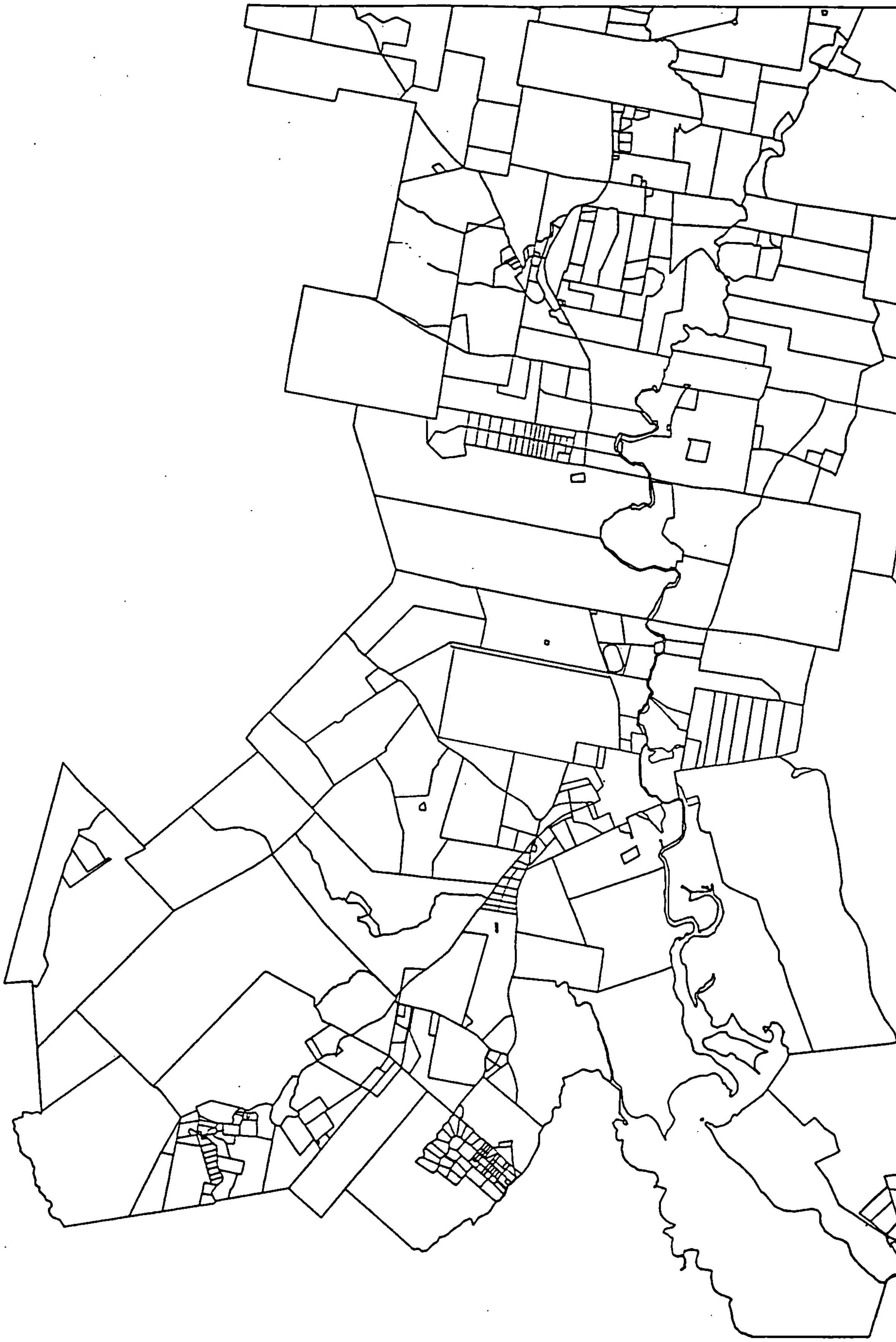


Figure 9-5.

9.3.2.3. Municipal Parcels

The determination of municipal parcels was straightforward using the UPI. The first two digits of the seven digit UPI represent the municipality in which the parcel is located. The remaining 5 digits were arbitrary. However, a number of crown land parcels were divided by a municipal boundary. Consequently the Mapping Division staff formed two distinct parcels when this occurred so that each parcel could be assigned a separate UPI. In doing this an internal boundary was added to the legal parcel. This of course was the method used in the combined layers model when parcels overlapped.

Unfortunately the same process was not performed when the overlap area was very small. Hence these small portions of parcels were not given a new UPI, resulting in the municipal code embedded in the UPI not matching the municipality (figure 9-6). Consequently the municipal code in the UPI could not be utilised as an identifier and so a separate municipal identifier field was added to the Central Index in the PAT.

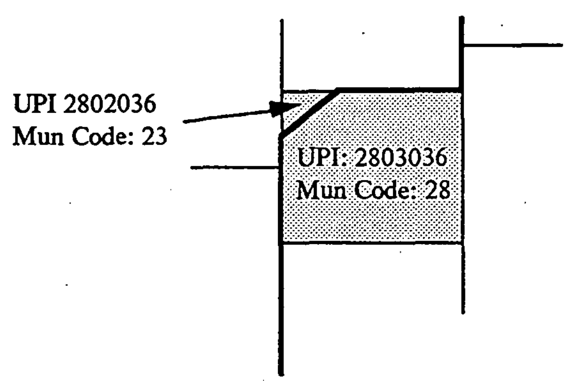


Figure 9-6.

9.3.2.4. Fiscal Parcels

The fiscal identifier was not as easily introduced. A cross reference file, consisting of the PID and the UPI, was provided by the Tasmanian Land Information Directorate. The file was fraught with errors and inconsistencies, many of which were not resolved at the time. Consequently many legal parcels had not been assigned a fiscal code and it was impossible to produce a fiscal layer. Fiscal files had also not been loaded into the system.

The errors and inconsistencies reflect the nature of the Valtex system. Data was not kept up to date and procedures were allowed to lapse. Data such as the title reference was difficult to derive from the system in a useful format. Consequently it was difficult to link the UPI and PID via the title reference which was represented in both systems. Unlike the urban HCC pilot of section 9.2, the address could not be used as a link because the pilot region was rural where addresses are unreliable.

Valuers were starting to include the UPI within the Valtex register. Unfortunately, where a fiscal parcel consisted of more than one legal parcel, they were including only the lowest UPI value suffixed with a + character! Clearly all possible UPI values should have been included with the fiscal parcel records if the data was to be related to all the correct legal parcels.

The mapping division of the Department of Lands Parks and Wildlife had started to include the PID in the UPI files. This will ease some of the identifier linking traumas in the future. However, it was still largely a manual process in rural areas.

9.3.2.4. Farms

The linking of the agricultural data with the legal data suffered similar problems. This data was maintained in two systems by the Tasmanian Department of Agriculture called PIST (Property Information System Tasmania) and MIST (Management Information System Tasmania). The key to both these systems was the PISTCODE.

The PISTCODE data included an AMG reference. These coordinates corresponded to the farm homestead location. However they were unreliable as a spatial link for two reasons. Firstly, they were error prone: field officers had difficulty scaling coordinates off maps. Secondly, the coordinates linked the PISTCODE to only one legal parcel, consequently the adjoining legal parcels, which were part of the farm, were not linked to the PISTCODE.

Fortunately the Department had started adding all possible UPI values to each PIST record. This provided an effective link, however the linking had not been completed by the department at the time of implementation. The pilot system was used to help link the remaining parcels to a PISTCODE. Plots were produced showing all legal parcels for the study area. Parcels with known PISTCODEs were labelled and highlighted. These plots were taken to the local field officers who associated the unknown legal parcels with a PISTCODE where possible. In most cases this was simply a matter of indicating which adjoining legal parcels belong to legal parcels with known PISTCODE. The task of assigning the PISTCODEs as indicated by the updated plans was also straightforward.

The PISTCODE linking process was time-consuming (two days for 400 legal parcels); however, there were significant benefits in that the PIST and MIST data were linked to a spatial data base.

As a result the PISTCODE was made part of the central index represented in the PAT. A large number of PIST and MIST files, which were keyed to the PISTCODE, were also loaded into INFO data files.

Included in the farm management data were details of farm visits. Since a farm could have any number of visits, the relationship between farm parcel and attributes was one to many. The solution to this problem in ARC/INFO is discussed in appendix A.

9.3.2.6. Census Districts

Census parcels for the region were already digitised by the Australian Survey and Land Information Group (AUSLIG). Unfortunately, the source for the digital data was a map at a much smaller scale than the 1:25,000 for the existing pilot study data. Consequently there were gaps between the CD boundaries and the legal boundaries. An overlay of the legal and census parcels produced many spurious polygons. Hence the following method was used to link the census district identifier into the central index.

1. The census layer was overlayed with the cultural parcel layer.

2. This produced a table which included a cultural parcel identifier (cultural-id), the census identifier and area. Using PULLITEMS these items were extracted from this table into a table called CENSUS.LINK.

3. Many legal parcels near the census boundaries were referenced to more than one census identifier due to the mismatch. However, the links (combined census/legal parcels) with the largest area could be considered more reliable. Hence the table CENSUS.LINK was sorted in descending order on the area item.

4. CENSUS.LINK was joined into the central index using the cultural-id as the relate item. In situations where there were more than one possible census-identifier, only the first was taken. That is, the one with the largest area. The area item from CENSUS.LINK was dropped from the central index leaving the census identifier.

The above was a useful general procedure for rectifying boundary mismatch problems. However, boundaries which actually severed the legal parcel were also rectified. These were redigitised to create new sub parcels in the usual way. Also, small parcels could have been linked to the wrong side of the overlayed parcels. Hence some degree of care was required in performing this operation.

The textual data for each parcel was represented in a two dimensional table by the Australian Bureau of Statistics. A method for representing this data in INFO had not yet been determined. Consequently textual queries on the census parcels were not possible.

The legal, fiscal, agricultural, municipal and census parcels were the only definitions implemented within the combined cultural layer of the pilot study. However, others were to be added in the future. A list of the PAT/central index items for the combined layer is provided in Table 9-2. Table 9-3 is a sample listing of this table.

9.3.2.7. Natural Layers

Other layers in the pilot system included natural themes such as height, slope, aspect, and soils. All of these were statistically independent and so there was no real advantage in maintaining them in a combined layer.

Nevertheless, many queries required the determination of combinations of certain natural criteria. There was some merit in retaining a layer consisting of a combination of the natural units that were most frequently required. However such combined natural layers may be considered secondary layers derived from the source natural layers. Although natural characteristics may change infrequently, their interpretation was variable. Different slope height and aspect maps were required for different applications. Hence the advantages of retaining a land form map (combined slope height and aspect) or any other natural combination was marginal. However it was obvious that the natural themes should be maintained as separate layers.

DATAFILE NAME: CULTURAL.PAT

10 ITEMS: STARTING IN POSITION 1

COL	ITEM NAME	WDTH	OPUT	TYP	N.DEC	ALTERNATE NAME
1	AREA	4	12	F	3	
5	PERIMETER	4	12	F	3	
9	CULTURAL#	4	5	B	-	
13	CULTURAL-ID	4	5	B	-	
17	UPI	7	7	C	-	
24	TITLEREF	12	12	C	-	
36	PID	11	12	C	-	
47	PISTCODE	8	8	C	-	
55	MUN	2	2	C	-	
57	CD	7	7	I	-	
	** REDEFINED ITEMS **					
17	MUN_PART	2	2	C	-	
24	LEGAL_SYSTEM	2	2	C	-	
26	TITLE-ID	10	10	C	-	

Table 9-2.

CULTURAL ID	UPI	TITLEREF	PID	PISTCODE	MUN	CD
208	2800246	CT2214/71	5891295	NO VALUE	28	6032704
209	2800245	CT3977/11	5891279	MFRM0141	28	6032704
210	2800243	CT3977/12	5891279	MBRM0240	28	6032704
215	2800038	DO53/1267	5891201	MDRM0260	28	6032704
217	2800248	CT2868/57	5891260	NO VALUE	28	6032704
219	2800022	CT3440/32	5891287	MARM0265	28	6032704
220	2800035	DO28/3846	5891228	MKRM0116	28	6032704
221	2800026	DO56/0190	NO VALU	MKRM0116	28	6032704
222	2800021	CT3666/23	5891244	MARM0089	28	6032704
223	2800023	CT3440/31	5891287	MARM0265	28	6032704
227	2800037	CT3979/50	5890110	MDRM0260	28	6032704
228	2800025	CT3928/68	7199999	MKRM0116	28	6032704
230	2800039	CT2441/62	5891180	MDRM0260	28	6032704
242	2800040	CT2481/75	5891172	MKRM0116	28	6032704
244	2800085	CT2413/22	5890209	MARM0126	28	6032704
255	2800041	CT4248/21	5891156	MGRM0119	28	6032704
292	281NV37	NO UPI	NO UPI	NO VALUE	28	6032704
293	2800047	NO VALUE	NO VALU	GOVT	28	6032704

SAMPLE OF CENTRAL INDEX ITEMS IN CULTURAL.PAT

Table 9-3.

9.3.3 Operation

Many of the queries on the pilot data were of an agricultural nature. This was mainly due to the involvement of Department of Agriculture staff, and also because the PIST and MIST data were successfully loaded into the system. A farm layer was produced from the cultural layer using the spatial aggregation process (DISSOLVE with pistcode as the dissolve item). A farm layer was produced because most queries were based on the MIST and PIST data set or natural criteria. Generally there was not a need to perform queries based on the relationships of farms with other cultural parcels. However, any modifications to the farm layer were performed on the cultural layer and spatial aggregation was then repeated to produce an updated farm layer. Hence the cultural layer was maintained as a primary layer.

Typical queries performed using the farm layer are listed below:

1. Show all farms not tested for pesticide residue.
2. Show all pig farms not checked for swill feeding since a particular date.
3. Show all sheep farms whose principle activity is fat lamb production, highlight those with a flock size greater than 2000.
4. Show farms that are within 1500 metres of the Coal River.

Typical queries using the cultural layer are listed below.

1. Show legal parcels without a pistcode.
2. List farms consisting of more than two legal parcels.
3. Show legal parcels not owned by farmer.

Typical queries that required the overlay of the farm layers with natural layers are listed below.

1. List slope classifications, and corresponding areas, for all farms.
2. List farms that have land suitable for growing grapes. That is, farms that have a particular combination of height, slope, aspect and soil.
3. Show farms with a vegetation cover of less than 20%.
4. Show sheep farms that are susceptible to foot rot. That is, all sheep farms with flat land.

Queries of a fiscal nature were not performed due to the absence of the Valtex data. Many agricultural officers used the Valtex data and it was expected the combined cultural layer would facilitate these queries. However, in the mainstream, a specialised farm layer would be used more frequently. It was expected also that there would be some advantage in producing a fiscal layer unlike in the urban situation demonstrated by the HCC pilot. 70 of the 236 fiscal parcels already linked into the system consisted of more than one legal parcel.

The legal data held in the UPI files was limited. However it did contain unverified grant data which could be used to produce a grant map.

One particularly useful application was to show the legal units that were discontinuous in area. As the discontinuities caused by roads were eliminated there should not have been any areal discontinuities except for the deed units. To test this notion, the cultural layer was spatially aggregated using the title reference. This legal identifier in the resulting PAT would have been unique for continuous parcels but not for units subject to fragmentation. The resulting PAT was therefore textually aggregated to count the frequency of each identifier. Ten legal identifiers had a frequency greater than one. Two of these were errors in the data, four were deed references, and four were Titles Office references. Three Torrens parcels were fragmented because subdivisions of the original legal parcels produced disjoint balances which were retained as one unit. The fourth was a result of digitising cadastral boundaries from a 1:25,000 map. The two disjoint fragments were connected by an area not visible at the map scale.

9.3.4 Conclusion

The combined layers model was also successfully implemented on the cultural data of the Coal River Pilot GIS. Although only the agricultural data was reliably tested, problems are not expected for the remaining census and fiscal data sets. It was found that a specialised agricultural layer derived from the combined layer by spatial aggregation was useful for queries on the data itself, but also for queries in relation to natural data. However, any modifications and updates were made to the combined layer and a new farm layer was redetermined. The combined layer was also useful for queries based on relationships between cultural units.

9.4 Telecom Research Laboratories Pilot GIS

9.4.1. Introduction

The GIS personnel within the Human Communications Research section of Telecom had undertaken the development of a Pilot GIS to investigate the capabilities of such a system in forecasting the need for Telecom services. The pilot study commenced in August 1988 and covered an area of approximately 1000 parcels in the vicinity of Toorak, Melbourne. The aim of the pilot was to integrate various telecommunication data bases with zoning, census and land use information and then test the practical use of these combined data sets.

This section examines the implementation and operation of these data sets within a combined layers model.

9.4.2. Implementation

Two of the main Telecom data bases to be linked into the pilot GIS were RASS and LEOPARD. RASS contained all the special services information such as details on PABX and emergency lines. LEOPARD was the general telephone services database. These data bases were purely textual although each did contain a geocode in the form of a common address.

Spatial Data was provided by the Melbourne Metropolitan Board of Works who had digitised fiscal parcel boundaries on their Integraph system. This data was loaded into ARC/INFO, extensively edited by automated processes, and subsequently formed into fiscal parcels. However textual data was linked to legal parcel centroids and so a quantity of fiscal parcels consisted of more than one centroid. The solution was to add pseudo internal boundaries where they were obviously required. These were not drawn when the fiscal parcels were displayed, but the advantage was that a legal parcel had been created which could be tagged with Telecom data. All boundaries were consequently tagged with a reliability factor.

RASS and LEOPARD data were linked to the parcels by address matching techniques. However, many parcels were linked to a number of RASS and LEOPARD services consequently the parcel and attributes produced a one to many relationship. The representation of these relationships is discussed in appendix A.

There was some doubt as to whether a telephone service should be represented by a parcel. The customer may have no relationship with the owner of the legal parcel. The only thing the telephone service and the parcel had in common was that the service was within the parcel. It seemed the most appropriate method of representing a telephone service was as a point feature.

Land use codes were also implemented within the legal layer described above. These were assigned manually according to the activity on each parcel. Land use boundaries did not subdivide the legal parcels in the pilot area. Zoning codes were also assigned to each parcel according to the relevant map.

Census district codes were to be assigned to legal parcels at a later date using similar methodology to that used in the Hobart City Council Pilot.

9.4.3. Operation

The integration of the data sets for this pilot study is still not complete, however some practical queries have already been applied to the combined layer. Specialised land use and zoning maps have been derived using spatial aggregation. These have been produced for mainly display rather than query operations.

Specific queries on the combined layer included

1. Show legal parcels with RASS services.
2. Show legal parcels with leopard accounts over $500.
3. Show commercial land use parcels without RASS services.
4. Show land use parcels that do not match zoning.
5. List Telecom services in relation to zoning and land use.

9.4.4. Conclusion

The combined layers model was effectively implemented in the Telecom Australia Pilot Study. Layers represented in the model included legal, land use and zoning parcels. An arbitrary number was used for the legal identifier in the absence of a convenient valid alternative. The common address, land use and zoning identifiers were also held in the central index which was implemented in the PAT in the usual way.

9.5 Conclusion

The three pilot studies examined in this section have successfully adopted the combined layers model for the representation of cultural parcel data. In most cases the smallest unit for these layers was the cadastral or legal parcel. However, some sub legal parcels were created for municipal parcels in the Coal River pilot, and census and zoning parcels in the urban pilots. The latter only required the subdivision of road parcels.

The advantage of the combined layer was that queries requiring the knowledge of relationships between parcel definitions could be implemented. Also, when a specialised layer was required, it could be created with expedience using spatial aggregation.

The model is also currently being tested on another pilot study undertaken by the Department of Lands, Parks and Wildlife in Tasmania. The pilot study is testing the creation and application of a DCDB.

10. CONCLUSION

A variety of disparate land parcel types can be represented and integrated within a single model in a Land Information System. This model allows the determination of parcel relationships for queries based on the combined data sets and preserves the spatial and textual identity of the represented parcels so that they may be treated as a distinct entity. The actual form of the model will depend on the relationships between the parcel types themselves which in turn depends on each of their spatial definitions.

Unrelated parcel types, whose boundaries are generally non-conterminous, are represented in separate layers within the model. These layers include spatial topology to allow for the efficient performance of the overlay process and the determination of parcel continuity. Textual data is represented in a relational data base which allows flexible queries through the use of special languages that operate on attribute items and values. Attribute values are held in tables where rows correspond to the parcel records and columns represent the attribute items. The features in the spatial files are linked to the records in the tables via an appropriate identifier.

When the parcel types are conterminous, they may be efficiently represented in one combined layer. This layer is linked to a central index which comprises an identifier item for each parcel definition represented in the layer. These identifiers in turn link the parcels to an array of textual tables, each being keyed to any one or more of the identifiers of the central index.

In this model the basic unit is an area of land with a particular combination of identifiers in the central index. A parcel boundary occurs when one or more of the identifiers of the central index changes. In terms of cultural parcels the basic units is generally the legal parcel, however it may also correspond to smaller parcels. Conceptually the combined layers model may be thought of as an overlay of the layers represented in the model.

The model handles the six basic relationships between parcels. The polygon network structure of the spatial component allows the efficient determination of meet parcels which in turn allows the determination of disjoint parcels. Higher level units which have common_bounds, concur and equal relations with the basic parcel are represented via identifiers in the central index. Unique identifier values indicate equal relations while repeated identifiers indicate common_bounds, concur and disjoint relations. Parcel types which produce overlap relations must be represented in separate layers, however these layers may be overlayed to order the parcels by inclusion. This produces new sub parcels which have either a common_bounds, concur, equal, meet or disjoint relationship with the original parent parcels.

Queries which require the knowledge of relationships of parcels represented in the model may be performed on the layers combined by overlay. Combined layers may also be queried as a function of any of the represented units given certain display and query operations. Furthermore, spatial aggregation operations may be readily implemented should it be necessary to produce a specialised layer to facilitate expedient responses to operations within a data set.

The model contends with a number of the deficiencies and inconsistencies which have not been adequately addressed by the existing single and multipurpose systems.

In particular, a number of different land parcels may be represented as distinct units, unlike systems based on compatible identifiers which require all land data to be represented at the legal parcel level. Furthermore, all land parcels represented in the model, including their associated textual data, may be integrated for queries and analyses based on parcel relationships.

As distinct from multipurpose cadastres, the parcels represented in the model do not need to consist of an integral number of a recognised unit, such as the legal parcel, as a prerequisite for the inclusion and integration of data. The model will incorporate parcels with arbitrary spatial extent and deals with all possible spatial relationships.

The model is particularly efficient in dealing with parcels that are conterminous, especially cultural parcels which are generally based on the legal parcel. The model adequately deals with the problems of fragmentation and anomalies which are found in legal parcel systems and tend to reverberate through most other units based on the legal parcel.

Units of record which consist of fragmented areas of land are represented in the model as a number of polygons with the same identifier. Hence the identifiers are not only useful for representing common_bounds, concur and equal relations but they may also be used to solve the problem of fragmented units. This problem is a result of roads or other anomalous parcels as well as recording policies developed over the decades and is typical of single purpose title registers based on the Torrens system. Fragmentation was solved in models based on deeds registers by allowing the legal parcel to correspond to fragments of the units of record.

In addition, legal parcel anomalies such as roads, rivers and unallocated areas of land which are not adequately recorded in the legal registers may also be represented in the model. They are initially represented as gaps in the cadastral pattern which may be officially recognised by the assignment of an appropriate identifier.

An issue which has not yet been adequately resolved by this and other models is the problem of quantitative attributes. The integration of disparate parcels results in the assignment of these attributes to portions of the actual unit to which they apply. This distribution process is a specialised task and techniques will vary according to the data sets. The model in its purest form will allow unwary users to list or query quantitative values of units at the sub parcel level which can produce misleading results. However this access may be controlled by applying restrictions to the linkage mechanism or by limiting access through menu driven interfaces. This problem needs careful consideration in the future as it will arise in any situation which allows the integration of the quantitative attributes of disparate parcels.

The significant advantage of the model is that the combined layer representing conterminous units becomes primary and any layers derived there from are secondary. All updates and modifications are performed on the primary layer and new secondary layers derived where necessary. This avoids the duplication of data collection and maintenance, also, inconsistencies between layers are avoided because all parcel layers with common boundaries are based on the one layer. There are also advantages in storage which do not compromise data access an retrieval efficiency.

Polygon topology is a fundamental basis of the model as it allows both overlay and spatial aggregation as well as efficient data storage, display and query operations. The successful implementation of the combined layers model also requires an identifier for each parcel type represented in the model. It is the identifier that allows a particular parcel type to be treated as a unit. Hence a family of identifiers is essential if various areal units are to be represented and utilised.

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APPENDIX A

One to Many Relationships in ARC/INFO

In a spatial information system a map feature such as a polygon may have many attribute values for the same class. For example: a legal land parcel may have any number of telephones linked to the address; a farm parcel may be subject to any number of visits over a given period and; a legal land parcel subject to a stratum subdivision may have a number of separate legal owners.

Table A-1 shows a list of farm visit details sorted on a farm code. There is a separate code for each farm represented in the spatial data base. This code may be used as the relate item to link the attributes with the parcels in a layer of farm parcels. A common query might require the display of all farms not inspected for lice since 3rd June 1987. Clearly all farms have been inspected for lice, but only two of those have not been inspected since 3rd June 1987. Hence it must be possible to select features based on any of the records which may be linked to a feature.

FARM VISIT DETAILS			
CODE	DATE	INSPECTION	RESULTS
MARM2046	4-5-87	LICE	NEGATIVE
MARM2057	5-5-86	FOOT ROT	NEGATIVE
MARM2057	9-7-86	LICE	POSITIVE
MARM2057	12 9-87	LICE	NEGATIVE
MARM2063	16-5-86	LICE	NEGATIVE
MARM2063	14-9-88	FOOT ROT	NEGATIVE
MARM2098	3-12-87	LICE	POSITIVE
MARM2116	15-11-86	LICE	POSITIVE
MARM2116	16-10-87	FOOT ROT	NEGATIVE
MARM2120	14-7-87	LICE	POSITIVE

Table A-1

The following is an extract from the ARC/INFO manual [ESRI 1987] and indicates the current situation at version 4.

One-to-many correspondence

SOILS.PAT

SOILS-ID	SOIL-TYPE
1	100
2	200
3	300
4	250

SOILS.EXPAND

SOIL-TYPE	SUB-CLASS	COMPACT	MOISTURE
100	A	40	12
200	B	60	40
250	A	18	55
300	C	45	40
100	D	38	76
250	A	17	61

Each record in the feature attribute table has a unique relate item value. In the related file, however, there are many records which have the same value for the relate item (or field). In these cases, there is no method available to relate from the feature attribute table to multiple records in the related table. ARC/INFO will establish the relate and "connect" to one of the relate records which match. However, the relate record used will vary depending on the type of relate established and the order of the relate item values in both the feature attribute table and the relate table. Also, note that ARC/INFO will not test for this situation. Neither will it warn you when this situation occurs.

Clearly one to many (feature to attributes) relationships are not supported in ARC/INFO version 4. This imposes a severe limitation.

The situation may be overcome to a limited degree by subdividing features with more than one record. For example in the soils sample above, the soil type polygon may be subdivided into soil sub class polygons so that there is a spatial feature for each attribute. The soil type and sub class can then be combined and used as a relate item. Stratum subdivisions with vertical boundaries may also be represented in the parcel layers so that an owner may be assigned to a distinct feature.

However, it is difficult to subdivide true stratums with horizontal boundaries in a two dimensional spatial system. It is also difficult to subdivide farms according to visits. Hence the creation of new polygons to produce a feature for each record is not a viable solution. Nevertheless, the same remedy can be applied using points as the feature instead of polygons. In ARC/INFO, this means the creation of a new coverage since point and polygon features cannot be stored within the one coverage.

A point is created inside each corresponding polygon for every record in the attribute table. These points may all be placed in the same location within the polygon. The existing polygon label is an appropriate location. The point and polygon must be linked by a common identifier. IDENTITY is an appropriate command for linking the points with their polygons.

Queries based on one to many relationships may be performed on this model using ARCPLOT. That is, the point coverage has a one to one relationship between points and attributes so points may be selected on any of the attributes. Once a subset of points has been chosen, all polygons which are linked to these points may then be chosen. This operation is performed by writing all common identifiers for the selected points to a file using INFOFILE and then selecting polygons whose common identifier is represented in that file. These polygons may then be queried further or displayed.

Typically this linking process may be repeated many times during a session and so it is convenient to streamline the procedure. LINK.AML is a macro program that is listed in appendix A-1. It was written to link a polygon cover called PARCEL and two point coverages PC1 and PC2 via a common identifier called COMMON-ID. PC1 and PC2 contain the attribute records for PARCEL. Hence typical operations such as the following may be performed:

1. Selections on PC1
2. LINK PC1 PARCEL (to select all parcels for selected points)
3. Selections on PARCEL
4. DISPLAY parcels
5. LINK PARCEL PC2 (to select all PC2 points for selected parcels)
6. Selections on PC2
7. LINK PC2 PARCEL (to select all parcels for selected points)
8. Display parcels

This operation is a little cumbersome and only provides an interim solution. ESRI (California) have verbally promised that one to many relationships will be supported in version 5 of ARC/INFO. Its arrival is eagerly awaited.

Appendix A-1.
(link.aml)

```
/*LINK.aml allows various link combinations between a parcel and
/*two point files facilitates one to many relates
/*[RJD 890414]

&args current desired
&if [null %current%] &then &return ~
   Usage: LINK <PARCEL | PC1 | PC2> <PARCEL | PC1 | PC2>

/*consts
&s relname link
&s linkfile T$LINK.LINKFILE
&s linkcode := common-id

/*set to capitals and remove spaces
&s current := [trim [translate %current%]]
&s desired := [trim [translate %desired%]]

/*correct any abbreviations and set coverage type
/*for currently selected data
&select %current%
  &when PARCEL, P, PAR, PARC
    &do
    &s current PARCEL
    &s current_sort := poly
  &end
  &when PC1, 1
    &do
    &s current PC1
    &s current_sort := point
  &end
  &when PC2, 2
    &do
    &s current PC2
    &s current_sort := point
  &end
  &otherwise
    &return Usage:  LINK <PARCEL | PC1 | PC2> <PARCEL | PC1 | PC2>
&end
```

Appendix A-1(continued).
(link.aml)

```
/*correct any abbreviations and set coverage type
/*for derired data
&select %desired%
  &when PARCEL, P, PAR, PARC
    &do
    &s desired PARCEL
    &s desired_sort := poly
  &end
  &when PC1, 1
    &do
    &s desired PC1
    &s desired_sort := point
  &end
  &when PC2, 2
    &do
    &s desired PC2
    &s desired_sort := point
  &end
  &otherwise
    &return Usage: AGLINK <PARCEL | PC1 | PC2> <PARCEL | PC1 | PC2>
&end

/* now lets do it!
&severity &error &routine bailout
&messages &off &info

/*remove link file if it exists
system arc kill [before %linkfile% .] info

/*create list of link codes for selected features
infofile %current% %current_sort% %linkfile% %linkcode%

/*set up relate for link file
relate add
link %linkfile% info %linkcode% %linkcode% linear
[unquote ' ']

/*select records represented in the linkfile for desired data
reselect %desired% %desired_sort% link//%linkcode% ^= ' '

/*thats all!!
&label finish
&messages &on

&return

&routine bailout
&goto finish
&return
```

APPENDIX B

AML Listings

Appendix B-1.
(external.aml)

```
/*EXTERNAL draws external boundaries of parcels with specified symbol
/*Used in arcplot
/*[RJD 890306]

&args cover ident symbol

&if [null %ident%] &then ~
&return Usage EXTERNAL <cover> <identifier> {symbol}
&if ^ [exists %cover% -cover] &then &return Coverage not found
&if [type %symbol%] = -1 &then linesymbol %symbol%
dropline %cover% %ident% notext

&return
```

Appendix B-2.
(internal.aml)

```
/*INTERNAL draws internal boundaries of parcels with specified symbol
/*Used in arcplot
/*[RJD 890306]

&args cover ident symbol

&if [null %ident%] &then ~
  &return Usage INTERNAL <cover> <identifier> {symbol}
&if ^ [exists %cover% -cover] &then &return Coverage not found

&severity &error &routine bailout

&s DF1name := T$INTERNAL.INFOFILE1
&S DF2name := T$INTERNAL.INFOFILE2
&S DFprefix := [before %DF1name% .]

&messages &off &all
/*remove file if it already exists
sys arc kill %DFprefix% info

/*create files with relate item and identifier
infofile %cover% poly %DF1name% %cover%# %ident%
infofile %cover% poly %DF2name% %cover%# %ident%

/*set up relates between these files
relate add
Linternal %DF1name% info lpoly# %cover%# linear
Rinternal %DF2name% info rpoly# %cover%# linear
[unquote ' ']

/*now perform selection
reselect %cover% line ~
  Linternal//%cover%# > 0 or Rinternal//%cover%# > 0
reselect %cover% line Linternal//%ident% = Rinternal//%ident%

/*and draw selected arcs and finish
arclines %cover% %symbol%
aselect %cover% line
&label end
&severity &error &fail
&messages &on
&return

&routine bailout
&goto end
&return
```

Appendix B-3.
(aggregate_label.aml)

```
/*aggregate_label: ensures that higher level polygons consisting of
/* more than one lower level polygon is labelled only once.
/*Used in arcplot
/*[RJD 890308]

&args cover ident

&if [null %ident%] &then &return ~
  Usage AGGREGATE_LABEL <cover> <identifier>
&if ^ [exists %cover% -cover] &then &return Coverage not found

linesymbol 0
dropline %cover% %ident%
linesymbol 1

&return
```

Appendix B-4.
(getbounds.aml)

```
/*GETBOUNDS selects arcs for selected polygons
/*Used in arcplot
/*[RJD 890306]

&args cover

&if [null %cover%] &then &return Usage GETBOUNDS <cover>
&if ^ [exists %cover% -cover] &then &return Coverage not found

&severity &error &routine bailout

&s DFname := T$GETBOUNDS.INFOFILE
&S DFprefix := [before %DFname% .]

&messages &off &all
/*remove info data file if it exists
sys arc kill %DFprefix% info

/*produce file of required identifiers
infofile %cover% poly %DFname% %cover%#

/*set up relates with this file
relate add
Lgetbounds %DFname% info lpoly# %cover%# linear
Rgetbounds %DFname% info rpoly# %cover%# linear
[unquote ' ']

/*now perform selections and finish
aselect %cover% line
reselect %cover% line Lgetbounds//%cover%# > 0
aselect %cover% line Rgetbounds//%cover%# > 0
&label end
&severity &error &fail
&messages &on
&return

&routine bailout
&goto end
&return
```

APPENDIX C

Extract from Moyer, D.D. and Fisher, K.P. (1973), Land Parcel Identifiers for Information Systems, American Bar Foundation, Chicago, workshop II -17.

Comment: PARCELS, ESTABLISHMENTS, AND LAND TITLE RECORDS

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THE FOLLOWING EXAMPLES illustrate the need to distinguish between parcels and establishments for title purposes, although the same need may not exist for taxation purposes.

1. B owns parcel No. 1 in fee simple absolute. B leases from C for 99 years parcel No. 2 which adjoins parcel No. 1. B builds a commercial building on parcels Nos. 1 and 2.

2. B owns parcel No. 1 in fee simple absolute. B purchases adjoining parcel No. 2, which is subject to a 20-year mortgage of $15,000 at a low interest rate. B farms parcels No. 1 and 2 as a unit. Only part of B's farm is subject to the mortgage.

3. At different times and from different persons B acquires title to three contiguous parcels. Each parcel has its own identifier number and its own description. B gives C a mortgage to secure a loan of $50,000. In this mortgage the separate parcels are identified by their respective identifiers. B constructs an apartment building on the three parcels.

4. B acquires from different persons at different times title in fee simple absolute to three contiguous parcels that B uses as a single farm. B sells his farm to C by a deed in which he either lists the identifiers for each parcel or he describes in the deed each parcel or both. If instead of listing the identifier for each parcel or describing each parcel, B had described the farm as a single parcel and by a new identifier number, then the total farm would be a parcel.

In any computerized mapping system based upon parcel descriptions in deeds or in plats, in all the examples the establishment would include two or more parcels.

Several things might be done to keep land title records and the parcel identifier system in proper relationship and also to accommodate the less demanding requirements of tax assessment and the administration of building, occupancy, safety, sanitation, fire, and other codes. First, there should be a governmental official who is responsible for the proper assignment of parcel numbers. One of his responsibilities should be to prevent the use of an excessive number of parcel identifiers. For example, A's parcel adjoins B's parcel. A purchases from B 3 feet of B's parcel; then A constructs a house on his original parcel and the recently acquired strip of 3 feet. Presently without a conveyance to another person it would be difficult for A to record a new description of his original parcel and the 3-foot strip acquired from B. It should not be difficult for a governmental official pursuant to statute or regulations to provide A with a simple means of recording the new dimensions of his expanded parcel and of obtaining an identifier for the expanded parcel.

Pending enactment of a statute providing for a governmental official to administer the parcel identifier system, proper adjustments might be made by handling establishments for tax purposes by means of a special symbol and the identifier of one of the parcels included in the establishment.

For the time being priority should be given to the needs of the system of land title records with tax assessors making any necessary adjustments to expedite their work.