UNIVERSITY OF SOUTHERN QUEENSLAND

3D CADASTRE IMPLEMENTATION ISSUES IN AUSTRALIA

A Dissertation submitted by

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ABSTRACT

Increasing pressure on our urban environment has resulted in the development of infrastructure and buildings above and below the surface of the earth. Jurisdictions in Australia and internationally have responded accordingly through the implementation of 3D cadastres. Most jurisdictions have what has been termed a "2D cadastre", however, "3D cadastre" situations have now created some significant challenges for the existing land administration infrastructure. The Australian implementation of the 3D cadastre is considered one of the best examples amongst other cadastral jurisdictions, however, because of the varying jurisdictional implementation arrangements within Australia, a clear understanding of complex 3D cadastral issues has been difficult to formulate.

The aim of this research is to investigate the institutional and technical issues and characteristics of 3D cadastre developments across Australia and Queensland in particular, to improve the ongoing implementation and developments across jurisdictions. A better understanding of these issues will assist in the identification of areas where future efforts should be focussed. Further, this will assist in highlighting the institutional and technical 3D cadastral implementation issues to be considered by cadastral jurisdictions.

A survey of the eight cadastral jurisdictions of Australia was carried out and the results were analysed to understand the current status of 3D cadastre implementation in Australia. A detailed case study of five cases in the jurisdiction of Queensland was then undertaken to identify specific issues and characteristics of the 3D cadastral implementation. The results were integrated using a mixed methods approach to identify the institutional and technical issues in 3D cadastre and to frame possible strategies to support ongoing implementation of 3D cadastre in Australia.

From the integration of results, eleven issues were identified and grouped into six component classes. The legislative framework of all cadastral jurisdictions was found to be adequate, supportive and encouraging of the implementation of 3D cadastre. Policies, standards and procedures were also found to be supportive but variable. The operational arrangements to support survey plan transactions in

Queensland were also found to be adequate and could be extended to a full 3D cadastral implementation in the future. Queensland registered 3D rights in a similar way to 2D rights; however, it was found that 3D data could not be stored in the existing cadastral database as a 3D object. Specific geometrical representations are yet to be finalised, however, the current practice of creating 3D objects through surface triangles has enabled the representation of 3D objects on paper plans. The development of a 3D specific database and the corresponding validation rules in the future will assist in the full implementation of 3D cadastre in Queensland and other jurisdictions.

This dissertation has provided a comprehensive study of national, as well as a jurisdiction level implementation of 3D cadastre, and has identified a range of institutional and technical issues and characteristics for the improvement of 3D cadastral implementation. It has also assisted in creating a more comprehensive understanding of the issues in 3D cadastre in an Australian jurisdictional context.

CERTIFICATION OF DISSERTATION

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Sudarshan Karki, Candidate | Date

ENDORSEMENT

A/Professor Kevin McDougall, Principal Supervisor | Date

Dr. Rodney J. Thompson, Associate Supervisor | Date

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PUBLICATIONS RELATED TO RESEARCH

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

With rapid growth of urban environments worldwide, there is an increasing need to develop more innovative and efficient land titling systems to support urban development in our crowded cities. The limited availability of land has necessitated the development of complex infrastructures below and above the ground and the need for the registration of the ownership of this infrastructure. Many countries around the world, including Australia, are now developing and implementing three dimensional (3D) cadastral frameworks to address these situations, but capturing and registering these rights within existing systems brings considerable challenges. As Stoter (2004, p. 3) maintains, "*even when the creation of property rights to match these developments is available within the existing legislation, describing and depicting them within the cadastral registration poses a challenge*".

The conventional two-dimensional (2D) parcel is considered to be a special case of the 3D parcel (Stoter & van Oosterom 2006). The 2D parcel is commonly considered to be the surface or base parcel and is in fact an intersection of a column of space with the earth's surface (Stoter 2004) usually with an unspecified depth below or height above the surface of the earth. This paradigm shift in considering a parcel from a 2D plan-world view to a 3D column of rights has necessitated the development of a 3D capable system where multi-dimensional rights and restrictions can be visualised and are also capable of being spatially sliced.

Implementing a 3D cadastre requires the co-existence of a judicial framework, a cadastral framework and a legal framework (Stoter & van Oosterom 2006). The technical and judicial framework assists in defining the cadastral framework along with other drivers such as the land market and the present land administration needs. Cadastral systems in many Australian jurisdictions allow the registration of 3D rights, so in most instances the judicial and the cadastral frameworks already exist. However, issues such as the scope and limitations of the 3D cadastre, legal rights, representation methodology and geometry, validation strategies and other technical aspects of integrating 3D data into a computer database have hindered the development of a fully functional 3D cadastre.

To understand the nature of a 3D cadastre it is necessary to understand the different situations in which a parcel or property unit may be considered to be 3D. The cadastre can be considered to consist of two components, a geometrical component and a legal component that covers among other things, the rights, restrictions and responsibilities (RRR). It is necessary to analyse 3D parcels from both a geometrical as well as the legal perspective because both components may not coincide in a 3D situation, such as in the case of a network object like a tunnel.

Therefore, it is important to explore a range of possible 3D cadastre scenarios and classify them according to a defined set of rules so that they can be treated homogenously. This research will help in understanding the problems and factors associated with a 3D cadastre by focussing on the variety of situations where 3D objects have been created. By recognising the various 3D cadastre situations it may be possible to increase the level of standardisation, reduce complexity and hence improve land administration operations.

1.2 RESEARCH FORMULATION

1.2.1 Statement of Research Problem

In its simplest form, cadastral registration consists of storing parcel geometry and its accompanying ownership record. In a 3D situation, because of the often complex geometry of a 3D object, the storage and manipulation of the geometrical data becomes problematic, which may also affect the registration of the rights.

Jurisdictions where the primary concern is apartment or condominium registration, have adopted an approach of storing individual apartments as layers on the 2D surface parcel with 3D descriptions often limited to scanned volumetric plans. However, these approaches cannot be considered to constitute a full 3D cadastre system as the geometry is not stored within the cadastral database, the individual 3D object does not exist in its own right within the cadastral system and the rights of the object are not registered independently.

In a 3D context, various researchers have raised concerns in areas such as geometry, storage, representation, manipulation and dissemination, registration of rights and restrictions, database design, modelling and extensibility, spatial querying, data validation, standardisation, application of 3D cadastre such as 3D city models, disaster management and the overall land administration outcomes.

The implementation of 3D cadastre in different jurisdictions varies considerably and a single solution to satisfy the requirements of all is highly unlikely. The issues need to be understood to a level where they still have significance or impact and then they need to be clustered according to homogeneity. An understanding of the issues in 3D cadastre processes will assist jurisdictions in identifying possible solutions and the development of appropriate implementation strategies.

Therefore, the central research problem for this study is:

"In Australia, although 3D cadastral objects are currently being registered, our understanding of the complex 3D cadastre issues and the varying jurisdictional implementation arrangements is incomplete, and is therefore limiting our ability to implement institutional and technical improvements."

1.2.2 Research Aim

The research will build on our existing understanding of the issues and characteristics of 3D cadastres across Australian jurisdictions and seeks to identify implementation arrangements that would lead to improved land administration processes in Australia.

The central aim of the research is to:

"Identify the key issues and characteristics that are impacting 3D cadastre developments across Australia and Queensland in particular, so that strategies for improving its institutional and technical implementation can be identified."

1.2.3 Research Questions

Based on the above research problem and the research aim, the following research questions were formulated:

1. What are the institutional and technical issues and characteristics relevant to 3D cadastre implementation?
2. What is the current status of 3D cadastre across the cadastral jurisdictions of Australia?

3. What are the specific issues and characteristics of 3D cadastre in Queensland?
4. How can we formulate implementation strategies to address the identified 3D cadastre issues?

1.2.4 Research Objectives

The following objectives were formulated to answer the research questions and to achieve the research aim:

1. To review the existing institutional and technical issues and characteristics relevant to the implementation of 3D cadastre in Australia and internationally;
2. To study the current status of 3D cadastre across the cadastral jurisdictions of Australia;
3. To undertake a detailed study in one Australian jurisdiction to identify specific institutional and technical issues and characteristics of 3D cadastre implementation; and
4. To frame possible strategies to support the ongoing implementation of 3D cadastre in Australia.

1.3 RESEARCH APPROACH

This research used a mixed methods approach for integrating the results of a questionnaire and case study as shown in Figure 1-1. Quantitative and qualitative data was collected from multiple sources for the questionnaire and the case study.

The research was formulated by providing a background to the topic, identification of the research problem, specifying the aim, objectives, and the research questions. It also included a review of existing literature on 3D cadastre from a land administration and technical perspective to formulate the research questions and an appropriate research methodology.

In the research design, data collection through a questionnaire and case study was considered the most appropriate approach for this study. The questionnaire was designed based on research objective – 2 and the gaps identified from the literature review. Further detailed analysis based on research objective – 3 and the identified gaps were performed for a single jurisdiction of Queensland. Descriptive statistical analysis of questionnaire data was performed to identify the issues and characteristics of 3D cadastre across the jurisdictions of Australia. Qualitative analysis of case study data of the jurisdiction of Queensland provided an in-depth analysis of the features of 3D cadastre implementation.

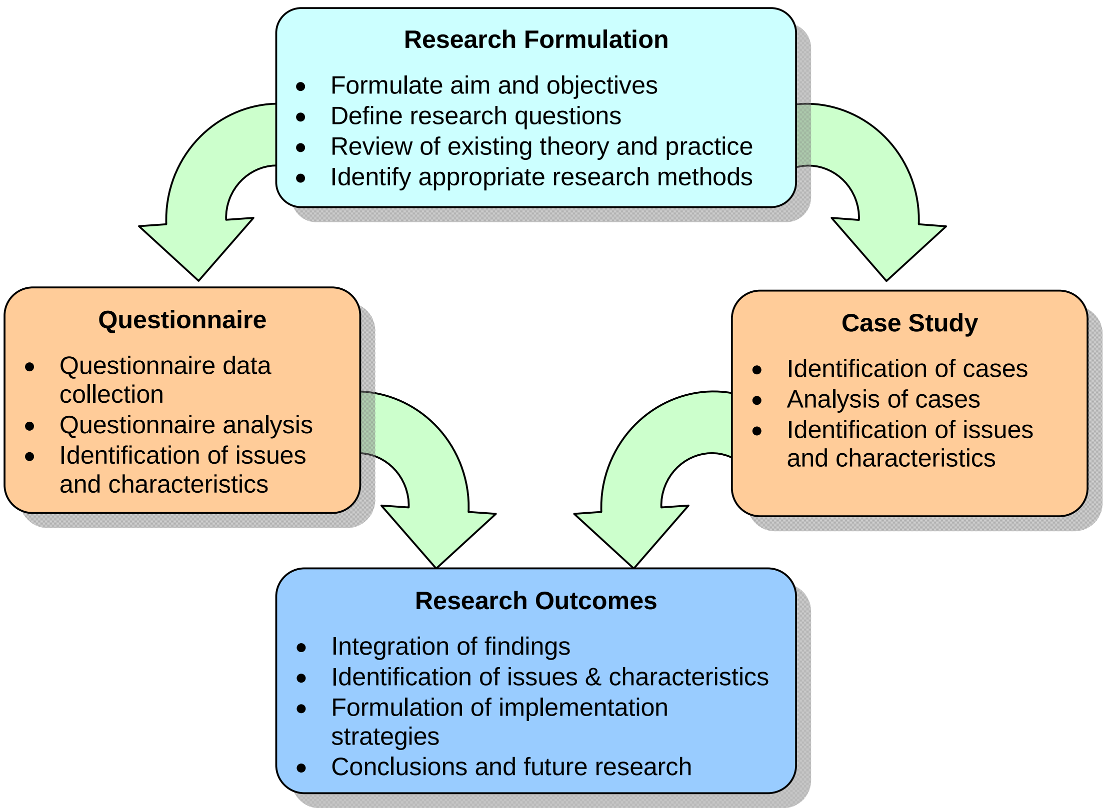


Figure 1-1: Research Approach

Finally, the integration of the findings of the questionnaire and the case study was undertaken. Within a mixed method design framework, and by using a triangulation approach, the outputs of questionnaire and case study analysis were consolidated to identify the 3D cadastre issues and to formulate possible future implementation strategies.

1.4 STRUCTURE OF CHAPTERS

The thesis is presented in seven chapters as illustrated in Figure 1-2. The chapters are aligned to answer the research questions and achieve the research objectives.

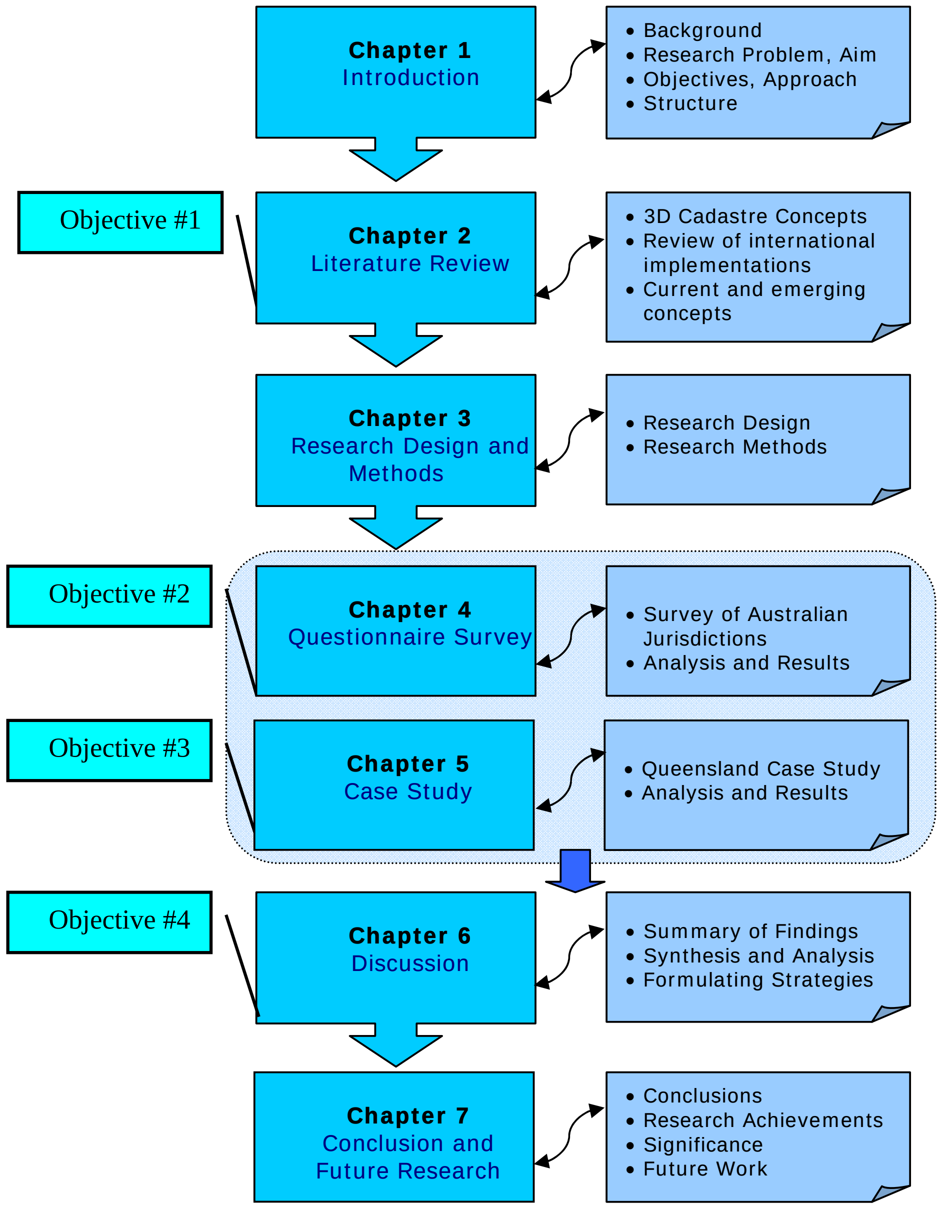


Figure 1-2: Chapter structure of the dissertation

Chapter One introduces the research background, formulates the research problem, states the research aim, questions and objectives. Chapter Two reviews the cadastre concepts and international 3D cadastre implementation to highlight the current issues and strategies of 3D cadastre and assists in identification of research gap. Chapter Three specifies the research method and design. It proposes a mixed methods research framework to achieve the research objectives. Chapter Four presents the result of a questionnaire survey, which identifies a range of institutional and technical issues and characteristics of cadastral jurisdictions in Australia. Chapter

Five examines the 3D cadastre issues within a particular jurisdiction, Queensland Australia, in detail and presents the results within a similar analysis framework as the questionnaire. Chapter Six integrates the results of the quantitative and qualitative research to identify key issues and to suggest possible implementation strategies. Chapter Seven is the final chapter and concludes with a discussion on the research achievements based on the research objectives and makes recommendations for future research.

1.5 CHAPTER SUMMARY

This chapter introduced the research background, problem, aim and objectives of this thesis. The research approach was outlined and the structure of the thesis was presented. The next chapter provides a review of the 3D cadastre developments and explores its implementation issues from a technical and institutional perspective.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter explores the 3D cadastral background, clarifies key 3D cadastre terminology and discusses the role of 3D cadastre in land administration. A review of international jurisdictions provides an overview of 3D cadastre implementation in a global context. Finally, issues relevant to 3D cadastre are discussed and the gap in existing research is identified.

2.2 CADASTRE

The International Federation of Surveyors (FIG) published statement on the cadastre (FIG 1995) states: "*A Cadastre is normally a parcel-based and up-to-date land information system containing a record of interests in the land (e.g. rights, restriction and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and often the value of the parcel and its improvements. It may be established for fiscal purposes (e.g. valuation and equitable taxation), legal purposes (conveyancing), to assist in the management of land and land use (e.g. for planning and other administrative purposes), and enables sustainable development and environmental protection*."

Effenberg (2001), identifies the purpose of the cadastral systems as being the necessary infrastructure to assist in the management of land and land use, to enable sustainable development and environmental improvement. The cadastral system supports different business systems in the area of land administration including:

- Land Tenure Systems – to secure legal rights in land
- Land Value System – to levy tax on the value of land
- Land Use Control System – to enable land use planning
- Land Development System – to enable regulation of land development

According to Dale & McLaughlin (1999), cadastres are registers of rights over, and attributes of, definable areas of land. Over time there have been three types of land cadastres. Juridical cadastres are a register of ownership of parcels of land. Fiscal cadastres are a register of properties recording their value. Multipurpose cadastres are a register of attributes of parcels of land.

Generally, the land register is textual and handled either by the local courts or a titles office, specifically created to administer the legal transfer of land and maintain appropriate legal instruments. The spatial components of the cadastre are normally under the governance of the jurisdiction's survey and mapping organisations. These may be separate departments within a single government (Effenberg 2001).

The data stored by these registers as described by Kalantari (2008) are cadastral data, which refers to all data related to value, ownership and use in the land administration subsystems. The spatial unit of the cadastre is the land parcel.

Effenberg (2001) interprets, land parcels to be complex, geometric features with ties to geographical, historical and legal objects. Further he adds, the process of maintaining the cadastral map must ensure the integrity of spatial cadastral data and the ability to integrate the spatial data with other land-related spatial and aspatial data sets. Similarly, Zevenbergen (2004) maintains that the parcel is not a physical reality (man-made or not), but an institutional creation. A parcel is a part of the continuum of the earth that a group of people have decided to treat as an identifiable unit. To a certain extent this can be reflected by the use that is made of it, but ultimately it is the legal rights that certain people have that determine the extent of and the boundaries between two parcels.

McDougall (2006) identifies that the land parcel is usually the smallest land unit capable of title registration and its transfer is managed through the state land administration systems. In Australia, these land parcels are usually very accurately defined by cadastral surveying processes, and subsequent titles are registered and form the basis of property ownership.

Kaufmann (2004), in the Cadastre 2014 document, distinguishes between the traditional 'parcel centric' approach and the 'land object-centric'. A land object is a piece of land in which homogeneous conditions exist within its outlines. Examples of legal land objects are: private property parcels, areas where traditional rights exist; administrative units such as countries, states, districts, and municipalities; zones for the protection of water, nature, noise, pollution, land use zones, areas where the exploitation of natural resources is allowed (Kaufmann 2004).

The differences in definitions and approaches extend not just to jurisdictions in different countries, but also to different jurisdictions within the same country. Effenberg (2001), discovered that within the jurisdictions of Australia, there is considerable diversity between different DCDBs.

2.3 3D CADASTRAL BACKGROUND

Stoter (2004) contends that from a juridical point of view, cadastral registration always has been 3D. The premise for this reasoning is that, although parcels are represented in 2D, someone with a right to a parcel has always been entitled to a space in 3D. A right of ownership on a parcel relates to a space in 3D that can be used by the owner and is not limited to just the flat parcel defined in 2D without any height or depth.

As society addresses continuing land shortages and resource scarcity, the imperative exists to better manage and plan land use (Kalantari 2008). Pressure on land in urban areas and especially their business centres has led to overlapping and interlocking constructions.

Constructions below or above the surface, such as tunnels and platforms used as foundations for buildings, are also treated as separate objects in a subdivision process, and are capable of being registered as separate real property (Kalantari 2008). The increasing complexity of modern cities suggests that modern land administration systems need an improved capacity to manage the third dimension (Zlatanova & Stoter 2006).

Thus, although 3D rights over individual parcels have always existed, it is in recent years that complex structures such as buildings and infrastructure has actually necessitated the inclusion in the cadastral database as objects in their own right. Development and construction of complex structures have continued at a rapid rate and it is up to the cadastral systems to be capable of accommodating the registration of these objects.

In Queensland, freehold title of a 3D cadastral object is guided by the Land Title Act 1994. Although "*in strata*" title has existed since the 1960s in Australia, it was only in 1997 that 3D geometry could be represented in the cadastral system of Queensland. 3D parcels have been accommodated in the Queensland cadastre via building parcels, restricted parcels, volumetric parcels and remainder parcels.

Modern day constructions, investments and ownerships, in the form of buildings or infrastructure have been considerable and these have been significant drivers for the registration of 3D objects. Technological developments have been another significant driver because of the enhanced capabilities of storage, depiction, modelling and dissemination. As most traditional cadastral definitions are 'parcel centric', the subsequent constructions on them are required to adapt to the parcel centric data models.

Stoter (2004, p. 90) concludes that a 3D cadastre should incorporate the following functionalities:

- "*register 3D information on rights (what is the space to which the person with a real right is entitled?) and make this information available in a straightforward way;*
- *establish and manage a link with external databases containing objects of interest for the cadastre (infrastructure objects, soil pollution areas, forest protection zones, monuments) and incorporate the location (and other information) of these objects in the cadastral registration; and*
- *use the information on these objects to support registration tasks, that is, to detect and correct errors in the process of registering and viewing the legal status of 3D situations*."

2.4 3D CADASTRE APPLIED TO LAND ADMINISTRATION

Land administration is the processes of determining, recording and disseminating information about the tenure, value and use of land when implementing land management policies. It is considered to include land registration, cadastral surveying and mapping, fiscal, legal and multi-purpose cadastres and land information systems (Steudler 2004).

Dale & McLaughlin (1999) suggests that a modern land administration system should provide appropriate infrastructure, which organises a broad range of social, environmental and economic interests in land to support its core policy of sustainability, while Enemark (2005) asserts that a land administration system is part of the infrastructure that supports the integrated management of land. The main characteristics of land administration is the relationship between land and the rights, which in most jurisdictions is a legally valid one (ISO 19152 LADM 2012).

Dale & McLaughlin (1999) identify that land administration consists of three types of functions: juridical, regulatory, and fiscal, with land information management integral to all three. Enemark (2005) believes land administration systems are now evolving from a focus on the core functions of regulating land use, land tenure and land valuation to an integrated land management paradigm designed to support sustainable development.

In land administration the three key attributes of land are ownership, value and use. The attributes of land administration depends on process, functions and components. Kalantari (2008) lists three processes: determination, recording and dissemination of land information. Similarly, Dale & McLaughlin (1999) categorises three functions of land administration, juridical (for land tenure), regulatory (for land use), fiscal (for land value) as well as four components, which are surveying and mapping, land registration, land valuation and land development.

Modern land cadastres supporting registration are highly sophisticated, and expensive to design, build and manage. Looked at as a whole, they display three-dimensional boundaries: height, width, depth, plus (when we add the text) a fourth dimension of time (how long the interest lasts for) (Wallace & Williamson 2004).

2.5 LEGAL FRAMEWORK OF 3D CADASTRE

"*Legal cadastral domain*" is used as a common term for laws and regulations regulating the content of traditional cadastre, multipurpose cadastre and land registers storing legal real property information, regardless of any national differentiation between these registers (Paasch 2004).

From the viewpoint of Cadastre 2014, the legal aspect is a basic characteristic of the cadastre. It is the cadastre which documents the legal situation of the land. Land administration work is fulfilled with the help of the lawfully relevant information extracted from the cadastre (Kaufmann 2004).

Zevenbergen (2004) categorises the types of legal rights that can be distinguished in the legal cadastral domain: ownership rights, derived rights (housing or animal farming), minor rights (easement) and lastly security rights (mortgages).

A standard parcel that is defined in 2D, but implies a 3D column of rights, is a lot (or a collection of lots) that is usually unlimited in height and depth. Stoter (2004, p. 71) identifies four types of parcels with a 3D component:

- "*building parcels, which are parcels that are generally defined by floors, walls and ceilings;*
- *restricted parcels, which are parcels restricted in height or depth by a defined distance above or below the surface or by a defined plane (restricted easements can also be restricted in height and depth). The boundaries of the restricted parcels must coincide with the boundaries of the surface parcel;*
- *volumetric parcels, which are parcels that are fully bounded by surfaces and are therefore independent of the 2D boundaries of the surface parcels; and*
- *remainder parcels, which are parcels that remain after a volumetric parcel or building parcel have been subdivided out of it.*"

Pertinent to the land administration, legal and technical aspects of 3D cadastre, Stoter (2004, p. 91) describes the following opportunities arising from the implementation of a 3D cadastre:

- "*3D registration provides information on the 3D extent of rights, limited rights and legal notifications and allows integration of 3D information in the current cadastral geographical data set;*
- *A 3D cadastre will incorporate digital information on 3D situations;*
- *When enabling 3D registration, the parties involved have a tool to register 3D situations;*

- *If the exact 3D location of infrastructure constructions is available within the cadastral registration (maintained in databases by holders of these objects), the cadastre can use this source for certain cadastral tasks e.g. during clean-up of registration or to support other cadastral tasks;*
- *Holders of infrastructure constructions will benefit from a clear registration of the location of infrastructure objects; and*
- *Linking databases containing infrastructure objects with the cadastral registration can also be used for registering pipelines*."

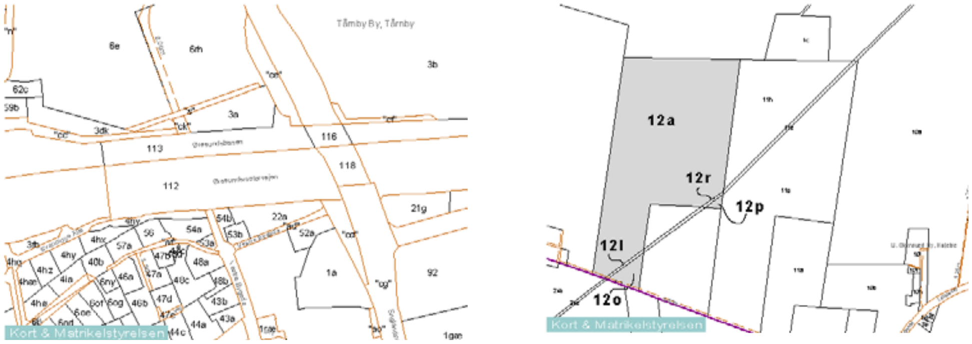
2.6 3D CADASTRE IN INTERNATIONAL JURISDICTIONS

An understanding of the issues and characteristics of 3D cadastre in various international cadastral jurisdictions assists in understanding the variety of implementation arrangements across jurisdictions. For this study, the following jurisdictions have been briefly reviewed (Table 2-1):

Table 2-1: 3D cadastre characteristics of international jurisdictions

Country	Characteristics
Denmark	Partial implementation of 3D cadastre, exists in some form
Greece	Has identified a lot of 3D issues, but not in the process of implementing 3D cadastre
Israel	Significant internal research and development completed and 3D cadastre implemented as an intermediate basis until better solution is presented
Netherlands	Significant research work completed and problems identified, partial 3D cadastre implemented
Turkey	Many 3D issues, 3D cadastre not yet implemented fully
USA	Similar to the Australian federal structure with independent jurisdictions at various levels of implementation of 3D cadastre

A study by Stoter et al (2004) regarding the registration of rights of apartment units in Denmark reveals that the cadastre deals with the various combinations of ownership such as ownership of a single unit, ownership of a block of units, and registered tenancy, differently, thus making the registration process quite complex. Further the cadastre does not register network infrastructure objects such as tunnels and they are not considered real properties since no right of ownership are established for them (Figure 2-1 left). When 3D objects such as underground utilities intersect surface parcels, easements are created, which fragments the base or surface parcel (Figure 2-1 right).



Tarnby Torv Tunnel in Denmark

Surface parcel divided into small fragments for pipeline

Figure 2-1: Examples of network parcel registration in Denmark (Stoter, Sorensen & Bodum 2004)

In Greece, according to Papaefthymiou et al (2004), the possessor of a floor or of a part of a floor, is the sole owner of the floor, including its own external walls, flooring, roof and communal spaces of the floor, The owner has no ownership on the land-parcel, and the possessor of the ground-floor is the sole owner of the land-parcel and the subsoil. The possessor of the upper floor is the sole owner of the air space, unless the air space has already been transferred to another person.

In Israel, according to Benhamu & Doytsher (2003), a recommendation by the research and development project team was that boundary points should have legally enforceable x, y coordinates and orthometric height, however the height need not be updated once the data is entered into the cadastre. As an adaptation strategy for 3D cadastre implementation, surface parcel identifiers should be numbered according to the existing numbering system, while parcels above the surface have a positive sign prefix (+), and parcels below the surface have a negative sign prefix (–). Benhamu (2006) further states that 3D parcel rights are created by deducting vertical space rights from the 2D column of rights and network objects spanning surface parcels create fragmented surface parcels (see Figure 2-2).

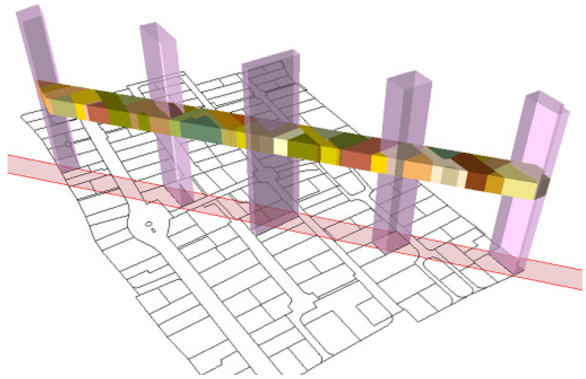


Figure 2-2: Example of 3D subsurface parcels on base parcels in Israel, (Benhamu 2006)

Significant research has been undertaken in The Netherlands and the findings by Stoter & Ploeger (2003a) identify that 2D parcel rights are columnar, rights of superficies exist, condominium registration is possible, DCDB stores 2D data, spatial querying of 3D objects is not possible and network objects are registered as superficies rights (Figure 2-3).

Figure 2-3: Example from the Netherlands, (Stoter & Ploeger 2003a)

According to Ayazl, Batuk, & Stoter (2008) and Doner & Biyik (2007), in Turkey parcel owners have columnar rights including mining rights. Further, easement rights dominate over ownership rights and the rights are transferable. Any construction above or below the surface parcel using superficies rights is dominant, however a land owner cannot own superficies rights. Condominium rights exist but the object itself does not exist in the cadastre as spatial objects.

In the USA, according to a study done by van Oosterom et al (2005), owners of land own the attached buildings, stratified rights are possible and usually achieved via leasehold, condominium rights exist, air rights can be sold and numerous cadastral jurisdictions exist with differing record keeping systems.

2.7 REVIEW OF ISSUES IN 3D CADASTRE

2.7.1 3D Geometrical Representation

3D properties have been complex to deal with because there are numerous ways to represent, store and visualise these objects as they may or may not be independent of the surface parcel. Additionally, validation and topology is complex as it depends on the 3D geometry chosen, network and crossing objects are not easily stored in the database, and spatial querying of 3D objects depend on the spatial location, storage and topology in the database

The geometric description of individual land parcels forms the building block of a jurisdiction wide map of parcels known as the cadastral map. For many modern cadastral systems around the world, the individual geometric parcel description, the cadastral map and the legal register of rights and interests, form the information in the database of the cadastral system. In concert with current technology, this cadastral map, and hence the geometry of the land parcel, is increasingly stored and manipulated in digital format (Effenberg 2001).

Karki, McDougall, & Thompson (2010) express that in a 2D cadastre, the most common method of representing a parcel is by bounding polygons, however, in a 3D cadastre there are numerous ways of storing the 3D geometry. The ISO19152 (2012) LADM has five ways of defining a parcel, which can be applied to both the 2D as well as the 3D parcel. The parcel is known as a spatial unit in the ISO standard and the parcel definition includes the point spatial unit, text spatial unit, line spatial unit, polygon spatial unit and topological spatial unit.

There are various methods of representing 3D objects that are currently being researched. Examples of the representation geometry of 3D objects includes: tetrahedrons (Penninga, van Oosterom & Kazar 2006), (Rahman & Pilouk 2007); simpler solids (Kolbe 2009); regular polytope (Thompson & van Oosterom 2007);

and extruding (Ledoux & Meijers 2009). Likewise, visualisation of 3D objects in a front-end tool include: primitive instancing (PI); sweep presentations (SWP); boundary representations (b-Reps); spatial partitioning representations (SPR); and constructive solid geometry (CSG) (Jarroush & Even-Tzur 2004).

2.7.2 Data Modelling and Information Management

Cadastral data modelling is particularly important in the domain of land administration. The modelling of a cadastral system has received special attention focused on the International Joint FIG Commission 7 and COST Action G9 Workshop on Standardisation in the Cadastral Domain in 2004 (Kalantari 2008).

Some of the models that can be utilised to store and manage 3D data are detailed in Table 2-2.

Table 2-2: GIS data models relevant to 3D cadastre, (Benhamu 2006)

Model	Characteristics	Advantages	Disadvantages
Layer Data Model	1. Organising multilayer information in layers rather than by space 2. Includes geospatial objects from all layers	Easier to discover the multilayer relationships between objects	Dependent on the surface parcel
Multilayer Data Model	Data organised in three layers, a. *Surface*, b. *Below Surface* c. *Above Surface*	1. Adaptable to existing data models in GIS systems 2. Permits multi-layer analyses 3. Preserves current surface cadastre layer	3D objects do not exist in their own right
Object Oriented Database	Data organised on the 3D object level rather than layer structure	1. 3D objects spatial property defined as object 2. Objects assigned spatial and chronological identity numbers	Loses the advantages of multi-layered GIS database systems
Integrated Database	1. Database linked to one surface cadastral layer 2. 3D objects linked as objects to the surface parcel	1. Surface information organised in multi-layers 2. 3D objects organised at object level	Too complex

2.7.3 3D Data and Topographic Elevation

Referencing elevation data to define a 3D cadastral object and storing that information in the database is influenced by the topographical surface and linking of the topographic elevation to 2D and 3D parcels. Some of the primary issues relevant to linking topographical elevation data to a cadastral surface parcel include topographic representation (Doner & Biyik 2007), integrating elevation to parcel boundaries (Stoter & Gorte 2003), representing 3D cadastre parcel relative to the surface parcel or relative to the height datum and update frequency of elevation data (Benhamu & Doytsher 2003).

2.7.4 Data Validation

The objective of validation in a 2D/3D cadastral environment is to form a rigorous definition of what is a valid object. It is the process of checking for possible errors in data via pre-defined rules usually before the data is processed or entered into the system. In digital cadastre, the need to validate arises from two simple questions: (i) who owns the particular land or space; and (ii) what is the extent of what is owned. Thus, the major reason to validate is to provide unambiguous answers to these questions (Karki, Thompson & McDougall 2009).

Validation rules in 3D geometry depend on the 3D geometrical representation method, for example, the validation rules for a line based encoding will be different to a polygon based encoding. Thompson (2007) states that, the fact that these particular representations can be rigorously defined and implemented demonstrates that such rigour is feasible, and opens the possibility that all computational representations can be similarly analysed. For a 3D cadastral object, validation is performed to ensure geometric validity, consistency with existing database and valid new content.

Situations that may require validation in a 3D cadastral situation include:

- Internal validity of 3D parcels – geometrical validations;
- Surface or base parcel – validation of objects on or below the surface parcel;
- Relationships to other parcels – validation of inter-parcel relationships;
- Unique geometrical situations – network and multi-strata objects;

- Further processing on the geometry – subdivision, consolidation, easements; and
- Entry level validations – includes spatio-temporal aspects, continuity.

2.7.5 Standardisation

Standards are required to identify objects, transactions, relationships between objects and persons, classification of land use, land value and map representations of objects (ISO-Ladm19152 2012).

A significant problem in the cadastral domain is the lack of a shared set of concepts and terminology. International standardization of these concepts (that is, the development of an ontology) could possibly resolve many of these communication problems (Kaufmann 2004).

The need for a nationwide standard is summarised by (McDougall 2006) saying national initiatives in land and property related information have mainly been directed towards coordination of state and territory activities through the development of national policies and standards. In a national land administration structure like Australia, where there are several independent cadastral jurisdictions, a common digital submission effort must address legal and semantic interoperability issues (Kalantari *et al.* 2005).

Paasch (2004) contends that in order to achieve an increased standardisation of the cadastral domain, it is necessary to classify the legal content of a cadastre, focussing on the right of ownership and restrictions connected with ownership. Thompson (2007) notes that for a geometrical representation, if the standardisation effort is to lead to a position where spatial data can be interchanged without manual intervention, cleaning and correction, a rigorous logic is needed to underpin the standards and support the definition of validity of that data.

2.7.6 Applications of 3D Cadastre

Data created from the implementation of 3D cadastre can be used in other areas. Application areas of 3D cadastre data outside the land administration domain include, 3D city models (Kolbe 2009), (Ledoux & Meijers 2009), underground property registrations (Cypas, Parseliunas & Aksamitauskas 2006), support complex property market (Wallace & Williamson 2004), disaster management, management of sub-surface and above surface infrastructure and input towards 4D cadastre.

2.7.7 Registration of Rights

The legal aspects of a cadastre require the registration and transfer of rights, restrictions and responsibilities related to the parcel. This can become complicated in a 3D cadastre situation because 3D objects may or may not be situated on the parcel or may not be registered in the cadastral register. Problems that need consideration include independence of 3D object from surface parcel, rights of 3D objects crossing the surface parcel, and creating network objects that are considered a single object.

2.7.8 Legal Rights Similar to Surface Parcels

In a conventional 2D cadastre, the land parcel can generally be subdivided or consolidated, easements, and full or partial leaseholds can be created. Similarly, in a 3D cadastre, to facilitate the land market and practical applications, the 3D parcel or 3D object should be able to be subdivided, consolidated and easements created. Other interests in land such as mining rights, water rights, and access rights may be applicable to 3D cadastre as well. In Australia, 3D objects have similar registration rights as the 2D cadastral object.

2.8 CONCLUSION

This chapter has reviewed the 3D cadastral background, international implementation and summarised 3D cadastre issues. A brief review of 3D cadastre implementation in international jurisdictions of Denmark, Greece, Israel, Netherlands, Turkey and USA were carried out. The main characteristics obtained from this review was that similar to the Australian cadastre, registrations of apartments are performed in Denmark, Netherlands, Greece, and USA and 3D ownership rights are transferable. Similarly, base parcels were fragmented when network subsurface parcels were created as in Denmark, Netherlands, and Israel. Different to Queensland, easements were created for registering network objects and air rights could be sold in the USA.

A review of 3D cadastre issues such as data geometry, storage, representation, validation, data modelling, 3D registration, and legal rights similar to surface parcel issues was undertaken. It was observed that although there are several methods to define a 3D geometry for 3D object creation and representation, these are not implemented in cadastral jurisdictions because they are still being examined for optimal storage, validation and topological requirements. There are three primary requirements for data validation in 3D cadastre: validating 3D geometry; validation against an existing database; and validating new content. Since most jurisdictions have not adopted a defined geometry type, data validation rules for these are yet to be developed. In the cadastral jurisdictions of Australia, each state has developed its own terminology and processes, which has created issues with standardised efforts such as the national ePlan model (Cumerford 2010). In Australia, 3D cadastre is being implemented; however there is a gap in research in understanding the complex 3D cadastre issues. Therefore, it is necessary to investigate the institutional and technical issues and characteristics of 3D cadastre in Australia and Queensland in particular to improve the current 3D cadastre implementations and developments.

The next chapter discusses the research design and methods that have been adopted to address the research problem and aim.

CHAPTER 3

RESEARCH DESIGN AND METHODS

3.1 INTRODUCTION

The previous chapter discussed the 3D cadastre research context by establishing a theoretical framework, defining key terminology, and identifying the current institutional and technical issues in the implementation of 3D cadastre.

3.2 RESEARCH DESIGN FRAMEWORK

In Chapter Two, a review of the current status of 3D cadastre and the international context was undertaken. In Chapter One, the research questions and objectives were formulated. The first research question was to assist in determining the current status of the development of 3D cadastre. The second research question was primarily quantitative in nature, while the third was mainly qualitative. Thus, within the framework of the mixed methods approach, both qualitative and quantitative data collection methods will be utilised. Figure 3-1 illustrates the research design framework that is suitable for addressing the research questions to achieve the objectives of this research.

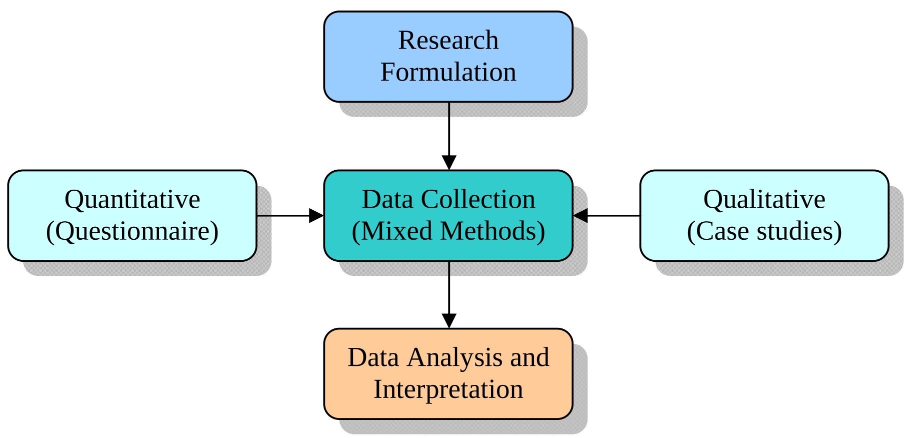


Figure 3-1: Conceptual research design framework

3.3 RESEARCH METHODS

This section explores the context of both quantitative and qualitative methods and their relationship to the research problem and questions. A mixed method approach is then proposed as a suitable research approach.

3.3.1 Quantitative Methods

Quantitative research uses statistical methods and numbers to explain and validate phenomena (McDougall 2006). According to Creswell (2003), quantitative methods are used mainly to test or verify theories or explanations, identify variables to study, relate variables in questions or hypothesis, establish standards of validity and reliability, and employ statistical procedures for analysis. Among others, survey and experimental design are the two main quantitative methods (Creswell 2009). A survey provides quantitative or numeric descriptions of trends, attitudes or opinions of a population (Creswell 2009). Experiments determine how the treatment of objects is influenced under a variety of conditions (Thomas 2003). In this research, a survey approach was utilised to investigate the institutional and technical aspects of the implementation of 3D cadastre in the jurisdictions of Australia.

3.3.2 Qualitative Methods

"*Qualitative research methods examine the how, what and why of various phenomena*" (McDougall 2006, p. 95). (Paudyal 2012, p. 95) maintains that although "*qualitative research methods include case study, narrative research, ethnographic research, phenomenology, grounded theory studies and action research*", yet "*the most common method among the qualitative approaches is case study research*". Further, Yin (1981b) points out that case study does not imply the use of a particular type of data and can be done on both qualitative and quantitative data.

According to Yin (1981a, p. 98), "*the need to use case study arises whenever an empirical inquiry must examine a contemporary phenomenon in its real-life context, especially when the boundaries between phenomenon and context are not clearly evident*". McDougall (2006, p. 96) identifies that, "*the case study strategy has been widely used across many disciplines including the investigation of organisational issues and information systems development and operation*".

In this research, the case study method was selected to examine the how, what and why of the implementation of 3D cadastre in one specific jurisdiction.

3.3.3 Mixed Methods

Gable (1994) argues strongly in favour of combining research methods generally, and more specifically for combining qualitative and quantitative methods. Qualitative methods and quantitative methods have their strengths and weakness when used individually. However, as Paudyal (2012, p. 97) states, "*in recent times there has been a growing recognition of collecting and analysing both qualitative and quantitative data in a research study and mixing them*". The overall strength of mixed method in a study is greater than either qualitative or quantitative research (Creswell & Plano Clark 2007).

As cited in Paudyal (2012, p. 97), *Baran (2010) reviewed 57 mixed methods studies, and summarised five main purposes for the mixed method studies:*

1. ***Triangulation**: seeking convergence of results;*
2. ***Complementary**: examining overlapping and different facets of a phenomenon;*
3. ***Initiation**: discovering paradoxes, contradictions, or fresh perspectives that may stimulate new research questions;*
4. ***Development**: using results from one method to shape subsequent methods or steps in the research process; and*
5. ***Expansion**: providing richness and detail to the study exploring specific features of each method.*

In this study, the mixed method approach has been utilised to integrate both qualitative and quantitative methods for converging the results of the two methods. The triangulation approach of mixed methods was utilised for converging the results where qualitative and quantitative studies are considered approximately equal.

3.4 DATA COLLECTION

This research has utilised survey and case study as the main research methods.

3.4.1 Survey

Within the mixed methods framework, a survey of cadastral jurisdictions of Australia (Figure 3-2) was conducted to investigate the 3D cadastral implementation within an institutional and technical framework.

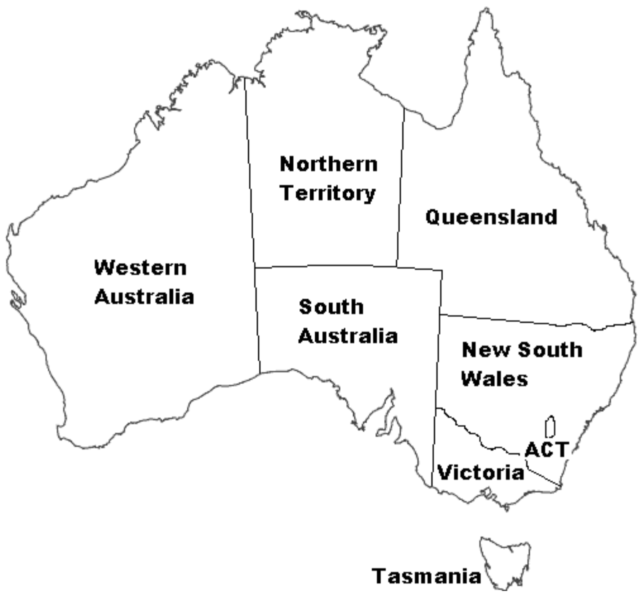


Figure 3-2: Study area for questionnaire survey

The questionnaire was developed based on literature review, by this researcher in association with another officer of the Department of Natural Resources and Mines (DNRM), and provided to the ICSM through DNRM. The questionnaire survey of cadastral jurisdictions of Australia was administered and the responses collected and provided to the researcher by the Intergovernmental Committee on Surveying and Mapping (ICSM). It was conducted between October and December 2010 simultaneous to the FIG survey of international jurisdictions and both groups were made aware of the other survey. The responses to the Australian survey were used as a data source for this research, except for Victoria, where the FIG responses were used.

The questionnaire consisted of nine sections related to the implementation of 3D cadastre in Australia: general 3D situation, infrastructure or utility networks, construction or building units, horizontal coordinates, vertical coordinates, temporal issues, rights, restrictions and responsibilities (RRR), digital cadastral database

(DCDB) and plan of survey (Table 3-1). The sections were decided based on homogeneity of issues from the gap analysis in literature review. The questionnaire consisted of 96 questions with definition of terms provided wherever necessary including an explanation of the purpose of some of the sections (Appendix 2). The questionnaire was initially provided to experts in the cadastral jurisdictions of Queensland, Australian Capital Territory and The Netherlands. Based on their responses and suggestions the questionnaire contained clarifications and sample answers. Since 3D cadastre is a complex topic, it was considered necessary to include sample answers as guidelines, so that appropriately distinct and meaningful responses could be extracted. The results proved that the sample answer did not act as leading but rather assisted in understanding the complex terminologies.

Table 3-1: Structure of questionnaire

Sections	Topics
Section 1: General 3D situation	3D real-world situations registered as 3D parcels, types of 3D geometries considered valid, and 3D representations
Section 2: Infrastructure or Utility Networks	Infrastructure network that is considered to be defined within the cadastre
Section 3: Construction or Building Units	3D properties that are related to constructions and apartment
Section 4: X/Y Coordinates	Horizontal coordinates on plan of survey, database, and 3D objects
Section 5: Z Coordinates	Vertical coordinates on plan of survey, database, and 3D objects
Section 6: Temporal Issues	Integration of 3D cadastre and time data
Section 7: Rights, Restrictions and Responsibilities (RRR)	Range of RRR applicable to 3D cadastre
Section 8: Digital Cadastral Database (DCDB)	Representation, structure, and software in data storage and dissemination
Section 9: Survey Plan	Representation of 3D objects on plan of survey

A similar questionnaire was sent by International Federation of Surveyors (FIG) at around the same time to various countries and their analysis was conducted independent to this survey. The questionnaire had the same nine sections and included sample answers from Queensland and The Netherlands as guidelines. The only difference between the two surveys was that the FIG questionnaire had additional questions relating to the language in which jurisdictions kept their legislative and policy documents (FIG 3D Cadastre Working Group 2011).

The questionnaire were sent to the cadastral jurisdictions of Queensland (QLD), New South Wales (NSW), Australian Capital Territory (ACT), Victoria (VIC), Tasmania (TAS), South Australia (SA), Western Australia (WA), and Northern Territory (NT) (Figure 3-2). All jurisdictions except Victoria responded to the questionnaire. Victoria responded to the FIG questionnaire only and information was extracted from the common questions between the two surveys.

3.4.2 Case Study

A case study explores a phenomenon in its natural setting, utilising various methods of data collection (Benbasat, Goldstein & Mead 1987). As reiterated by Yin (1999, p. 1211), "*the feature of a case study is its intense focus on a single phenomenon within its real-life context.*" Therefore, the case study method was considered to be the most suitable approach to identify and examine the in depth issues and characteristics of the implementation of 3D cadastre in a jurisdiction.

Queensland was selected as the jurisdiction to undertake the case study due to its lead in 3D cadastre implementation and the accessibility to case study data. The case study performed an in-depth analysis of the nine sections of the questionnaire and explored the institutional and technical 3D cadastral issues. The results were then summarised into legal, policy, tenure, geometry, and data representation.

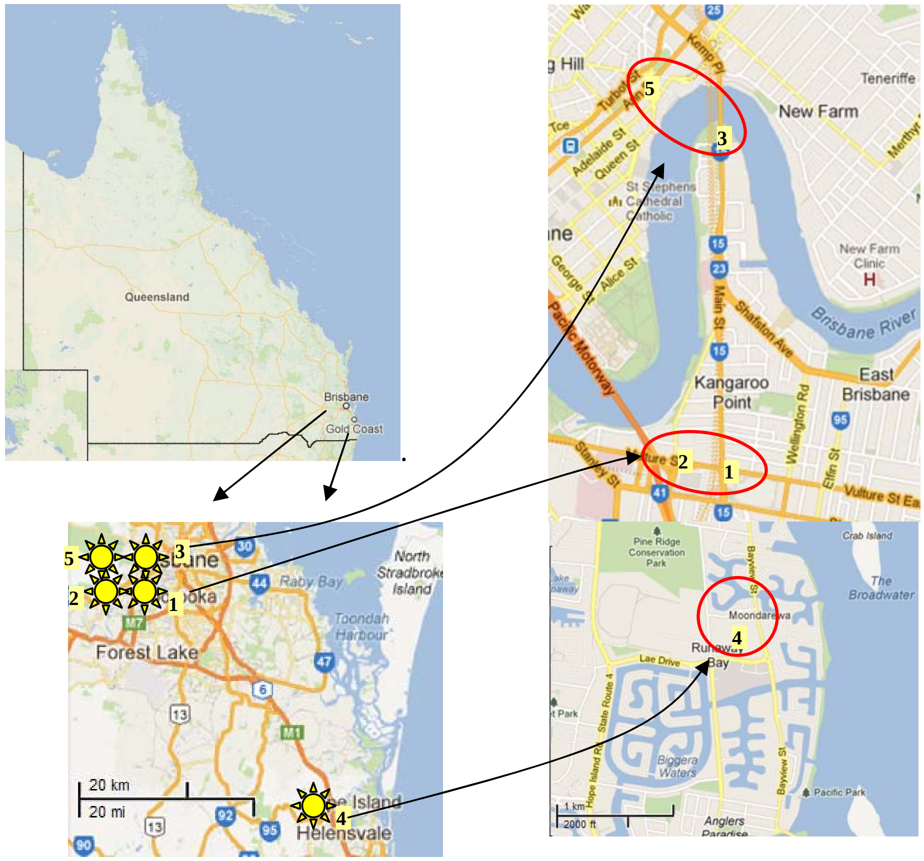


Figure 3-3: Location of case studies

The locations of case study areas were two major cities in Queensland; Brisbane (cases 1, 2, 3, 5) and Gold Coast (case 4) as shown in Figure 3-3. The selection of cases was based on the complexity, uniqueness and representative of 3D cadastre issues in Queensland. Table 3-2 illustrates the five cases and their characteristics.

Volumetric Encroachment: The volumetric encroachment at Woolloongabba cricket stadium (case 1) provides an example of creation of a volumetric strata parcel where the base parcel is a unallocated state land (USL).

Volumetric Network Parcels: The network parcels intersecting at Woolloongabba busway and Clem7 tunnel (case 2) demonstrates the situation where two volumetric network parcels are registered in the cadastre and intersect each other in 2D making it difficult to store and visualise them.

Volumetric Ambulatory Boundary: The volumetric ambulatory boundary created at the intersection of the Clem 7 tunnel and Brisbane River (case 3) illustrates the situation where a 2D ambulatory boundary forced the creation of a 3D ambulatory boundary even when there was no possibility of the boundary to ambulate because of permanent constructions on the two banks and the Clem7 tunnel underneath.

Volumetric Doughnut: This case (case 4) displays a unique geometrical situation in Gold Coast, where 3D volumetric doughnut figures were created and registered in the cadastre by reserving the airspace without a connection to the base parcel.

Volumetric Road: This case (case 5) in Brisbane city shows an example of a 3D road parcel being excised from a 3D column of space and registered in the cadastre. The base of the narrow volumetric road lies about two storeys above the new building. This case also provides an example of the implementation of building format plans in Queensland.

Table 3-2: 3D cadastral cases and their characteristics

Cases	Characteristics
Volumetric Encroachment	Encroachment in strata, 3D space registered as volumetric lease over 2D unallocated state land
Volumetric Network Parcels	Network parcels are created and registered in volumetric format and intersect each other in 3D
Volumetric Ambulatory Boundary	Creation of a 3D ambulatory boundary
Volumetric Doughnut	Registration of airspace without any physical construction
Volumetric Road	Volumetric road starting two stories above ground level and implementation example of a building plan

3.4.2.1 Data Source

The data for the case study were primarily collected from the Department of Natural Resources and Mines (DNRM). As illustrated in Figure 3-4, plans, titles, digital cadastral database (DCDB), aerial photographs, expert consultations, and seminars and workshops were used as the data source.

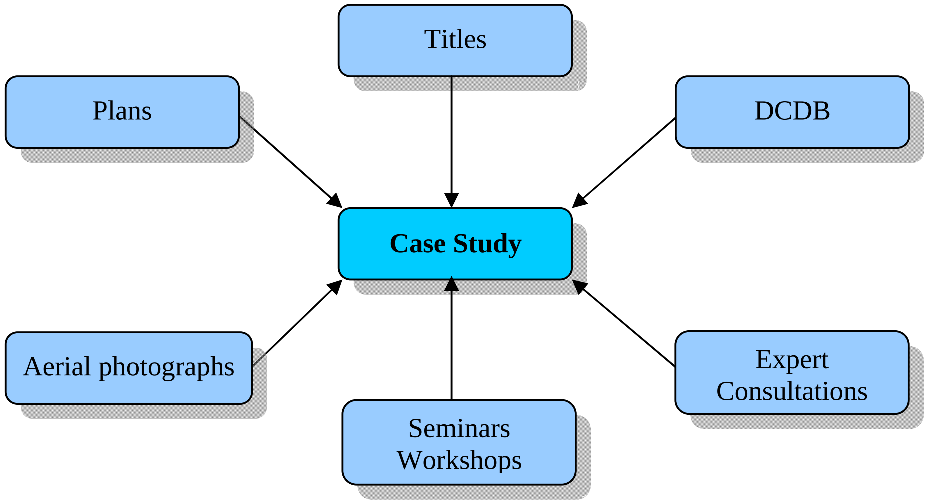


Figure 3-4: Data sources for case study

3.5 DATA INTEGRATION AND INTERPRETATION

After the completion of the analysis of questionnaire and case study, the results were integrated to identify the institutional and technical 3D cadastral issues in Queensland and other cadastral jurisdictions of Australia and are presented in Chapter 6. The results of the questionnaire identified the implementation characteristics of 3D cadastre in the jurisdictions of Australia and provided a guideline for the case study. The results of the case study provided an in-depth analysis of the issues and characteristics of 3D cadastre in Queensland. The integration of questionnaire and case study results through triangulation enhanced the validity of the research outcomes.

3.6 CONCLUSION

This chapter presented the research design and methods for this dissertation. As the research questions formulated in Chapter One were both quantitative and qualitative in nature, a mixed method design was adopted and justified as being an appropriate strategy for this research. Within the mixed method design framework, the quantitative data were collected and analysed through survey while the qualitative data were collected through the case study approach. The results of the survey are presented in Chapter Four and that of the case study are presented in Chapter Five. The survey of Australian jurisdictions provided an overall view of 3D cadastre issues and characteristics while the case study provided an in-depth analysis of specific 3D implementation issues and characteristics in Queensland. The integration of qualitative and quantitative data sources are presented in Chapter Six.

CHAPTER 4

STATUS OF 3D CADASTRE IN AUSTRALIAN JURISDICTIONS

4.1 INTRODUCTION

The previous chapters discussed relevant literature on 3D cadastre and research design and methods to achieve the objectives set out at the beginning of this thesis. In this chapter, the results of the survey of the cadastral jurisdictions in Australia are presented. This chapter undertakes a qualitative and quantitative analysis of the overall situation of 3D cadastre in the cadastral jurisdictions in Australia.

The objective of this chapter is to determine how 3D cadastre is being implemented in the cadastral jurisdictions of Australia and to identify the similarities and differences amongst the jurisdictions. This was achieved by conducting a nationwide questionnaire survey of the cadastral jurisdictions and analysing the responses according to the framework defined in the previous chapter. The questionnaire was developed by this researcher for a survey conducted by the Intergovernmental Committee on Surveying and Mapping (ICSM), and the response to the survey was used as a data source for this study. As ICSM did not receive a response to the questionnaire from Victoria, this study utilised the responses sent to the international questionnaire conducted by FIG (van Oosterom *et al.* 2011).

The questionnaire attached in Appendix 2, consists of nine sections covering aspects of current 3D status in Australia. The survey was designed to ascertain the institutional and technical framework that supports the current implementation of 3D data capture and their integration into the existing cadastre.

4.2 DISCUSSION FRAMEWORK

The nine sections of the questionnaire included General 3D real world situations, Infrastructure/utility networks, Construction/Building units, Rights, Restrictions and Responsibilities, X/Y coordinates, Z coordinates, Temporal issues, DCDB and Plans of Survey. The framework for discussion for this chapter is detailed in Table 4-1. The responses are initially analysed according to the sections of the questionnaire and then summarised according to the Legal, Policy, Tenure, Institutional, Geometry and Data Representation factors of the framework of analysis.

Table 4-1: The framework for discussion

Framework	Sections
Institutional	General 3D real-world situations Infrastructure/Utility Networks Construction/ Building Units Rights, Restrictions and Responsibilities
Technical	X/Y Coordinates Z Coordinates Temporal Issues DCDB Plan of Survey

4.3 CADASTRAL JURISDICTIONS OF AUSTRALIA

Australia is a large country of 7,692,024sq.km (Geoscience-Australia 2012) with a population of 21,507,717 according to the Australian Bureau of Statistics (2011). There are eight cadastral jurisdictions (see Figure 4-1) in Australia and each jurisdiction has their own juridical and technical framework, which has given rise to different semantics and processes (Cumerford 2010). This has resulted in each jurisdiction adopting varying processes for 3D cadastre according to their occurrence of 3D parcels in the jurisdiction.

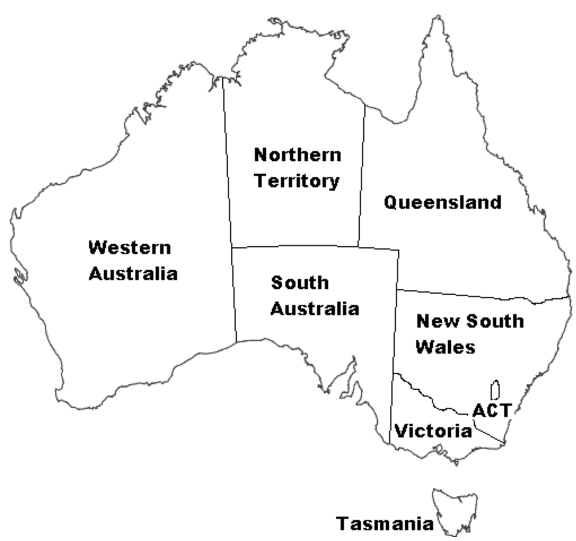


Figure 4-1: The eight cadastral jurisdictions of Australia

(Source: Geoscience Australia)

Table 4-2: Statistics relating to cadastral properties, area and population of Australia

States	Cadastral Properties (May 2012)	Area of State/Territory (Sq km)	Population '000 (December 2011)	Parcels per person
QLD	2417026	1730648	4513.0	0.5
NSW	3777206	800642	7247.7	0.5
ACT	156408	2358	370.7	0.4
VIC	4584477	227416	5574.5	0.8
TAS	307179	68401	511.7	0.6
SA	1217602	983482	1645.0	0.7
WA	1124944	2529875	2387.2	0.5
NT	75036	1349129	232.4	0.3
Total	**13659878**	**7691951**	**22482.2**	

Table 4-2 shows the number of cadastral properties in each state compared to the area of the state and its population. The cadastral properties data was sourced from information provided by the Public Sector Mapping Agency (PSMA). The information on the areas of State/Territory was sourced from Geoscience Australia (2012). The population data is projected for December 2011 and is sourced from the Australian Bureau of Statistics (2011).

In jurisdictions with highly urbanised population centres such as Victoria and New South Wales, pressure due to unavailability of land gives rise to conditions for 3D parcel creation.

Queensland and Western Australia are large states, but because urban growth is limited to certain areas only, these areas face a similar pressure of availability of land. Queensland has a larger population, more urban centres and more parcels in the urban centres, and thus a significant number of 3D parcels are created in the south-east region of the state.

The Australian Capital Territory has the highest number of parcels per square kilometre of area, but because of a lower population, the pressure to create 3D parcels is not as high as the other states.

Tasmania, Northern Territory and South Australia face relatively lower pressure to create 3D parcels, however each state has 3D parcels in their cadastre and their characteristics are discussed in the following sections.

4.4 INSTITUTIONAL FRAMEWORK

4.4.1 Existing 3D Situations

The purpose of this section of the questionnaire was to determine the status of 3D cadastre in all the jurisdictions, while more specific juridical and technical questions followed in the remaining eight sections. The analysis of responses to this section provides information on the existing legislation to support 3D cadastre, and a discussion on how complex 3D geometries such as curved surfaces or natural ambulatory boundaries are dealt with. It further critically evaluates 3D specific problems such as how each jurisdiction integrates 2D with 3D data when 3D is created over existing 2D lots.

4.4.1.1 Legislative framework to support 3D cadastre

All jurisdictions in Australia support 3D data in their cadastre. Building format plans and volumetric format plans contain 3D cadastral data. Table 4-3 identifies the various legislation in the jurisdiction to support 3D cadastral parcel. It can be seen that all jurisdictions have a similar approach in creating legislation to support 3D cadastre.

The various legislation are designed to support 3D data capture and assist in the development of 3D cadastre by treating the 3D objects similar to 2D cadastral objects. This has assisted in the capture and registration of 3D objects.

The legislative framework of Queensland is discussed in more detail in the next chapter to provide a greater insight into a specific jurisdiction. The introduction of legislation has allowed the creation and registration of 3D objects such as building units in the cadastre. As a result, there has been a choice for surveyors to create plans that are 2D, 3D or a mixture of both. This has resulted in the growth of strata based real property and guidelines on how to create, register, transfer and manage them.

Table 4-3: Legislation to support 3D cadastre

Cadastral Jurisdiction	Legislation to support 3D cadastre
QLD	Land Act (1994), Land Title Act (1994), Body Corporate and Community Management Act (1997) supported by Registrar of Titles Directions for the Preparation of Plans (2008)
NSW	NSW Strata Schemes Management Act (1996), NSW Community Land Management Act (1989)
ACT	Unit Titles Act (2001) and guideline and/or Surveyors (Surveyor-General) Practice Directions (2010)
VIC	Transfer of land (Stratum Estate) Act (1960), Strata Title Act (1967), Subdivision (Procedure) Regulations (2000)
TAS	Strata Titles Act (1998) regulates strata titles. Recorder of Titles' Circular Memo 5/1998 and Surveyor General's Survey Directions specify parcel description criteria.
SA	Community Titles Act (1996), Real Property Act (1886), Plan Presentation guidelines
WA	Strata Titles Act (1985). Transfer of Land Act supported by Survey and Plan Practise Manual for Western Australia and Strata Titles Practise Manual.
NT	For Strata (Unit) subdivisions it's the Unit Titles Act and Unit Titles Schemes Act. For Stratum (Volumetric) subdivision the Land Title Act applies although it is silent on 3D subdivisions, which is interpreted as allowing such subdivisions.

Complex volumetric lots have been made possible with the legislative support, and where the legislation is unclear on certain aspects, like 3D subdivision, the jurisdictions have supported the development of 3D cadastre by guidelines or policy.

4.4.1.2 3D parcel within 2D base parcel

Volumetric parcels, such as tunnels, are often extensive structures or 3D spaces that intersect with many surface parcels. The surface parcels may be registered or unregistered cadastral objects. Registered cadastral objects are those that are spatially represented, have unique identifiers and have a title created for them. Jurisdictions may differ in what is not registered in the cadastre, so unregistered cadastral objects usually include objects such as roads, road intersections, road reserves, water bodies, parks, and forests that may be spatially represented in the DCDB of the jurisdictions, but may not have a unique identifier or a title.

Regardless of the registration status of a cadastral object, when a volumetric parcel extends beyond the bounds of a base or surface parcel, it can be dealt with in three different ways. The first method is not to register it in the cadastre, but to keep a record in the respective public works department or equivalent office, which is done in many jurisdictions internationally (van Oosterom *et al.* 2011). The advantage of this method is that, since records are not maintained in the cadastre, it does not complicate the storage in the DCDB. The disadvantage is that since it does not usually create a cadastral property record, it is difficult to get an immediate count of the number of such lots unless they are stored in another register. It also creates a difficulty in discovery of existing lots for other network developers to plan their development and maintenance activities. This option is useful for state owned land or development projects; however, private owners of such parcels would want the security of a registered title and a spatial representation of the extents of their parcel as well as the neighbouring lots.

The second alternative is to register the volumetric parcel in the DCDB as a single linear feature unconstrained by the surface parcel. This is achieved by registering the legal space of the cross-boundary object (Stoter & Ploeger 2003b) as well as storing the spatial location of the object in the cadastral database. According to van Oosterom et al (2011), there are some jurisdictions that register the linear network in the cadastre without spatially representing them. The advantage is that it allows 3D objects to exist in their own right without relying on the 2D surface parcels to determine its existence. The disadvantage is that the capability of such integrated storage is yet to be developed and consequently it is not possible to represent them spatially in the DCDB. This prevents discovery of an existing network at relative depths, although an outline of individual networks can be visualised in 2D in the cadastre.

The third method is to constrain the 3D object to be within the outline of a 2D surface parcel as currently adopted in Queensland. This splits the cross-boundary volumetric lot into a number of cadastral parcels that do not extend beyond the bounds of each surface parcel. The advantage to this method is that individual 3D objects (or the current practice of outlines of the volumetric objects) are able to be stored in the existing DCDB and related to the 2D surface parcels. In addition, individual titles are created for each intersected parcel. This further assists in the discovery of volumetric lots within the 2D parcel, and to view the entire network based on interconnected outlines in the DCDB. It also ensures the owners of the volumetric parcels rights are recognised through registering the rights of the 3D space and inclusion of the data in the cadastral database. This assists in a 2D-3D hybrid implementation (Stoter & Salzmann 2003) utilising the existing cadastral database and data capture methods. The disadvantage to this approach is that the full 3D network object does not exist in their own right in the database and it is not possible to determine its dimensions or the 2D or 3D neighbour adjacent to the surface parcel. The process also creates many small lots with varying validation requirements and need for greater database resources; however, currently in Queensland a process is underway to consolidate such multiple volumetric lots to form a single title.

As seen from Figure 4-2, most states have adopted a strategy where 3D parcels remain constrained within a 2D surface (base) parcel. Figure 4-3 shows an example of a 3D lot being constrained within a 2D base lot by dividing the 3D lot to reflect the outline of the base parcel. There were three states, Western Australia (WA) and Northern Territory (NT) and New South Wales (NSW), which did not have any such restrictions. There were examples provided in the responses by these jurisdictions where underground road tunnels or train stations did not remain constrained within the base parcel.

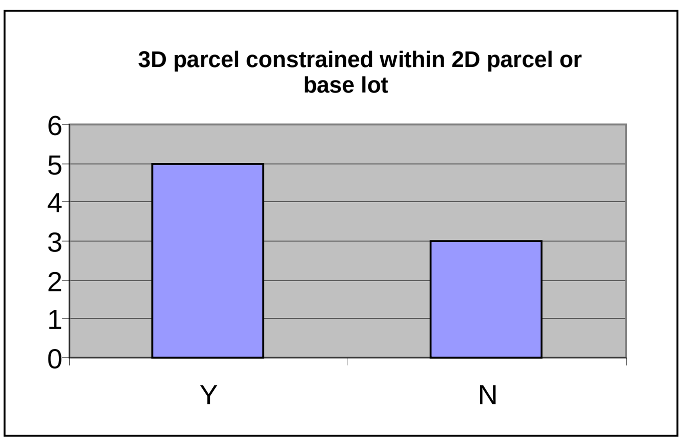
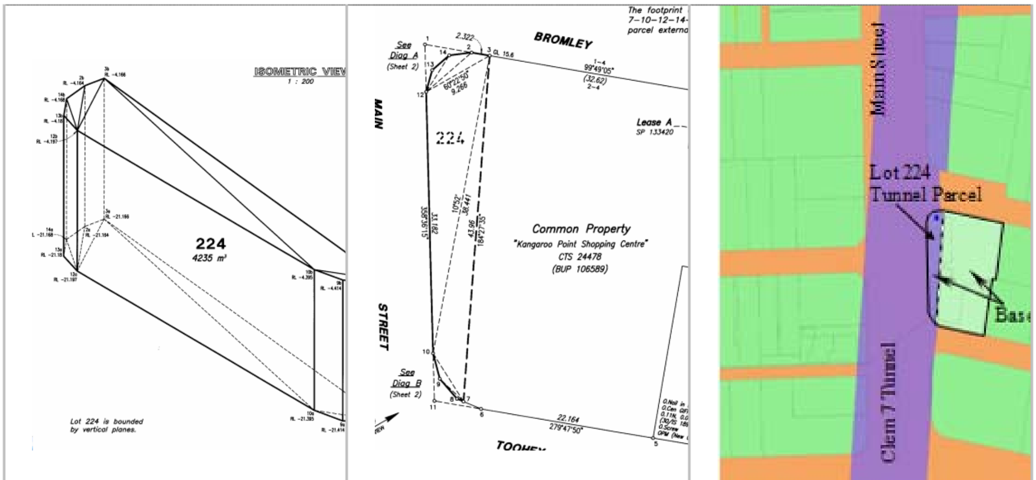


Figure 4-2: Number of jurisdictions where 3D parcels are not necessarily constrained within 2D base parcels



(a) Isometric view of a below-ground volumetric lot	(b) Outline of 3D lot on the 2D lot	(c) Volumetric lot created for a small part intersecting a standard lot

Figure 4-3: Example of a 3D lot constrained within a 2D lot

(Source: DNRM QLD)

4.4.1.3 Registering 3D ambulatory boundaries

According to the Survey and Mapping Infrastructure Act (SMIA 2003, p. 44) of Queensland, an ambulatory boundary is a "*boundary of a land bounded by water, whether tidal or non-tidal" where "the change to the location at law … is gradual and imperceptible*". The boundary of the land parcel follows the movements of a natural feature such as a river (see Figure 4-4), and its position is determined at points of time when a survey is carried out, but between such fixes, the definition of the property is the position of the real world natural feature.

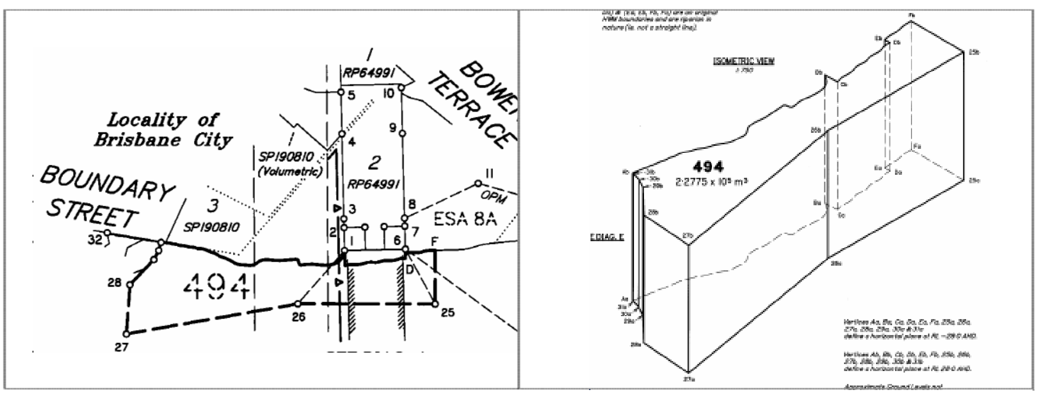


Figure 4-4: Example of an ambulatory boundary and its 3D representation

(Source: DNRM QLD)

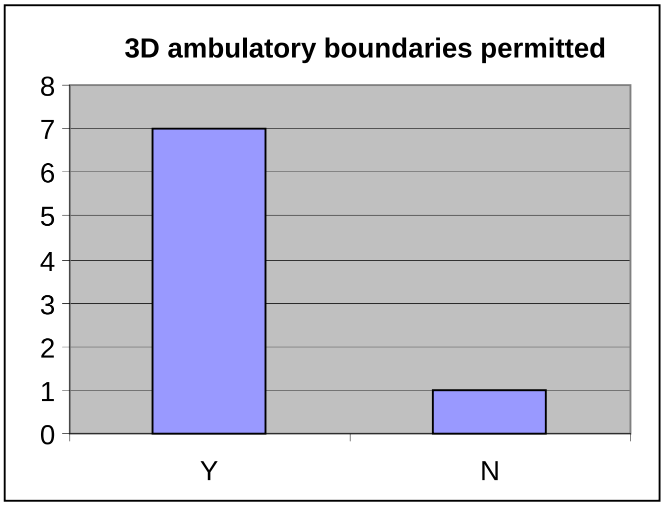


Figure 4-5: Number of jurisdictions that register 3D ambulatory boundaries in the cadastre

From Figure 4-5, it can be seen that most jurisdictions allow 3D natural ambulatory boundaries to be registered in the cadastre. The Australian Capital Territory (ACT) did not have examples of coastal ambulatory boundaries although it is silent on riparian ambulatory boundaries.

4.4.1.4 Registering disconnected 3D part lots

A multi-part lot is one where the lot is divided into several parcel units not connected to each other and may have other lots or infrastructure between them (see Figure 4-6).

In 3D, disconnected multi-part lots may be in the same building (see Figure 4-7), other buildings, part airspace or part sub-surface. In Australia, all jurisdictions allow the registration of 3D air-space. However, as shown in Figure 4-8, not all jurisdictions allow disconnected multi-part parcels of a single lot to be registered.

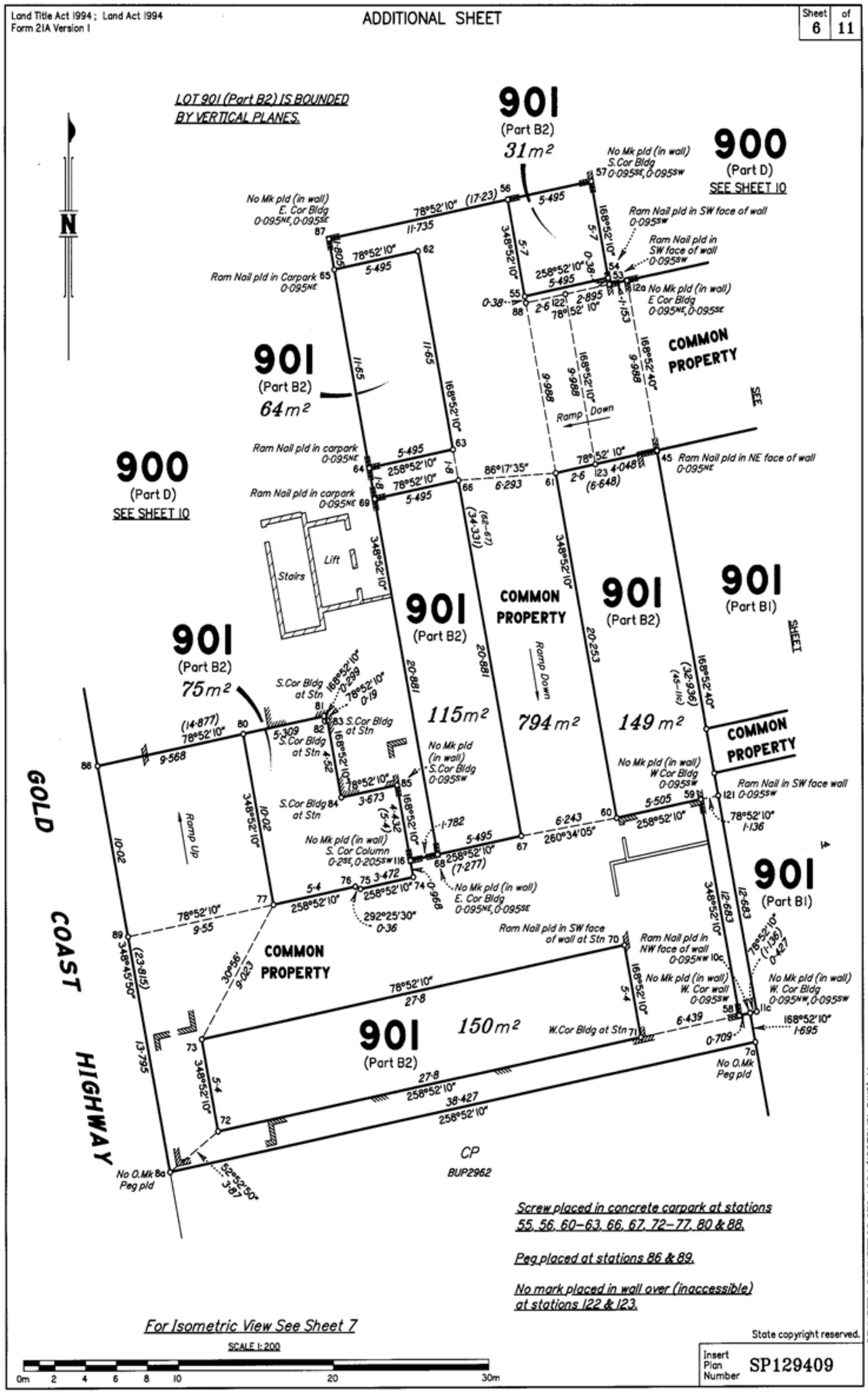


Figure 4-6: Example of a single 2D disconnected multi-part lot

(Source: DNRM QLD)

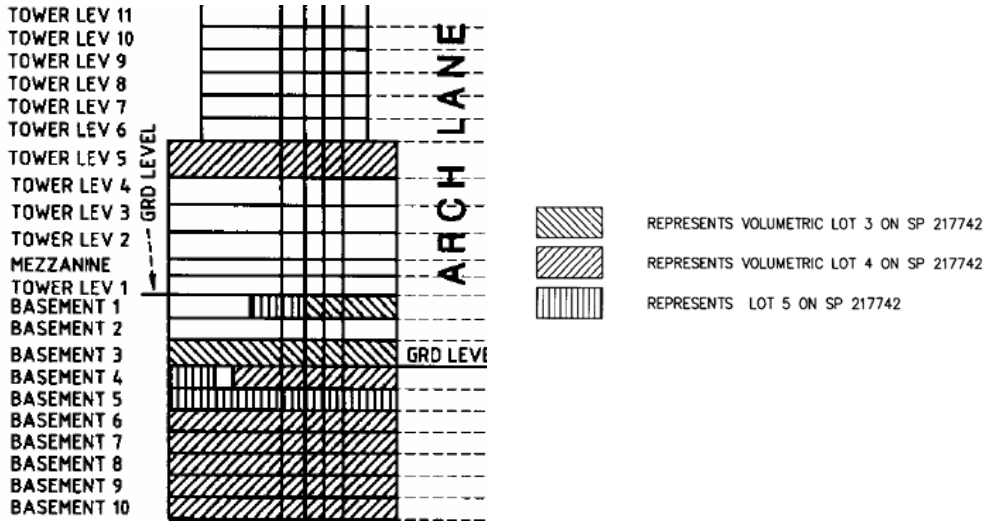


Figure 4-7: Example of multi-part lots in a building format plan

(Source: DNRM QLD)

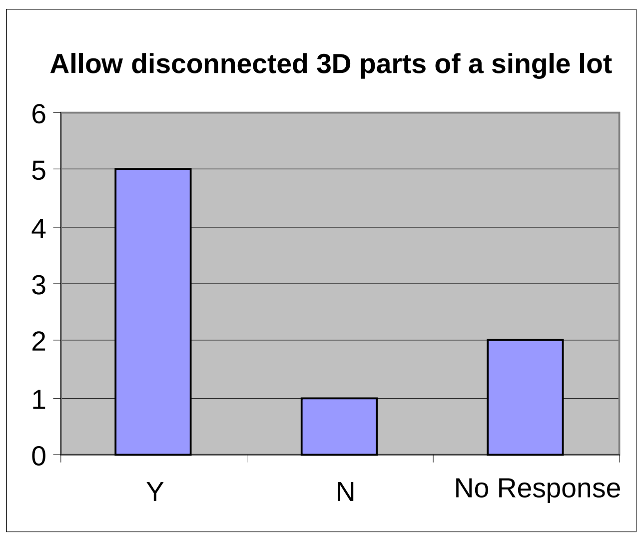


Figure 4-8: Number of jurisdictions that register disconnected 3D parts of a single lot

4.4.1.5 Registering curved surfaces

Curved boundaries in 2D usually occur in lots at road corners, and all jurisdictions allow such 2D curved surfaces as a series of short chords to complete the arc. None of the jurisdictions have any restrictions on 3D curved surfaces as long as the shapes were able to be defined geometrically. Figure 4-10 shows an example of the representation of a curved surface (left) as a series of polyhedrons (right), similar to a series of short chords along road boundaries (Figure 4-9 Right).

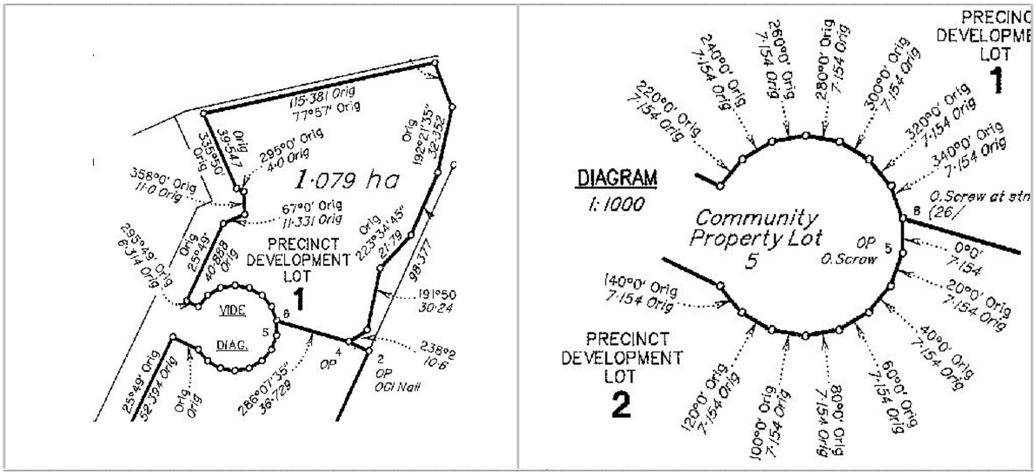


Figure 4-9: Example of a circular road shown as a series of short straight chords

(Source: DNRM QLD)

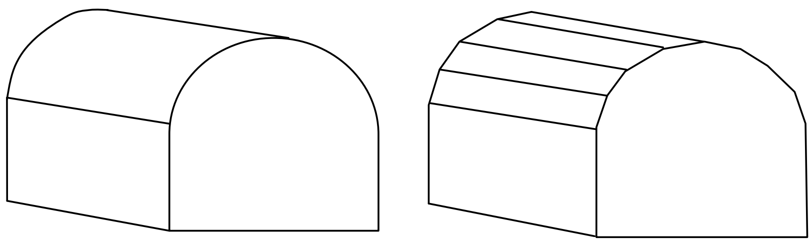


Figure 4-10: Curved surface and its corresponding planar polyhedral surface (similar to short chords), Karki et al (2011)

4.4.2 Infrastructure / Utility Networks

Infrastructure networks such as tunnels, and utility networks such as water, sewerage, electricity transmission lines, gas, telephone are usually linear features that extend over a number of surface parcels. Utility networks can be constructed under the surface, over the surface or a combination of both.

As these networks require significant investments, rights and interests of the owners are protected if they have a title and are registered in the cadastre. Cadastral jurisdictions in Australia register network interests differently as illustrated in Figure 4-11. Where the interests are allowed to be registered in the cadastre, they are usually registered as volumetric parcels (QLD), as easements (QLD, NSW) or as easements registered but not spatially mapped (SA).

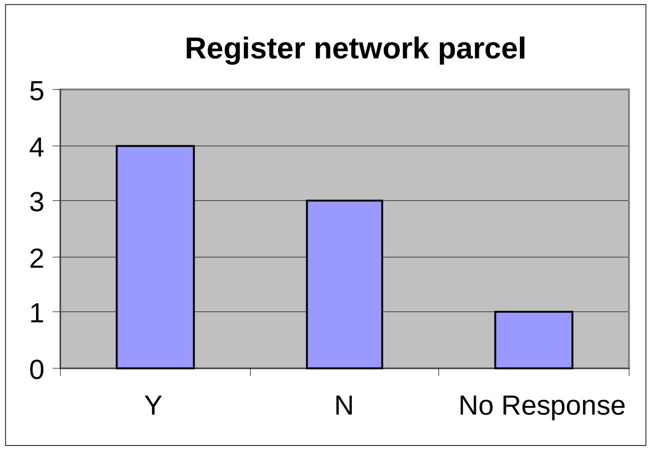


Figure 4-11: Number of jurisdictions where network parcels are registered

4.4.3 Construction / Building Units

Building units or apartments are registered as individual properties in all jurisdictions of Australia and they are treated similar to 2D parcels for registration and transfer of rights. This section firstly discusses how common properties are dealt with to understand how they are registered and maintained. Next, it discusses how ownership rights relating to building parcels are maintained in the cadastre and finally how building parcels are represented in the DCDB.

4.4.3.1 Common Properties

A block of units in a building usually consists of individual building units and one or more common properties. The units themselves represent a single entity over which ownership rights are applied, for example, a one-bedroom unit or apartment may be registered as a single entity with a single title. Similarly, a three bedroom unit with a garage space and a private yard may also be considered a single entity because it will also be registered with a single title.

All common spaces such as stairs, lifts, yard, driveway are common properties and are administered by a Body Corporate or an Owners Corporation. In Australia, common properties are not considered part of the unit-holders title area, nor can they sell their share of the common property. Very often they have access rights to most areas of the common property, and they have a shared responsibility to maintain the common areas. This is mostly achieved through proportionate financial contributions to the fund manager of the Body Corporate or the Owners Corporation.

Common properties in individual block of units or apartments are either unallocated, unregistered space left between registered properties (ACT) or registered space owned by everyone in the unit block (all other jurisdictions). Regardless of whether a title is issued or not for the common property, the area is normally owned and managed by the Body Corporate or the Owners Corporation.

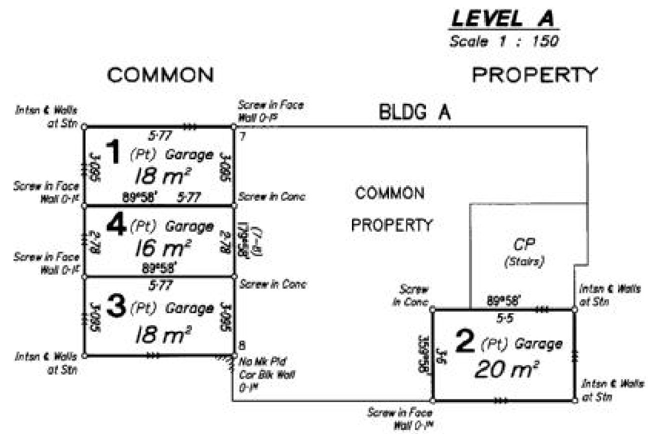


Figure 4-12: Example of a common property inside and outside of a building

(Source: DNRM QLD)

Figure 4-12 shows an example of a common property inside and outside of a building for which all owners share a right of access as well as a responsibility of maintenance. The rights and responsibilities of the owners extend beyond their individual units to other common properties within the bounds of the surface parcel on which the unit is built.

4.4.3.2 Representation of building parcels

All jurisdictions have a similar approach and allow building parcels to be registered as individual lots that are dealt with in a similar way to the 2D surface parcels. No jurisdiction stores 3D data spatially in the DCDB, however, the ownership and other rights are stored as attributes attached to the base parcel, which is the only entity represented spatially in the DCDB.

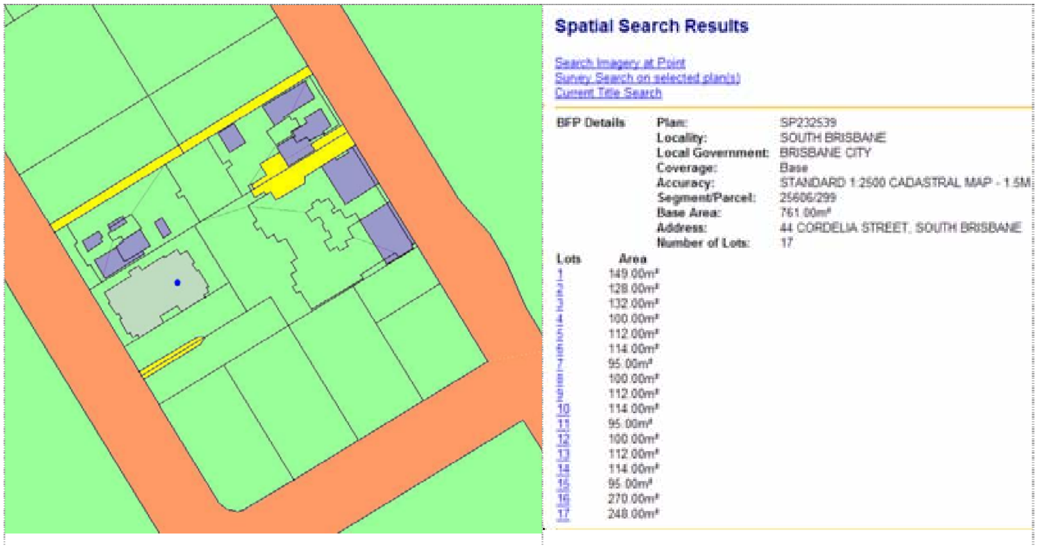


Figure 4-13: Outline of a building (left); details of the building units stored as attributes (right)

(Source: DNRM QLD)

In Figure 4-13, the figure on the left shows an example where the DCDB represents the spatial outline of a multi-level building with 17 lots, while on the right it shows that the 17 lots in the building are stored in the attribute table without being spatially represented in the DCDB. Each lot has a separate title and other details like area, zone, and use attached to it similar to a 2D parcel.

Although the 3D space has not been stored spatially in the DCDB, their rights and interests were secure so that even if the building was destroyed, the owners still had a right to their portion of the building. Any change to the configuration or rights would have to be dealt with by lodging a registered plan. Once the building was rebuilt, the unit would be restored to the owners on the same building block, at the same level, with the same size and general location. However, since the 3D coordinates are not required to be shown in the plan, they need not be reinstated at the same 2D location and may differ from the original 2D location without any impact on the owner or the cadastral database.

The footprint of building at ground level is stored spatially, while the unit information such as building, level and unit number are stored in attribute tables related to the base parcel. The numbering system of units varies between jurisdictions. In Queensland and South Australia, any numeric identifier provided by the surveyor is accepted. The lot number does not correspond to the street address number as in Australian Capital Territory, and are expected to start from one and be consecutive, as in New South Wales, Tasmania and Western Australia. Northern Territory follows a similar approach, but sometimes may have unit numbers that are a prefix to the base parcel number.

4.4.4 X / Y Coordinates

Cadastral plans in all the jurisdictions of Australia are prepared according to the standards set out by the respective jurisdictions and surveying bodies. The measurements of the objects in the plans are usually very accurate relative to other objects in the plan. The cadastral corners do not have horizontal coordinates but are relatively referenced through reference marks, occupations, or cadastrally connected permanent marks with or without coordinates.

Figure 4-14 shows the example of a plan where corners are referenced to marks or objects near the boundary. The boundary lines of a parcel are shown as bearing and distance, but there is no X/Y coordinate on the cadastral parcel. All modern plans are mostly oriented based on the Map Grid of Australia (MGA) meridian, but there exists plans that have been oriented towards an arbitrary meridian such as the County Arbitrary Meridian. Parcels in these plans are entered into the DCDB by applying a swing correction between the arbitrary meridian and the MGA meridian. The approach is similar in all jurisdictions and cadastral parcels are not captured with X/Y coordinates in any of the jurisdictions.

As the plans do not capture real world coordinates, there is no legal guarantee of the absolute location of a parcel even though it may be represented in its proper position in the DCDB. Some parcels such as marine leases or mining leases may have X/Y coordinates, but it is not universally applicable.

The position of the lots in the DCDB is continuously being shifted through upgrade programs and as new data becomes available. For 3D building units, parcels are determined in relation to walls, ceilings and floors and not being defined by absolute coordinates.

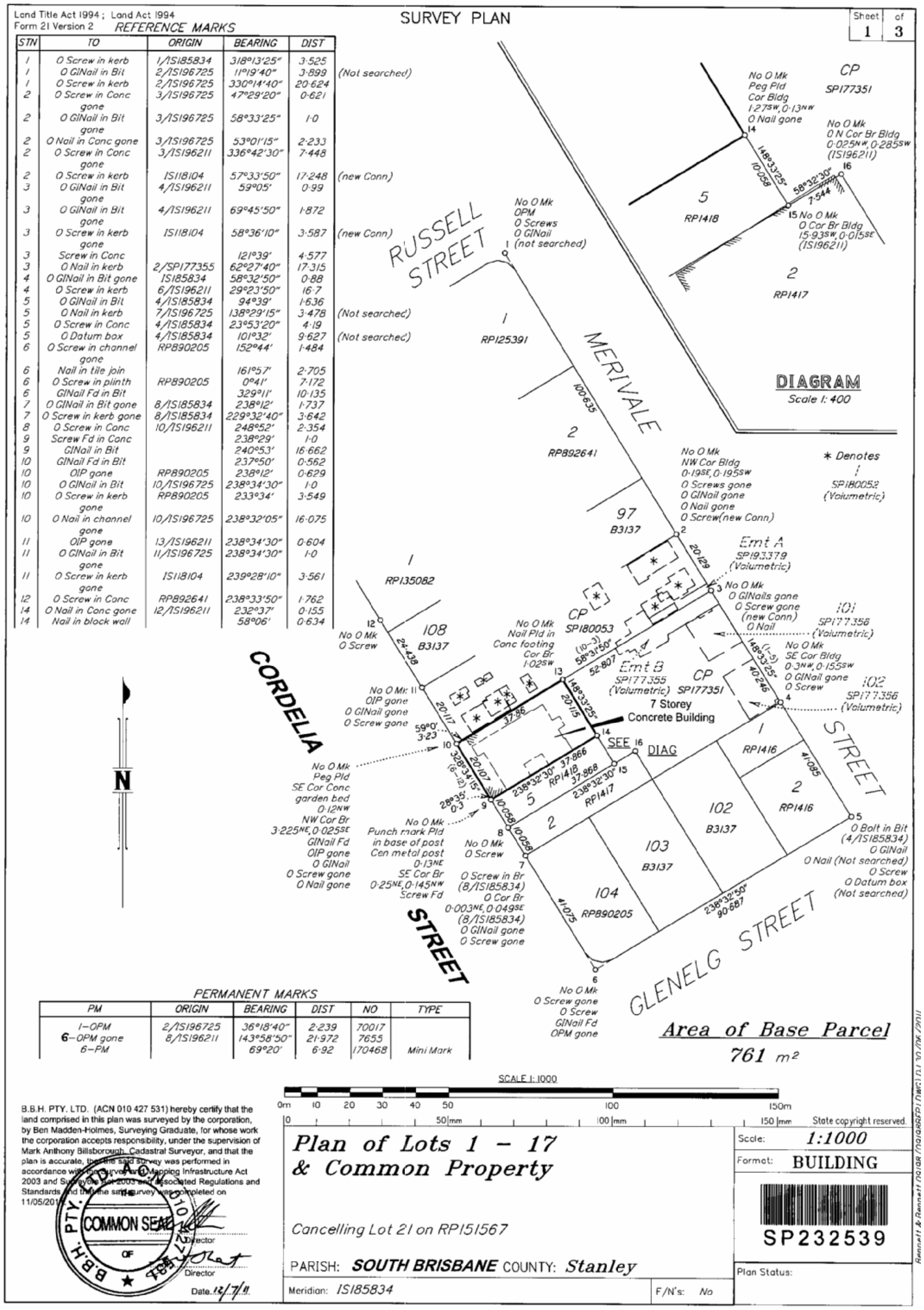


Figure 4-14: Example of a survey plan without X/Y coordinates

(Source: DNRM QLD)

4.4.5 Z Coordinates

In Queensland, plans with 3D objects are volumetric plans, whereas in other states they are called stratum plans. Volumetric plans or stratum plans show Z-coordinates that are referenced to a permanent mark or benchmark. The permanent mark is defined by reduced level based on the Australian Height Datum (AHD). Building plans or strata plans do not show Z-coordinates.

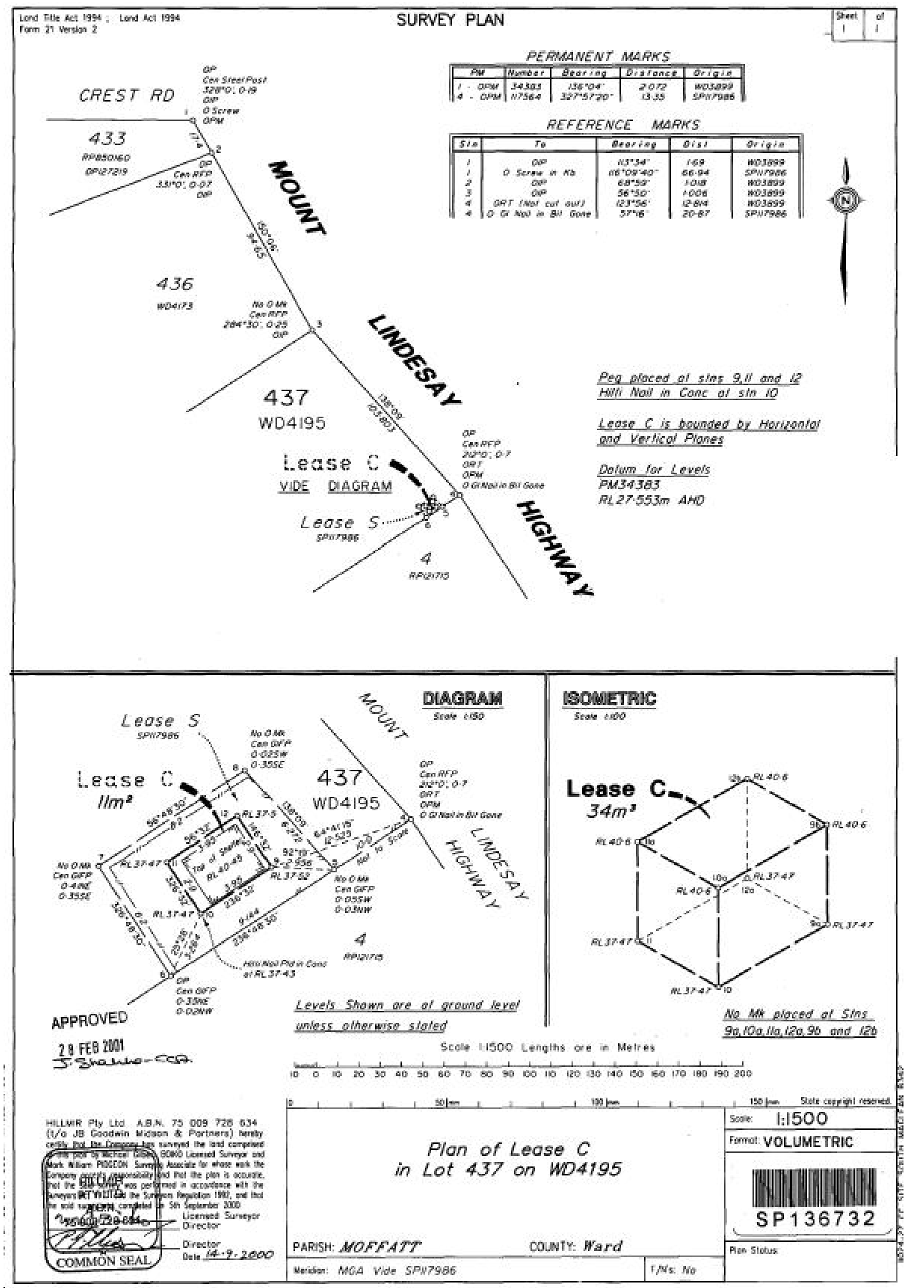


Figure 4-15: Example of a 3D plan with Z coordinates

(Source: DNRM QLD)

Figure 4-15 shows an example of a volumetric plan from Queensland where the vertices of a 3D parcel are referenced to reduced levels that are relative to the Australian Height Datum (AHD). Cadastral corners for 3D objects are not marked if they are not accessible, or not stable, or there are no structures as in the case of registered airspace or in the water. In 2D lot boundaries, each cadastral corner is marked and referenced to an object.

4.4.6 Temporal issues

In this section of the questionnaire, a number of temporal issues were raised including: if temporal limits were part of the parcel definition; whether moving parcels were allowed; whether there were any limitations on the range of temporal limits; whether 2D and temporal representations were integrated; and how movements in 3D ambulatory boundaries were represented.

All jurisdictions responded that although there were no efforts to include temporal data, the nature of the cadastre allowed timeshares, or ambulatory boundaries to be registered. Also, since the cadastral data can store all parent-child parcel relationships, there were some aspects of temporal data that were stored automatically.

4.4.7 Rights, Responsibilities and Restrictions (RRR)

This section discussed the responses to the questionnaire on rights, responsibilities and restrictions (RRR) related to 3D cadastre in the jurisdictions. Questions were asked on the range of RRR applicable to 3D cadastre and the future applications of RRR to 3D cadastre.

While all 2D parcels can be considered to a have 3D ownership rights on, above or below the surface, the responses to this question concentrated on the legislative support for RRR in each jurisdiction and the application of RRR on 3D cadastre. The legislative support applicable to RRR for 3D cadastre for each jurisdiction has been tabulated in Table 4-3.

The responses to the range of RRR were similar in all the jurisdictions. All jurisdictions treated 2D and 3D objects similarly for legal registration purposes. However, none of the jurisdictions had the capacity to store 3D information in the cadastral database. There were additional responsibilities or restrictions for 3D properties; for example, common properties involved additional responsibilities of maintenance as well as restrictions on exclusive use or relinquishing of rights. For volumetric or stratum lots, all jurisdictions had no restrictions on who could own sub-surface lots, either public or private, which is similar to 2D lots. All jurisdictions allowed strata ownership to be different to the ownership of the base lot, which was owned under the community management schemes such as body corporate or owners corporate.

All jurisdictions had similar views on the future applications of RRR for 3D cadastre. Some of the application areas that were raised were not just confined strictly to 3D cadastre but were general statements that could be applicable to cadastre in general. Ensuring unique definition of property rights was raised as being important by QLD and ACT, but these already exist in the current cadastral system in all jurisdictions. Other issues raised were: better representation of 3D RRR interests (NSW); asset relationship to 3D strata; and 3D city modelling and draping.

4.4.8 Digital Cadastral Database (DCDB)

The purpose of this section of the questionnaire was to determine how 3D data was included in the current digital cadastral database (DCDB). The responses to the questionnaire are arranged into two groups of similar issues related to DCDB. The discussions were focussed on determining how 3D data was represented in the DCDB, and what software was used for cadastral data manipulation and dissemination.

4.4.8.1 Representing 3D in the DCDB

The digital cadastral database (DCDB) of all the jurisdictions is a 2D database and is able to store 2D data only. When 3D cadastral data is lodged at the respective departments of each jurisdiction, the 3D parcels are stored in the DCDB as an outline only while the attribute data is stored in tables of the database. There is no automated validation at data entry or database level verification of 3D content.

A persistent identifier (PID) database is maintained by some jurisdictions for cadastral corners in a separate point database. In Queensland this database is called the Survey Point and Marks Database (SPDB). NSW do not maintain it for 2D natural boundaries, and since 3D data is not stored in the database, none of the jurisdictions record a PID for 3D data.

4.4.8.2 Software used in the DCDB

As seen from Table 4-4, all jurisdictions use different software to store, update, visualise or disseminate cadastral data in their jurisdictions. All jurisdictions have modified or customised the commercially available software to suit the requirements of the cadastral data. Some of the software used had some 3D viewing capacity; for example MicroStation can view 3D isometric data and ESRI 3D Analyst assists in visualising 3D topographical or extruded building data. However, none of the software utilised have the capacity to store, visualise, maintain, query or manipulate 3D data. Consequently, no jurisdiction stores 3D data in the cadastral database.

Table 4-4: Software used in DCDB in all jurisdictions

Jurisdiction	Database	Data update	Visualisation/ Dissemination
QLD	Ingres	MicroStation	Internal customised software
NSW	Informix	ESRI ArcGIS and LPMA customised maintenance environments.	ESRI ArcGIS Server
ACT	Geomedia / Oracle	Geomedia with some ESRI	ESRI. 2D only
VIC		Internal, LASSI.	Internal, LASSI.
TAS	ArcGIS	ArcGIS	FME for data distribution, ArcIMS for visualisation
SA	Oracle	ESRI	
WA	Oracle and SDE. DCDB maintenance software	Spatial Maintenance software internally developed for Landgate by ESRI	Only for visualisation – Oracle Web Logic written in Java.
NT	Oracle 10.2	MicroStation – Current add on Cadastral Fabric Manager	ArcIMS used for web display

4.4.9 Plan of Survey

This section of the questionnaire explored how plans of survey with 3D content were created in the jurisdictions. The issues discussed were related to what types of 3D plans were created and the contents of a 3D plan of survey.

Figure 4-16 shows an example of a 3D volumetric format plan from Queensland. Reference marks or volume dimensions are sometimes tabulated on the plan but can also be shown on the face of the plan as dimensions. Other cadastral jurisdictions in Australia have stratum plans which are equivalent to volumetric format plans from Queensland. Volumetric format plans or stratum plans define a lot as a three dimensional bounded surface referenced to a 2D base lot.

Building format plans in Queensland define a parcel using structural elements of a building, while similar plans in other jurisdictions are called Strata plan. Strata lots have a different meaning in Queensland, where a strata title is generally created for non-freehold titles or different tenure types or secondary interests such as leases, occupational leases, licenses, covenants, depth restricted lots, or other restricted lots. However, plans containing these lots are not called strata plans, but treated as a standard plan or a restricted plan, and may not include 3D content.

All jurisdictions in Australia treat 2D and 3D objects similarly and allow all 2D transactions such as sale, mortgage, subdivision, amalgamation, as well as creation of easements, leases, and covenants to be performed on 3D objects. Currently all 2D and 3D plans are submitted as paper-based plans, but 3D content is not included in the DCDB.

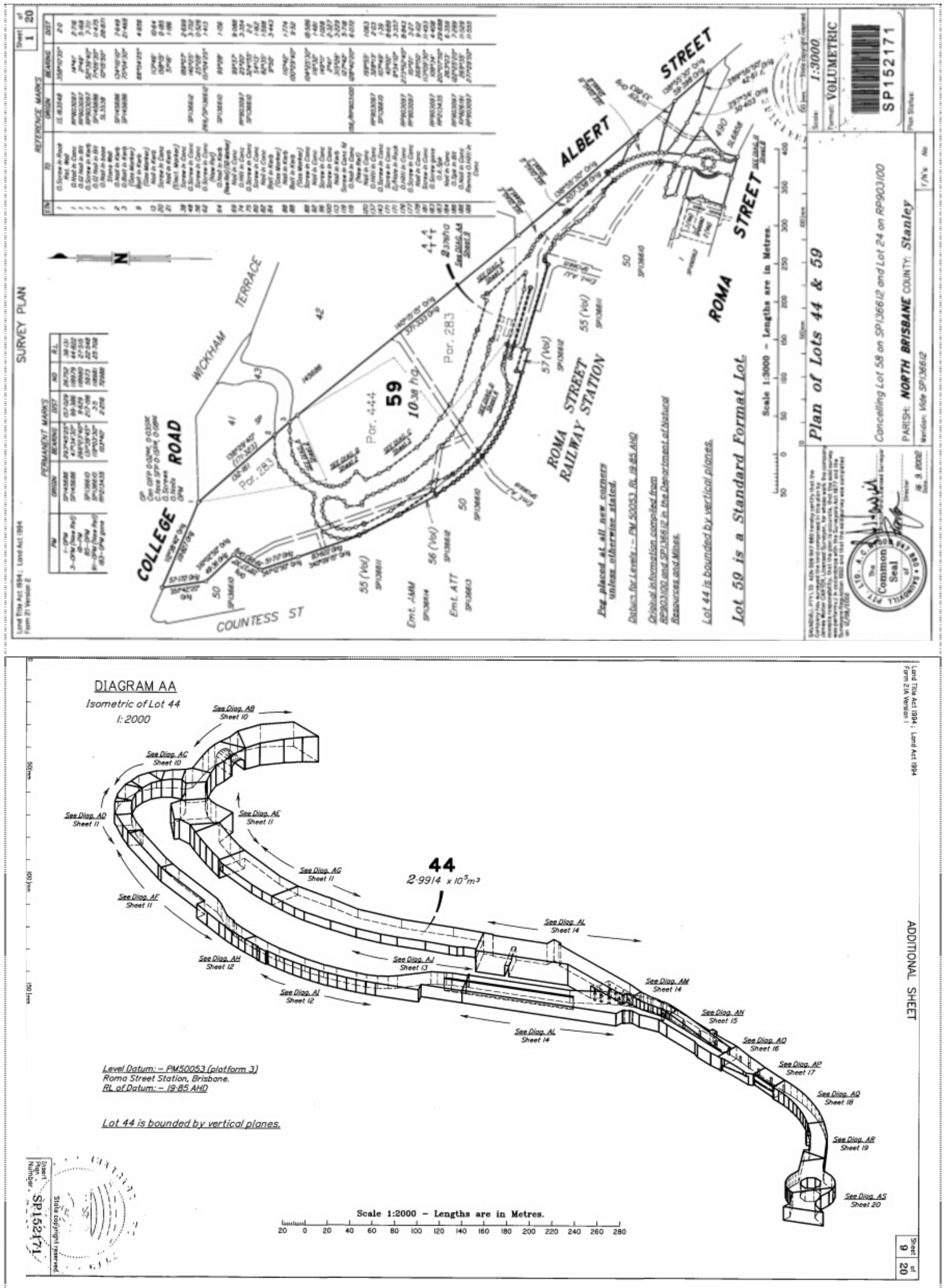
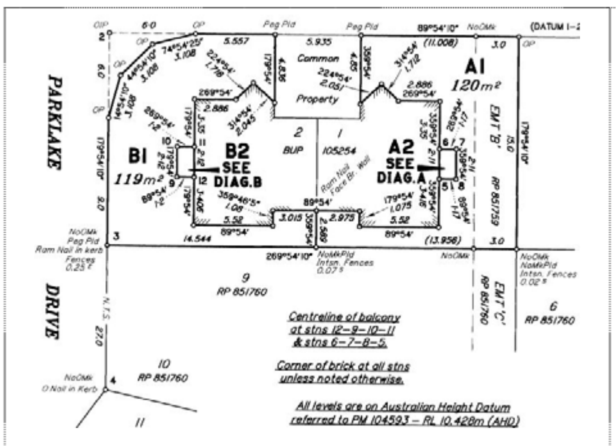


Figure 4-16: Example of a 3D volumetric plan of survey from Queensland

(Source: DNRM QLD)

Survey plans containing 3D parcels in all the jurisdictions showed reference marks along the 2D surface lot boundaries. None of the modern survey plans in any jurisdiction showed 2D or 3D topographical features. Reference marks are used by surveyors to reinstate cadastral corners and boundaries. These reference marks are also known as monuments or occupation, and usually consist of iron pins, reference trees, reference walls or other constructed features. The marks are placed on the ground reasonably close to the cadastral corner it refers to, and a separate table of measurements to reference marks is generally included on the face of the plan.

Figure 4-17 shows an example of a building format plan of Queensland, which shows reference marks along the boundaries of the 2D base lot, such as OP for original peg, OIP for old iron pin. A separate reference table shows the bearing and distance measurement to the reference mark from the cadastral corner and the original plan where it was first recorded.



REFERENCE MARKS

STN	TO	ORIGIN	BEARING	DIST
1	OIP	19/RP851759	at	Stn
1	O SPIKE IN BITUMEN	19/RP851759	45°56'40"	9·724
2	OIP	18/RP851759	at	Stn
3	RAM NAIL IN KB.		213°16'	4.579
4	O NAIL IN KB.	17/RP851760	285°15'40"	4.428

Figure 4-17: Example of a building format plan showing reference marks (left), and a reference table (right)

(Source: DNRM QLD)

While reference marks are shown on 3D plans showing 2D surface boundaries, 3D building lots are not referenced to monuments. Volumetric lots can be located with reference to surface parcel boundaries and the elevation is referenced to a permanent mark which is reduced from the Australian Height Datum (AHD). In Queensland, isometric drawings are required to be submitted with all volumetric format plans. Elevation or relative heights are shown on the vertices of all isometric drawings. Currently, as 3D objects are not entered into the cadastral database, there are no automated validations of 3D objects and most checks are performed manually.

4.5 CONCLUSION

This chapter presented the results of the survey of cadastral jurisdictions of Australia. Registration of 3D cadastral objects was allowed, however, the legislative framework in the cadastral jurisdictions of Australia were not consistent to support the implementation of 3D cadastre. There were differences in the level of implementation of 3D cadastre in the lodgement and registration of 3D geometry and rights.

Discussions on the specific construction of 3D parcels revealed a number of similarities and differences, such as, 3D parcels were constrained within 2D parcels in most jurisdictions, 3D ambulatory boundaries were allowed and 3D air-space was registered in the cadastre. Jurisdictions were supportive of complex 3D cadastre features and there were some differences in the method by which network parcels were registered throughout the jurisdictions.

There were differences in semantics and processes in capturing and presenting 3D specific plan information. Individual jurisdictional requirements for documentation, delivery and lodgement continued to vary. There was no consistency in moving forward towards uniformity such as complying with the ISO 19152 LADM. There was no consistent geometry adopted in the capture and representation of 3D cadastral objects. None of the existing digital cadastral databases allowed the full integration of 3D data in their databases.

In the next chapter, a detailed study of the jurisdiction of Queensland is undertaken to identify specific issues and characteristics of the implementation of 3D cadastre. The results from Chapter Four and Chapter Five are integrated and discussed in Chapter Six.

CHAPTER 5

QUEENSLAND CASE STUDIES

5.1 INTRODUCTION

In Chapter 4, the status of 3D cadastre in all the jurisdictions of Australia was examined. It provided an overall picture of the characteristics, similarities and differences amongst the jurisdictions from a national perspective. Although, the national perspective provides a higher level view of 3D cadastre issues and characteristics, an understanding of the operational issues can be better accomplished by an in-depth analysis of a particular jurisdiction. Therefore, this chapter examines the institutional framework (legal, policy, operational, and tenure), and the technical framework (geometry, and data representation) in a particular jurisdiction, namely Queensland, Australia. Five cases were selected for a detailed descriptive qualitative analysis to explore the characteristics of 3D cadastre implementation in Queensland. All the data and plans obtained for this case study were provided by the Department of Natural Resources and Mines (DNRM).

Section 5.1 of this chapter presents the introduction and discusses the objective of the case study. Section 5.2 discusses the institutional and technical framework for cadastre in the jurisdiction. Section 5.3 examines five cases relating to 3D cadastre in Queensland using the same framework as the questionnaire survey of the previous chapter to extract information for the described framework. Finally, section 5.4 presents a brief summary of the chapter.

Yin (1999, p. 1215) emphasises that "*good case studies should contain some operational framework, even if the case studies fall into the classic exploratory mode. Even when exploring, some framework should be in place to define the priorities to be explored*". In this chapter, the cadastral situation of Queensland is examined according to an institutional and technical framework (Table 5-1). The cases are discussed according to the framework of the questionnaire discussed in Chapter 4 which included 3D real-world situations, infrastructure or utility networks, construction or building units, rights, restrictions and responsibilities, X/Y coordinates, Z coordinates temporal issues, DCDB, and plans of survey.

Table 5-1: Discussion framework for analysis of case studies

Factors	Expected Outcomes
Legal	Identification of legislative framework
Policy	Identification of policies, standards and guidelines
Tenure	Identification of tenure types and implementation of registration
Operational	Identification of cadastre related institutions, roles and responsibilities, and their interactions
Geometry	Identification of 3D issues and how they are dealt with
Data representation	Identification of data storage, manipulation, validation, and query

5.2 QUEENSLAND OVERVIEW

Queensland (Figure 5-1) became an independent self governing colony of Australia in 1859 after separating from New South Wales. The Department of Natural Resources and Mines (DNRM) is the custodian of cadastral data in Queensland and has stored all cadastral data since 1859 when the state was formed. Partial cadastral data between the years 1844 – 1859 AD is available at DNRM, while the remainder is stored by the relevant New South Wales government authority. Cadastral legislation in Queensland has undergone changes to meet the requirements of the cadastre of the time and the current over-arching legislation for property registration are the Land Act (1994) and the Land Titles Act (1994).

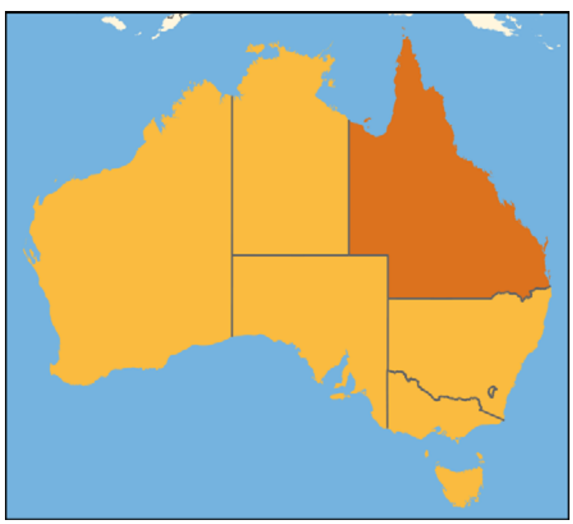


Figure 5-1: Queensland location

Source: (McDougall 2006)

Table 5-2 provides a summary of the total base lots, building format lots, volumetric lots and strata lots at both August 2011 and August 2012. There were 203,772 building units in August 2012, which is a growth of more that 7,400 units over the past year. This represents an increase of 3.8% from 2011 numbers (Figure 5-2 Right) and is a growth of 17% of the total new properties during this period (Figure 5-2 Left). Most of these building units are situated in coastal towns of Queensland with a majority of them in Brisbane and Gold Coast.

Table 5-2: Statistics for 2D and 3D cadastral lots in Queensland taken at August 2011 and August 2012

	Base Lots	Building Format Lots	Volumetric Format Lots	Strata Lots
August 2011	2191904	196369	1628	35892
August 2012	2224905	203772	2141	37567
Growth-1 yr	*33001*	*7403*	*513*	*1675*
Growth percentage	*1.5%*	*3.8%*	*31.5%*	*4.7%*

(Source: DNRM DCDB)

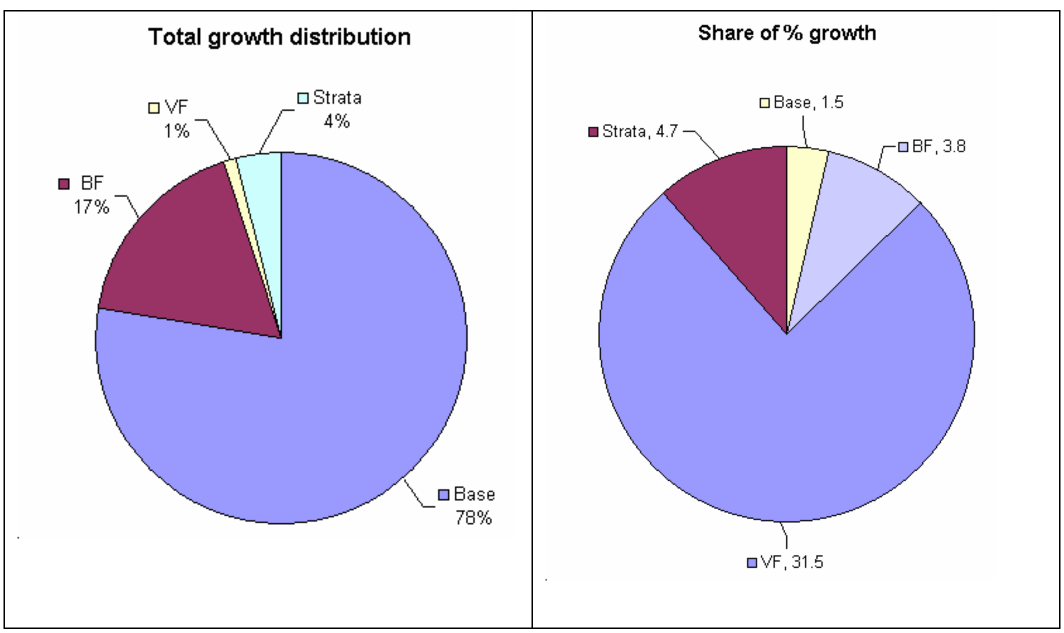


Figure 5-2: (Left) Distribution of total growth in one year, (Right) Share of % growth in each category

Similarly, volumetric format lots have grown by 513 (31.5%) in the same period to reach 2,141 in August 2012 (Figure 5-2 Right). This represents a 1% growth among the total new properties for the year (Figure 5-2 Left). Although there are a comparatively low number of volumetric lots, they have been found to be created in complex cases and important infrastructures as seen in some of the cases in Section 5.3.

In Queensland, strata tenures are created in the digital cadastral database (DCDB) for secondary interests (permit to occupy, licenses, leases), restrictions (restricted to depth lots, covenants) and for subdivision or amalgamation of building format or volumetric format lots. Currently it is impossible to determine the number of 3D lots in strata title.

5.2.1 Legislative Support

The Land Act (1994) and Land Title Act (1994) are the main Acts for title registration of all real properties while the Survey and Mapping Infrastructure Act (2003) is the primary Act for cadastral surveying infrastructure in Queensland. The core Acts that directly guide the cadastral framework of Queensland are listed in Table 5-3. Other Acts and Regulations relevant to the administration of land in Queensland are listed in Appendix 3.

The Body Corporate and Community Management Act (1997) and the Building Units and Group Titles Act (1980) are the Acts which support the registration of apartment units and the management of common properties.

The Land Act (1994) administers the non-freehold land such as roads, rivers. The Land Title Act (1994) administers the registration of freehold land and the interests on it.

The Surveying and Mapping Infrastructure Act (2003) provides for the surveying and mapping as well as maintaining the survey infrastructure. The Sustainable Planning Act (2009) administers the sustainable development of land, is managed by the local government of Queensland and assists to make decisions on the development needs of a specific zone when a development application is lodged.

Table 5-3: The core legislative framework of Queensland cadastre

Name of Act	Purpose mentioned in the Act
Body Corporate and Community Management Act (1997)	An Act providing for the establishment and administration of community titles schemes
Building Units and Group Titles Act (1980)	An Act to provide for the horizontal subdivision and vertical subdivision of land into lots and the disposition of titles
Land Act (1994)	An Act to consolidate and amend the law relating to the administration and management of non-freehold land and deeds of grant in trust and the creation of freehold land
Land Title Act (1994)	An Act to consolidate and reform the law about the registration of freehold land and interests in freehold land
Surveying and Mapping Infrastructure Act (SMIA) (2003)	An Act to provide for developing, maintaining and improving the State's survey and mapping infrastructure
Sustainable Planning Act (2009)	An Act to seek to achieve ecological sustainability by managing the process and effects of development and by coordination and integration of planning at all levels

5.2.2 Policies, standards, and guidelines

In addition to the Acts mentioned in Table 5-3, there are various policy documents, manuals, standards, and guidelines that assist in maintaining a consistent methodology, outputs, and quality of cadastral survey work in Queensland and are listed in Table 5-4. These documents are often used as reference documents by cadastral surveyors, plan auditors and staff from the titles registry.

There are standardised forms and templates for cadastral surveys which are based on the documents in Table 5-4 and are used by cadastral surveyors regularly including: Form 6: Permanent Mark Sketch; Form 13: Certification by Surveyor for Surveyed Plan; Form 18: Certification by Surveyor for Compiled Plan; Form 21: Plan Form; and Form 38: Digital Lodgement Plan Form.

Table 5-4: Guidelines and manuals in Queensland

Document Name	Purpose compiled from document
Cadastral Survey Requirements (2010)	This sets out a range of information for cadastral surveyors: 1. Standards and guidelines under the Survey and Mapping Infrastructure Act 2003 2. Information about requirements under other legislation 3. Specific requirements related to actions under other legislation
Land Title Practice Manual (2009)	It is aimed at industry professionals and details the required practice and procedures for preparing and lodging land registry forms
Registrar of Titles Directions for the Preparation of Plans (2008)	It details the standards and specifications for the types of plans acceptable to the Titles Registry and contains directions for 3D plan preparation

5.2.3 Registration of Tenure

In Queensland, all titles are registered and maintained by the Titles Registry Office. As identified in Karki et al (2013), 2D and 3D plans are treated the same for the registration of titles. The storage and dissemination system in the Titles Registry is called the Automated Titling System (ATS). Currently, Queensland has 25 tenure types that are represented in the DCDB (source: internal DNRM publications).

Table 5-5 shows a sample of the most frequently used tenure types in Queensland DCDB. The first four tenure types complete the continuous coverage of the cadastral fabric, while the remaining three are secondary interests that are created over a base lot. The remaining minor tenure types are: Commonwealth Acquisition, Carbon Abatement Interest, Forestry Entitlement Area, Forest Reserve, Boat Harbour, Housing Land, Industrial Estates, Mines Tenure, Marine Park, Main Road, National Park, Port and Harbour Boards, Railway, State Forest, Timber Reserve, Transferred Property, and Water Resource.

Table 5-5: Sample of tenure types in Queensland DCDB

Tenure Type	Description
Freehold	Land held in Fee Simple (freehold title) which includes titles surrendered to the State of Queensland (or Crown) in terms of Section 358 of the Land Act (1994)
Lands Lease	Leasehold land administered by the DNRM excluding Mining Homestead Tenement Leases.
Reserve	Land reserved by the state for community or public purposes
State Land	Land held by the State of Queensland as Unallocated State Land (USL) and other areas vested in the State (or Crown) but not held in Fee Simple or as a lease issued under the Land Act (1994).
Below the Depth Plans	A registered right or interest over a parcel of land whose location is defined as below a depth or to a depth below the surface of the earth
Covenant	A registered right or interest over a parcel of land used to restrict usage of that land
Easement	A right or interest on a property that is registered against the title

5.2.4 Operational Aspects

This section discusses the operational aspects of cadastre in Queensland from two perspectives: the overall roles and activities of the actors and their roles in undertaking surveying work and registration (Section 5.2.4.1); and the view from the registering authority (DNRM) involved in registering the lodged plan (Section 5.2.4.2).

5.2.4.1 Overall Plan Lodgement Process

Figure 5-3 shows an UML use-case diagram of the institutional interactions when a cadastral survey event occurs. A brief description of the various actors and actions of the use-case diagram in the process is discussed below.

Client: The trigger to this process is the client from whom the request for a survey originates. The client is also at the end of the process, where he or she is notified of the changes brought due to the initiation of the process and how it affects him or her.

Cadastral Surveyor: In Queensland, surveyors with a cadastral endorsement from the Surveyors Board of Queensland can sign off a cadastral plan. Upon surveying the lot or parcel (in Queensland a lot may contain several parcels), the surveyor obtains the necessary permissions from the respective local government authority acting under the Sustainable Planning Act (2009) and lodges the plan to DNRM for registration. It is common for surveyors to lodge an advance copy prior to council approval, known as Deposited Plans (DP), to expedite the plan checking process and the final copy is registered as a Survey Plan (SP).

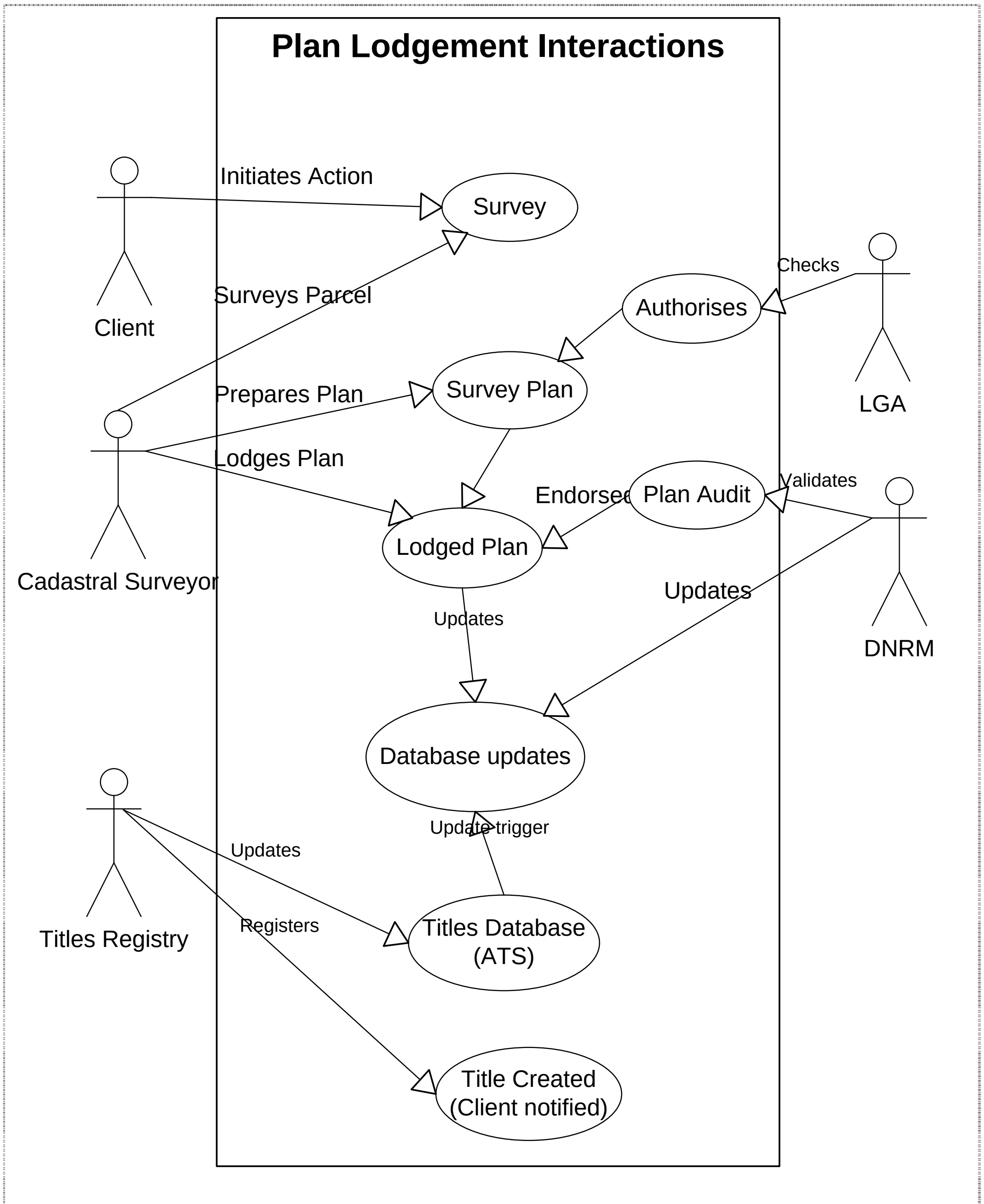


Figure 5-3: Institutional interactions on plan lodgement in Queensland

LGA: The Local Government Authority (LGA) maintains zoning restrictions such as minimum street frontages, minimum lot size, restrict or permit building units and authorises sub-divisions, amalgamations prior to plan lodgement as a Surveyed Plan (SP).

DNRM: The Department of Natural Resource and Mines (DNRM) is the custodian of cadastral data in Queensland. From Figure 5-3, the DNRM validates the Deposited Plans (DP) or Survey Plans (SP), updates its databases and notifies the office of the Registrar of Titles to register the title. The databases that are updated at this stage are the Survey Control Database (SCDB), Computer Inventory of Survey Plans (CISP), and Survey Points and Marks Database (SPDB). The Digital Cadastral Database (DCDB) is updated by DCDB unit upon notification by the Titles Registry that the registry queue has been actioned. DNRM also maintains a visualisation and discovery tool called SmartMap where information from the DCDB, SCDB, and CISP is displayed.

Titles Registry: From Figure 5-3 it can be seen that after notification by DNRM, the Titles Registry registers the title and updates the Automated Titling System (ATS) database and notifies DNRM of the completion so that the DCDB can be updated. The client is notified through the cadastral surveyor or the client's solicitor but no paper title certificate is issued through the Automated Titling System. Queensland like other Australian states, guarantees the title under the Torrens System of titles registration.

5.2.4.2 Units involved in plan lodgement in DNRM

Figure 5-4 illustrates the interaction of the various units in DNRM when a cadastral plan is lodged in the department. The regional service centres accept lodged paper plans and image or scan them in the system. This process updates the "*plan markout*" database for a list of plans to be captured digitally by the Survey Information Processing (SIP) unit. The digitally captured plans by SIP unit are then verified by plan auditors and a notification sent to Titles Registry for registration. Documents such as field notes, permanent mark sketches, deposited plans, survey plans are sent to the Records Management System (RMS) unit for record keeping. Databases such as the Computer Inventory of Survey Plans (CISP), the Survey Points and Marks Database (SPDB), and the Survey Control Database (SCDB) are usually automatically updated. The Digital Cadastral Database (DCDB) is updated by the DCDB Unit. Other databases are updated as actions for them are triggered.

Records in other areas such as Local Government, Land Tax, and Valuations are notified for updates.

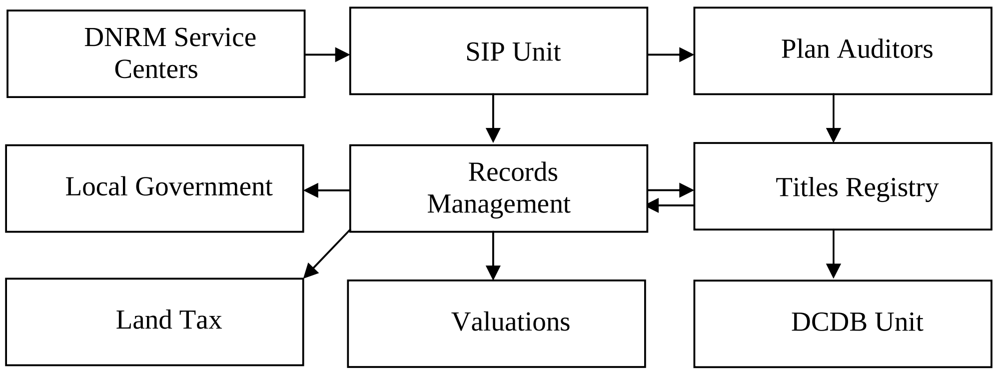


Figure 5-4: Institutional interactions within DNRM

5.2.5 Geometrical Aspects

The Queensland cadastre is not restrictive towards the surveying and registration of 3D geometry provided it can be defined mathematically according to Section 10.2 and Section 10.5.1 of the Registrar of Titles Direction for the Preparation of Plans (2008).

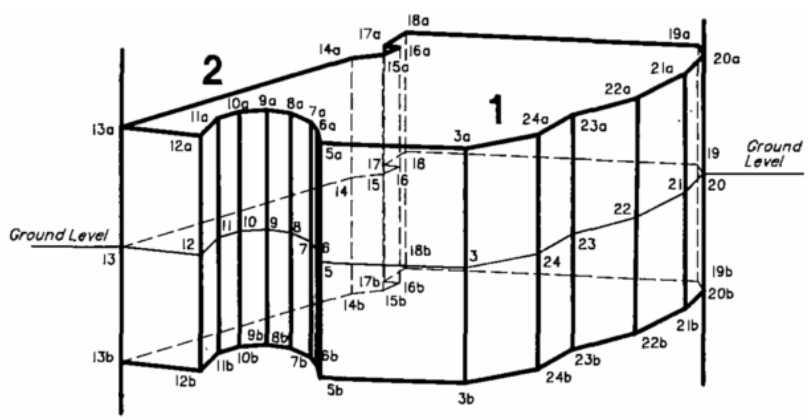


Figure 5-5: Example of a 3D curved surface

(Source: DNRM QLD)

Currently, although examples of registration of curved 3D surfaces in Queensland were not found; however there is nothing in the legislation to prevent it. As mentioned in Karki et al (2011), curved surfaces may be constructed as a polyhedra, similar to a corner truncation on curved road corners (see Figure 5-5).

<u>Spatial Reference (X/Y and Z coordinates)</u>

Currently cadastral plans in Queensland are not referenced to a horizontal spatial reference system and the plans do not show X/Y coordinates. Z-coordinates are referenced to the Australian Height Datum (AHD) in volumetric plans. Volumetric plans typically show a connection to a permanent mark with a known AHD height or Reduced Level (RL). The nodes of the volume present the respective RL derived from the connection to the permanent mark while the edges are represented by bearing and distance. Standard plans and building format plans do not include elevation data. As this is the same across all the cases discussed in this chapter, it will not be repeated in the discussions of the other cases.

5.2.6 Database Representation

In Queensland, the digital cadastral database (DCDB) stores all geometrical cadastral data and links with other databases such as the titles database. to complete the cadastral information. The database stores cadastral data digitised from historical plans but has steadily replaced them with survey accurate data through regular DCDB upgrade programs and DCDB updates based on survey plans lodged in the Department.

The Digital Cadastral Database (DCDB) is a 2D database that holds geometric data of the cadastre in Queensland. Cadastral data is stored in an Ingres database and data upgrades as well as updates are achieved using the Bentley MicroStation software where the data is stored in layers with predefined line-string properties. This information can be retrieved using SmartMap, a web service available based on subscription and managed by authorised logins.

DNRM stores information regarding ownership and valuation in separate databases, while the local governments store information regarding land development and planning. It also holds attribute data such as the lot-plan parcel identifier, administrative data, dimensions and area, parcel counts in a lot, parcel type, tenure type, parcel history and modification history.

The DCDB is a 2D database (Karki, Thompson & McDougall 2013), and does not store elevation values at present, however since each vertex is stored as a unique Persistent Identifier (PID), it may be possible to include elevation value at surface level in the future. No 3D information is stored in the DCDB at present; however, the outline of the 3D parcel is stored in a separate layer just like an easement and is used to visualise in a 2D environment. 3D information is currently stored on linked plans only and no geometric data is stored. Thus, at present there is no capability to capture and store 3D geometric information, perform automatic validations, visualise 3D information or perform 3D data manipulation and query.

The ownership and tenure is registered in the ATS, the survey related data is stored in CISP, the valuation data is stored in Queensland Valuation and Sales (QVAS) database, and records of public land is stored in the Government Land Register (GLR). Information about the survey controls is stored in the Survey Control Database (SCDB), data relating to the cadastral corners in Survey Points and Marks Database (SPDB) and information regarding placenames is stored in the Placenames Database (PNDB).

All data is validated prior to entry into the DCDB, however, since it is a 2D database, automated validation is not performed for 3D data (Karki, Thompson & McDougall 2013). Neighbourhood queries are difficult, as it is not easy to determine the adjoining lots and their extents on the vertical plane. Also, at the database level, it is impossible to determine if there is a vertical encroachment, the only way to do it at present is to open both plans, either on-screen or on paper and assess any possible vertical conflicts.

5.3 CASE STUDIES

Each of the five cases listed in Table 5-6 presents example implementations of 3D cadastre in Queensland and are a representative of the various kinds of 3D situations that exist. The cases are discussed within a similar framework to the questionnaire as discussed in Section 5.1. The cases were selected to provide a representation of the diverse range of issues encountered with 3D cadastres and provide a clear picture of the 3D cadastral issues in Queensland.

Table 5-6: 3D cadastral cases and a brief description

Case	Features of the case
Volumetric Encroachment	Encroachment in strata, 3D space registered as volumetric lease over 2D unallocated state land
Volumetric Network Parcels	Network parcels are created and registered in volumetric format and intersect each other in 3D
Volumetric Ambulatory Boundary	Creation of a 3D ambulatory boundary
Volumetric Doughnut	Registration of airspace without any physical construction
Volumetric Road	Volumetric road starting two storeys above ground level and ending taller than the tallest building in Brisbane

The ***Volumetric Encroachment*** case at Woolloongabba Cricket Stadium (Figure 5-6) presents an example of the creation of a volumetric parcel that infringes in strata the 2D space of a road parcel.

Figure 5-6: Location of Case 1: Volumetric encroachment at Woolloongabba Stadium

(Location Source of Figures 5.4 – 5.8: Google Maps)

The ***Volumetric Network Parcels*** case at Wolloongabba-Clem7 tunnel (Figure 5-7) demonstrates the situation where two volumetric network objects intersect each other on and below the surface.

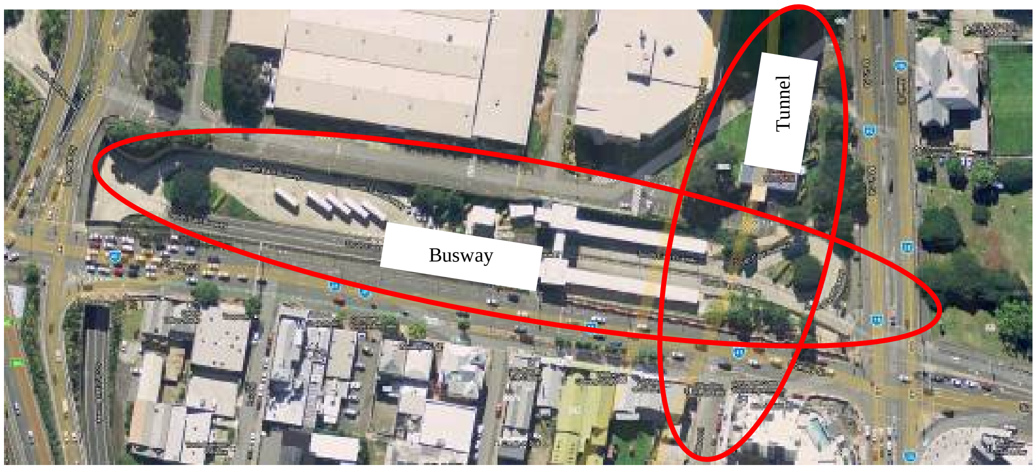


Figure 5-7: Location of Case 2: Volumetric network parcels at Woolloongabba Busway

The ***Volumetric Ambulatory Boundary*** case at Brisbane River near Kangaroo Point of Brisbane (Figure 5-8), illustrates the situation where a 3D ambulatory boundary was created as a vertical projection of a 2D ambulatory boundary line.

Figure 5-8: Location of Case 3: Volumetric ambulatory boundary at Brisbane River

The ***Volumetric Doughnut*** case at Morala Avenue, Gold Coast (Figure 5-9) shows an example of 3D airspace being registered with complex geometrical shapes without a direct connection to the base parcel. The registration of these doughnut volumetric parcels was necessary because it reserved the airspace for communications equipment on the tower.

Figure 5-9: Location of Case 4: Volumetric Doughnut along Morala Avenue, Gold Coast

The ***Volumetric Road*** case at Brisbane city (Figure 5-10) shows an example where a 3D road parcel is created as a 3D airspace. It also provides an example of how building units are created and registered in building format plans.

Figure 5-10: Location of Case 5: Volumetric Road along Boundary Road, Brisbane City

5.3.1 Volumetric Encroachment

The Brisbane Cricket Ground, commonly known as the Gabba Stadium because of its location in the suburb of Woolloongabba, is a major sporting venue in Brisbane (Figure 5-11). It hosts national and international events for games such as cricket, rugby and AFL. Towards the end of the 1990s and early decade of 2000, the Gabba Stadium underwent a major redevelopment. The grandstand was expanded on two sides to accommodate more spectators and was constructed with its sides overhanging Vulture Street and Stanley Street. Figure 5-12 shows the stadium overhanging Stanley Street. Traffic flow on both the streets has not been obstructed but the airspace above the two streets has been closed volumetrically and a term lease has been created in strata. The action statement on AP9927 (Appendix 1), permit to occupy for construction works, shows that a space of about 15.5m horizontal and 35 metres vertical of Stanley Street was reserved for the stadium.

Figure 5-11: Google map view of the location of the Gabba Stadium

Figure 5-12: The Gabba Stadium on Stanley Street overhanging Stanley Street

(Source photograph: Dr. Rod Thompson)

<u>General 3D situation</u>

The overhanging structure has been registered in the cadastre by creating volumetric lots of restricted airspace between a reduced-level of 10m to 35m (CP900152, SP120175, SP134698 and SP179933). The base parcels in those sections are unallocated state land (USL), which in this case is the public transport infrastructure, namely, Stanley Street and Vulture Street.

The Land Title Practice Manual (2009) defines the unallocated state land (USL) as all land in Queensland that is not freehold, or those that are road reserves, parks or those that are subject to a lease, permit issued by the state.

The USL in this case has been closed in strata and plans were created with reference to adjacent parcels because the base parcel was not part of the cadastre at the point of the lot creation. For example in Figure 5-13, in survey plan SP134698, the plan description states "*Plan of Lot 103*" whilst the cancelling clause states "*Cancelling part of USL, being closed road, adjacent to Lot 2 on RP803783*". This description is provided because there is no existing registered lot/plan to be cancelled, and so the created lot is located with reference to an adjacent registered lot.

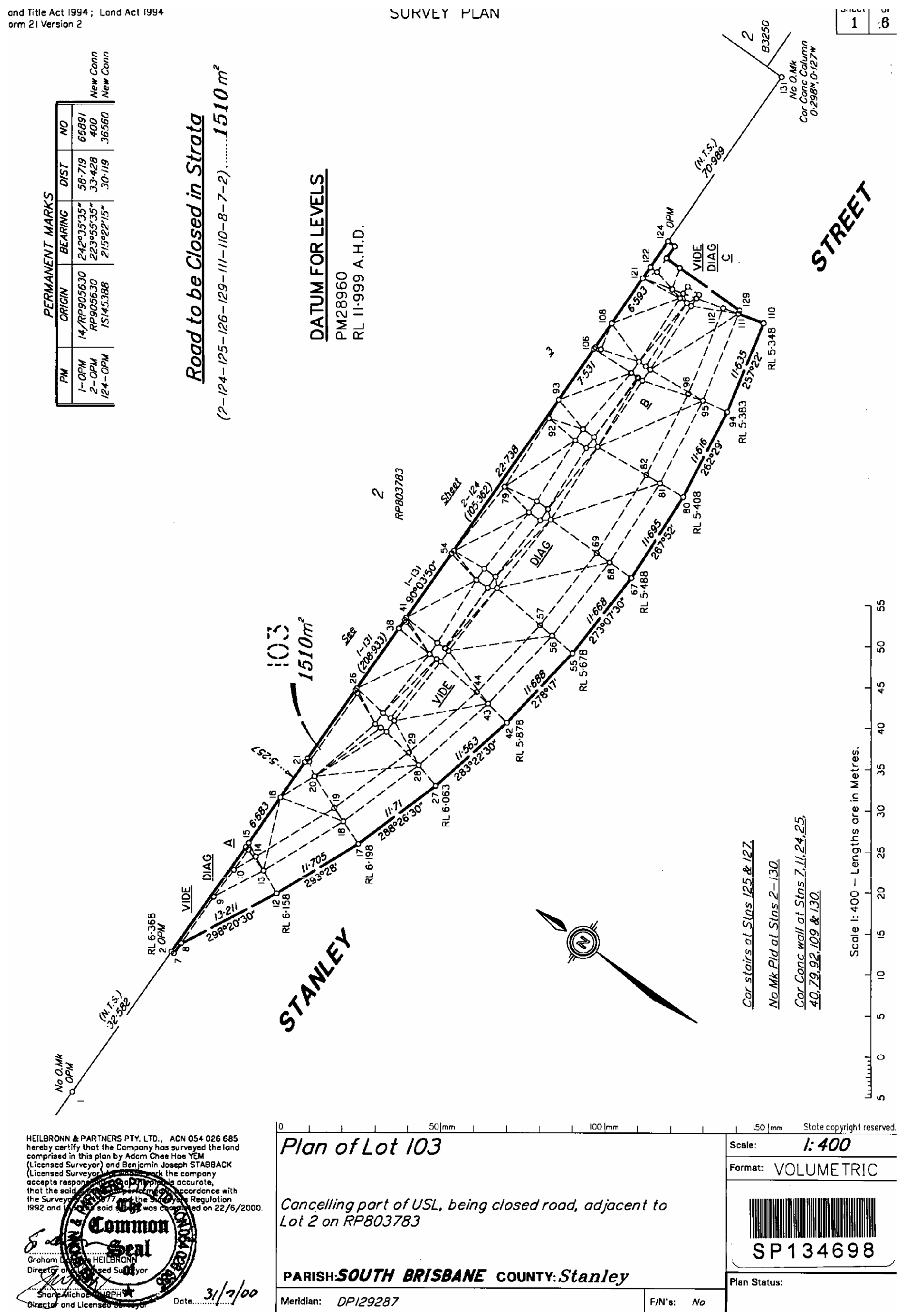


Figure 5-13: SP134698 creating one of the volumetric lots

(Source: DNRM QLD)

<u>Plan of Survey</u>

Four volumetric lots overhanging the Vulture Street and Stanley Street, two on each street have been created to facilitate the construction of the grandstands, namely:

- Vulture Street – Lot 100 on Plan CP900152 (Mar 1996), Lot 101 on Plan SP120175 (July 1999); and
- Stanley Street – Lot 103 on Plan SP134698 (July 2000), Lot 104 on Plan SP179933 (Oct 2005).

Prior to 1997, plans of various types were created; for example a registered plan (RP) dealing with private land, crown plan (CP) dealing with state land. However, after 1997, all plans were registered as surveyed plans (SP). According to Section 10.2.2 of the Registrar of Titles Direction for the Preparation of Plans (2008), volumetric lots created in volumetric plans define lots or parcels that:

- are fully enclosed by bounding surfaces, which may or may not be vertical or horizontal;
- have all bounding surfaces, either vertical or horizontal capable of a precise mathematical definition; and
- are above, below or intersecting the surface of the ground.

The volumetric lots are surveyed by a combination of triangles and polygons to form a wire-frame figure, similar to a triangulated irregular network (TIN) where the topographic surface is represented using triangles. The advantage of using this method is that actual field data capture becomes relatively easy and planarity of individual triangle and polygon faces can be assured. The disadvantage is the difficulty in assuring that adjacent consecutive triangles or polygons form a coplanar 3D object. Furthermore, the introduction of a large number of edges and vertices creates additional problems in data validation and storage.

Registration of rights/tenure

The rights of use for the volumetric lots (Figure 5-14) are created by term lease. The term leases for Lot 100 and Lot 101 on Vulture Street were 30 year term leases beginning on 11/07/1997 and expiring on 10/07/2027. The term leases for Lot 103 and Lot 104 on Stanley Street were also 30 year term leases beginning on 21/12/2001 and expiring on 20/12/2031. The leases may be extended by the Minister in accordance with section 155 of Land Act (1994).

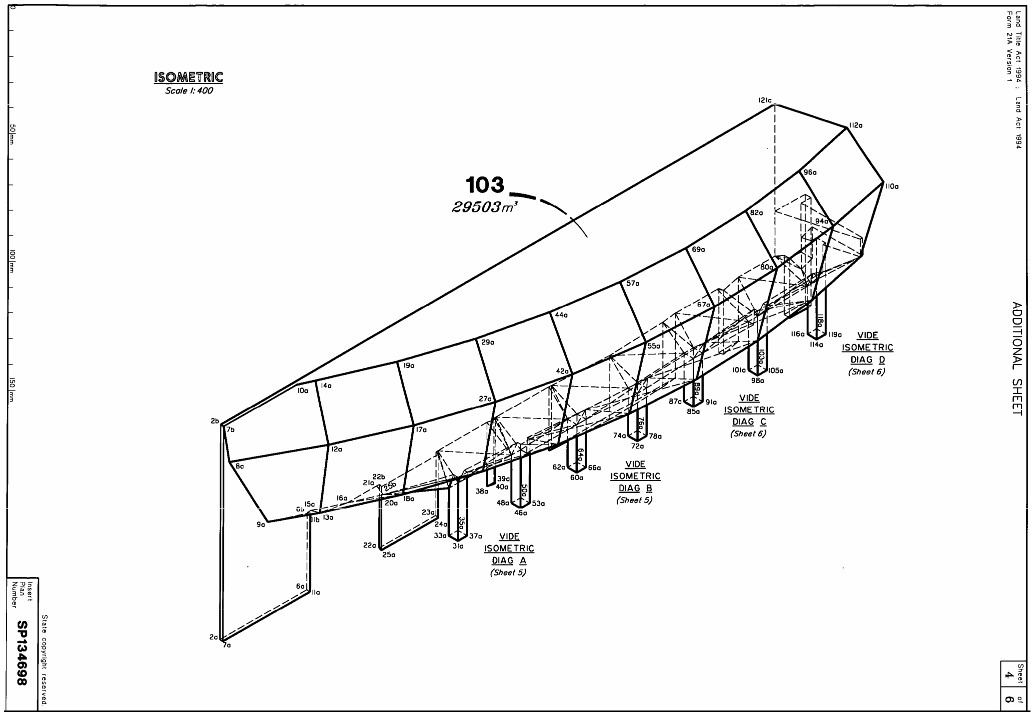


Figure 5-14: Isometric drawing of 103/SP134698 creating the volumetric lot

(Source: DNRM QLD)

A term lease is a tenure issued for a specific purpose, for a term of years, over state land in accordance with the Land Act. Under Section 15(2) of the Land Act (1994), the Minister may lease unallocated state land (USL), or land in a reserve, for a term of a number of years only. A term lease in strata is issued over an area above or below the land surface. Typically a lease in strata is issued for a structure that crosses an area of road for features or objects such as walkways, light rail lines, building encroachments into the road space, or for viaducts and tunnels below the road surface. The road area is permanently closed and a term lease is issued over the USL that is in strata. These are referred to as volumetric leases (SLAM 2011).

While creating the tenure for the volumetric lots, the rights in strata of the road have been restricted. For example, in Figure 5-13, the action statement on the body of the plan mentions "*Road to be Closed in Strata*" and gives exact station numbers and area to be affected by the closure.

The lease term of 30 years seems relatively short compared to the substantial investment in the stadium as well as the subsequent socio-economic improvements to the suburb and the city. In contrast, other lease arrangements exist in the Land Act

(1994) such as section 155 (2)(a) and (2)(c) which can provide a non-rural lease for 100 years in case of a significant development or a high level of investment.

Temporal aspects

Figure 5-15 illustrates the progression of the growth of the area surrounding Gabba Stadium over time. The change is presented as a mix of aerial photos and cadastral plans over a number of years. The DCDB of Queensland supports the storage of temporal data by creating and storing records in a separate history table.

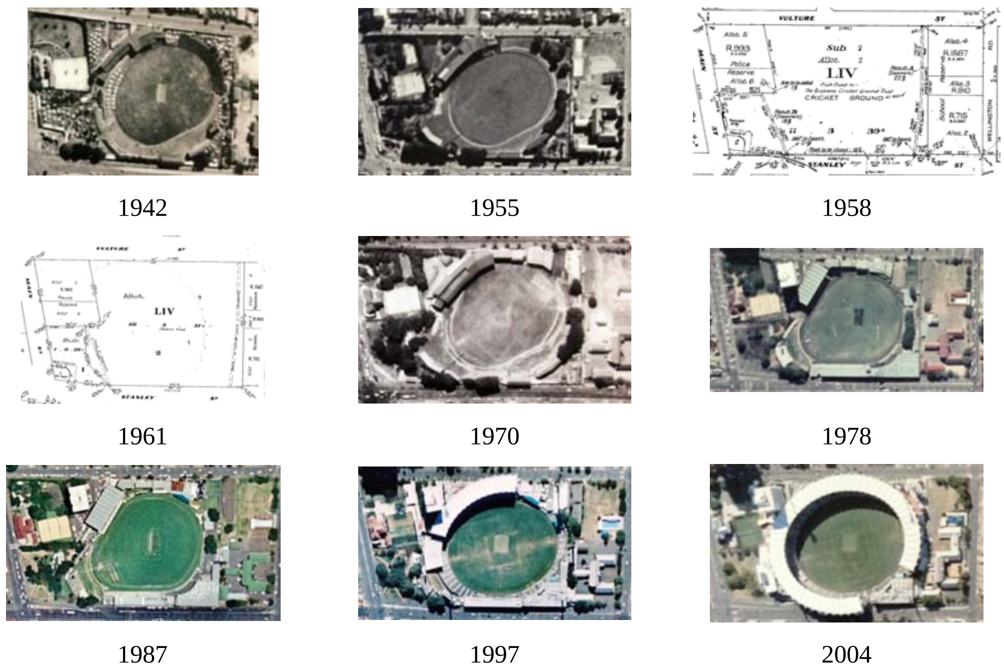


Figure 5-15: The progression of the Gabba Stadium over time

(Source: DNRM QLD)

Digital Cadastral Database (DCDB)

Figure 5-16 illustrates the DCDB view of the location of the Gabba Stadium and the volumetric lots over the streets. Lots 100 and 101 overhang Vulture Street while lots 103 and 104 overhang Stanley Street. The stadium is built on Lot 2/RP803783. No 3D data is stored in the DCDB for these survey plans, except the 2D outlines.

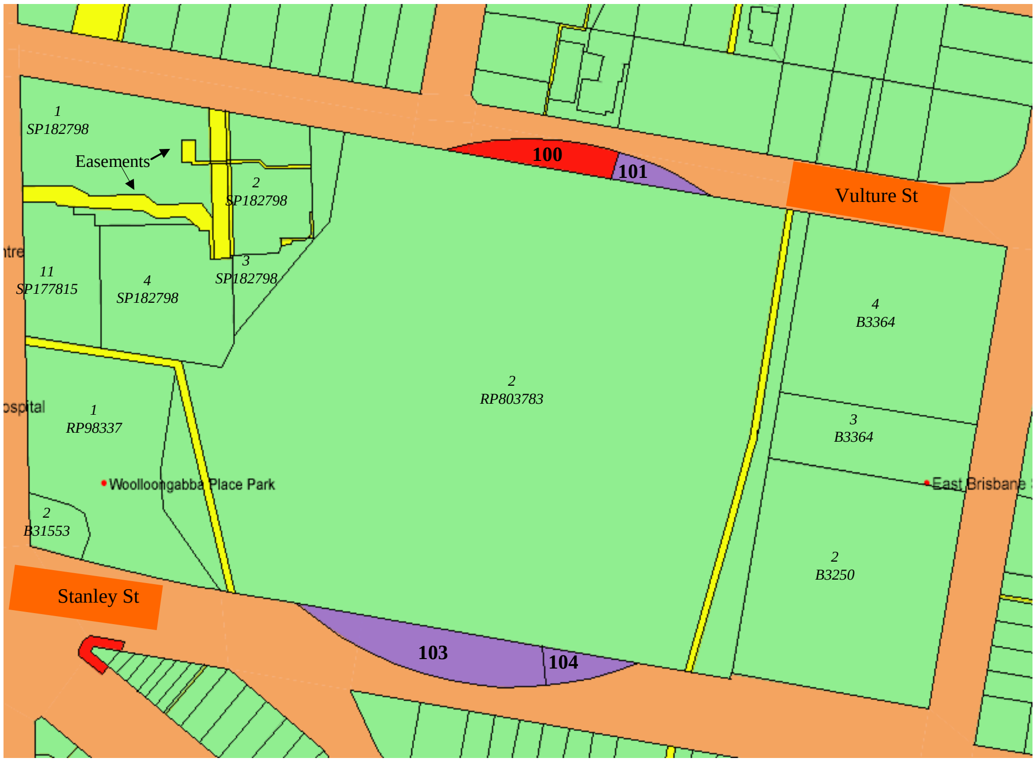


Figure 5-16: SmartMap view of the DCDB over the Gabba Stadium and surroundings

(Source: DNRM QLD)

5.3.2 Volumetric Network Parcels

<u>Infrastructure Network</u>

Woolloongabba Busway: The Woolloongabba busway is located on the site of an old railway shunting station that was used to supply coal to steamships on the Brisbane River. Due to its central location it was converted to a busway in the late 1970s and tunnels were created in some sections leading to South Brisbane in the early 2000s. It has become a major hub in the transport infrastructure south of the Brisbane River, and almost every bus travelling to the south and south-east of Brisbane travels through Woolloongabba. The Woolloongabba Busway is constructed parallel to Stanley Street between Main Street and Leopard Street and is at a lower level than Stanley St and Leopard St (Figure 5-17 and Figure 5-18).

Clem 7 Tunnel: The 6.8 km Clem 7 tunnel is one of the largest infrastructure projects to be completed in Queensland (www.clem7.com.au). The actual construction work began in 2007 and was opened to the public in March 2010. It passes underneath

Woolloongabba and the Brisbane River, where two of the case studies in this chapter are discussed.

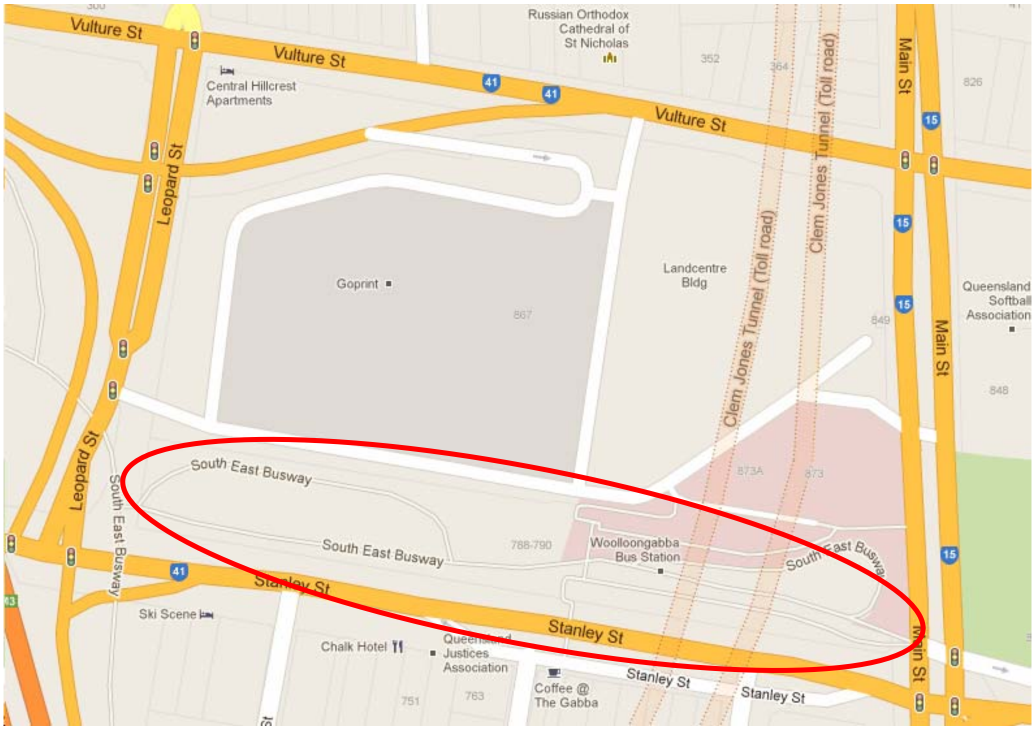


Figure 5-17: Google Maps view of the location of the Busway and the Tunnel

Figure 5-18: Google Street view from Main Street of the volumetric lots

<u>Plan of Survey of Busway</u>

Volumetric lots have been created to provide access rights for the buses in the busway. As intended, this created an exclusive space which is now being used by Translink buses and its repair vehicles only. The volumetric parcel, Lot 4/SP149278, is situated within the standard format base Lot 3/SP149278, but it does not excise the area of the standard format lot nor restrict the future volumetric rights of the remaining areas of the base lot.

Further, the lot is not of uniform height but fluctuates between RL 22m at the highest point, to RL 20 and RL 12 metres at the middle region to RL 1.0 at the lowest level with ground levels shown at vertices of the volumetric parcel on Sheet 2 and 3 of the survey plan SP149276 (Figure 5-19). The plan is prepared according to Section 10 of Registrar of Titles Direction for Preparation of Plans (2008) and includes graphical representations such as, isometric views, ground levels, dashed line lot representation and numbering, and a table of heights.

The volumetric lot for the busway was created on the 16th September 2002 from Lot1/SP149276 into Lot 3 and Lot 4 on SP149278. Lot 3 has an area of 1.183 hectares. It remained the standard lot from which Lot 4, the volumetric lot with a footprint area of 6502 m^2, was created. The height of the volumetric parcel ranged from RL 1.0m to RL 22m. The standard two-dimensional lot was first sub-divided on 14th June 2002 through survey plan number SP149276 and the busway was created on Lot 1.

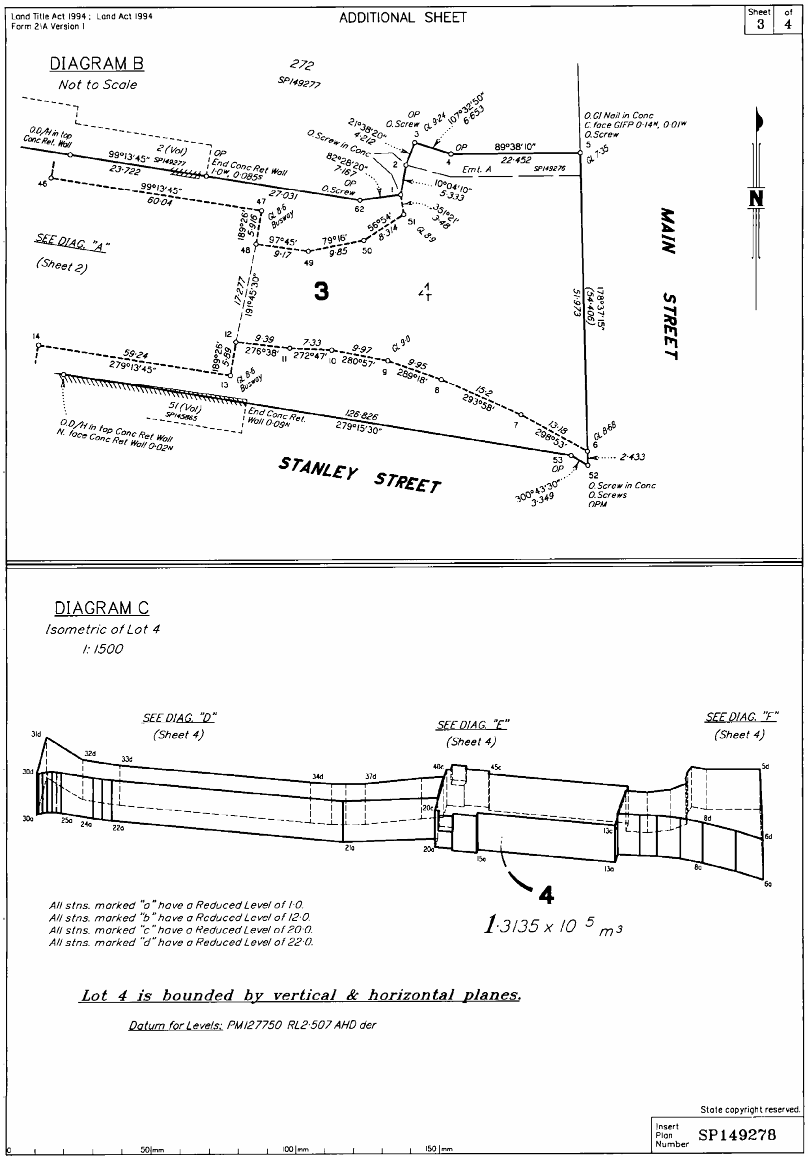


Figure 5-19: Volumetric Lot 4 on SP149278 (Top) and its isometric view (Bottom)

(Source: DNRM QLD)

<u>Plan of Survey of Tunnel</u>

Individual volumetric lots were created for each base parcel that the tunnel crosses. Volumetric Lot 160/SP184385 was created approximately five metres below the volumetric lot of the Woolloongabba busway. It covers the entire north-south width of the standard lot unlike the busway lot which was created inside the boundary lot leaving some space on all sides. As the tunnel is a linear network feature, it extends beyond the particular base parcel. The plan creating the volumetric parcel for the Clem 7 Tunnel at the intersection with Lot 3 and 4 of SP149278 was created on the

19th October 2006. It created two Lots, 60 and 160/SP184385 on the old Lot 3/SP149278 (Figure 5-20). Lot 60 is the old Lot 3 and Lot 160 is the volumetric lot created for the tunnel. The footprint of the tunnel volumetric lot is 1420 m^2 extending from a reduced level of around -3.3 m to -21.3m. The base of the lot slants slightly to the eastern side, the walls were created vertical, but the top as well as the bottom bound of the lot varies in height.

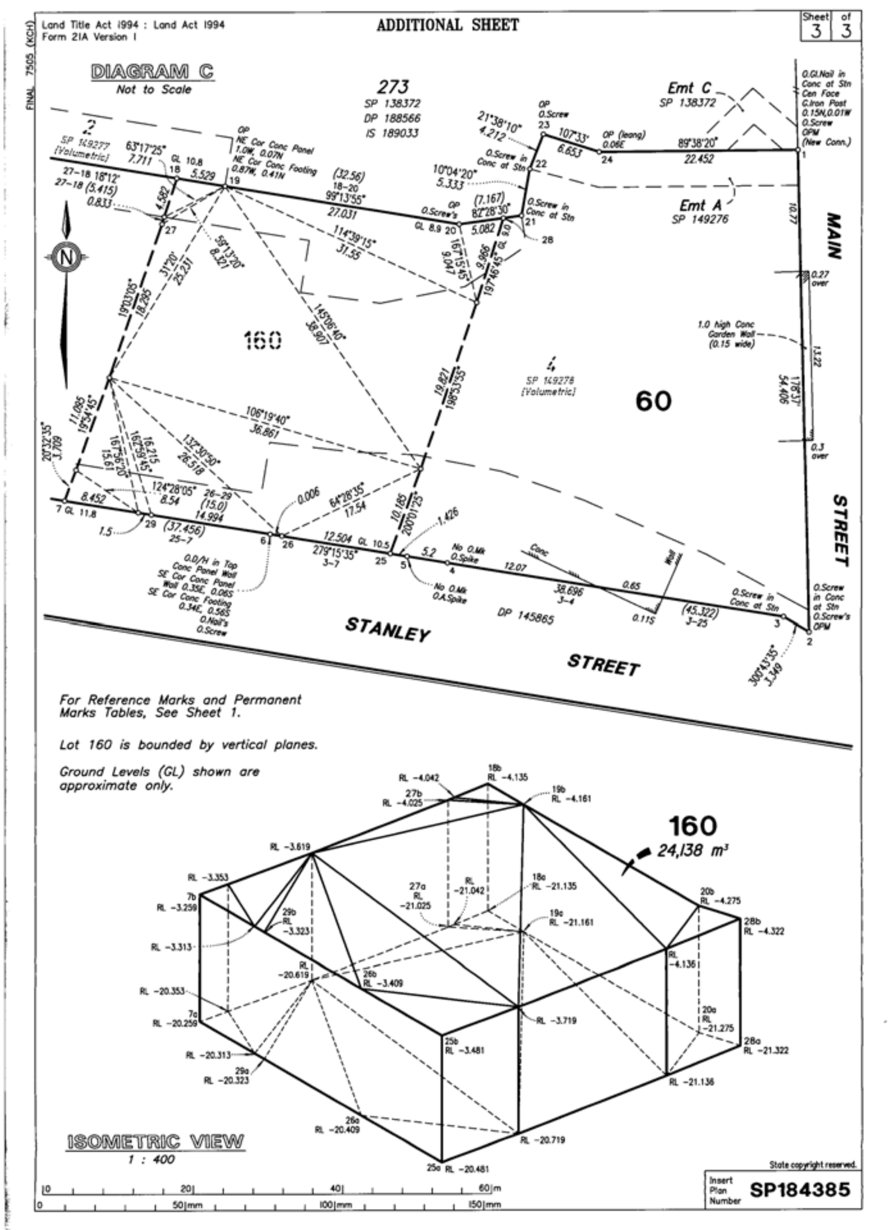


Figure 5-20: Volumetric Lot 160/SP184385 of Clem 7 tunnel underneath the busway

(Source: DNRM QLD)

<u>Registration of rights/tenure (Busway)</u>

Busway – The title of the lots is Estate in Fee Simple (freehold title) and the registered owner for the volumetric lot as shown in Title Reference number 50620709 is the State of Queensland represented by the Department of Transport and Main Roads. The lot is encumbered with easement A/SP149276 and is benefited by easement C/SP138372.

Tunnel – A perpetual lease with Tenure Reference number PPL 0/234528 and Title Reference 40061246 has been created for the tunnel volumetric lots along the Clem 7 tunnel commencing on 29/10/2010. This is administered by Land Act 1994 and the tenure is registered to the State of Queensland represented by the Department of Transport and Main Roads.

<u>Temporal Aspects</u>

Figure 5-21 shows the changes in the area surrounding the busway as well as the tunnel. As mentioned in Section 5.3.1, plan data is stored in the DCDB whereas images can be viewed from the image library of DNRM.

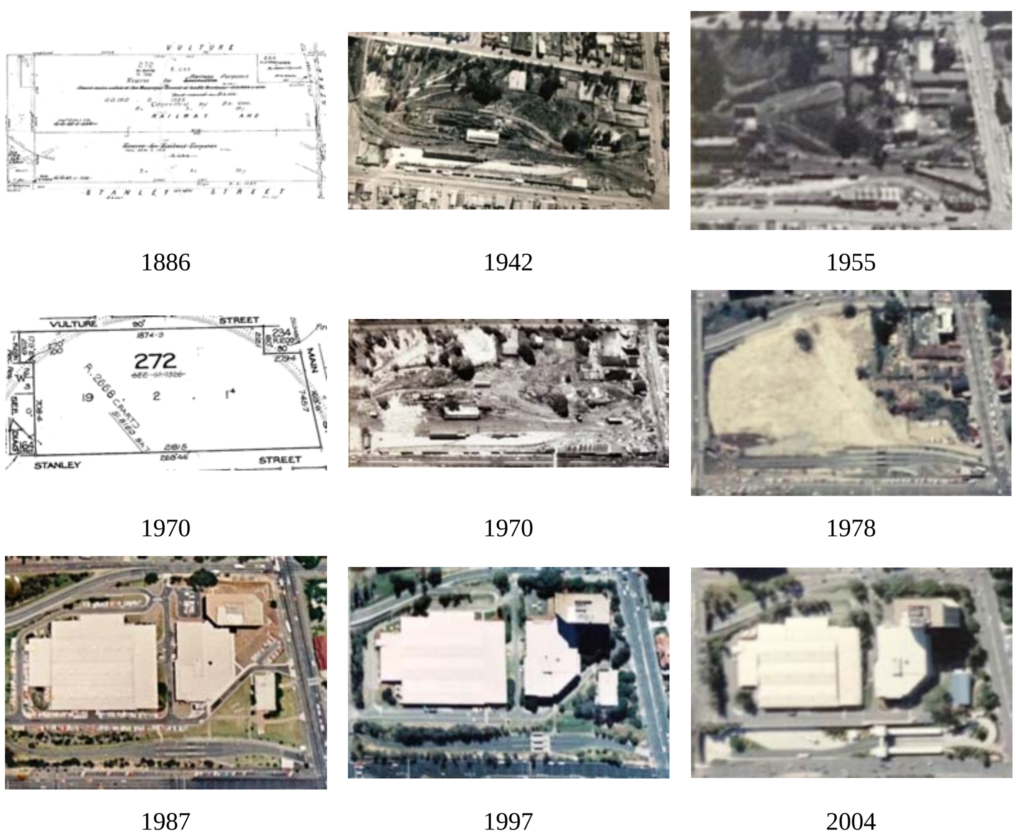


Figure 5-21: Changes to the Woolloongabba busway over time

Digital Cadastral Database (DCDB)

The digital cadastral database (DCDB) of Queensland can store spatial 2D data and stores the standard lots as base lots and the outline of the volumetric lots in a different level. The volumetric lots as illustrated in Figure 5-22 are represented in the SmartMap in a different colour thus demonstrating that the database recognises the difference between 2D and 3D data, which in turn imposes differing validation requirements.

Figure 5-22: SmartMap view of the DCDB of the two volumetric lots

(Source: DNRM QLD)

5.3.3 Volumetric Ambulatory Boundary

General 3D situation

In Queensland, tidal watercourse boundaries and non-tidal watercourse boundaries such as lakes and riparian boundaries are called ambulatory boundaries because their boundaries can ambulate or change over a period of time. Ambulatory boundaries with 2D cadastral content in riparian or marine boundaries are common. However, this case discusses a 3D ambulatory boundary which has been created by following the 2D riparian boundary to the vertical extents of the tunnel that intersects the Brisbane River at Kangaroo Point in Brisbane (Figure 5-23).

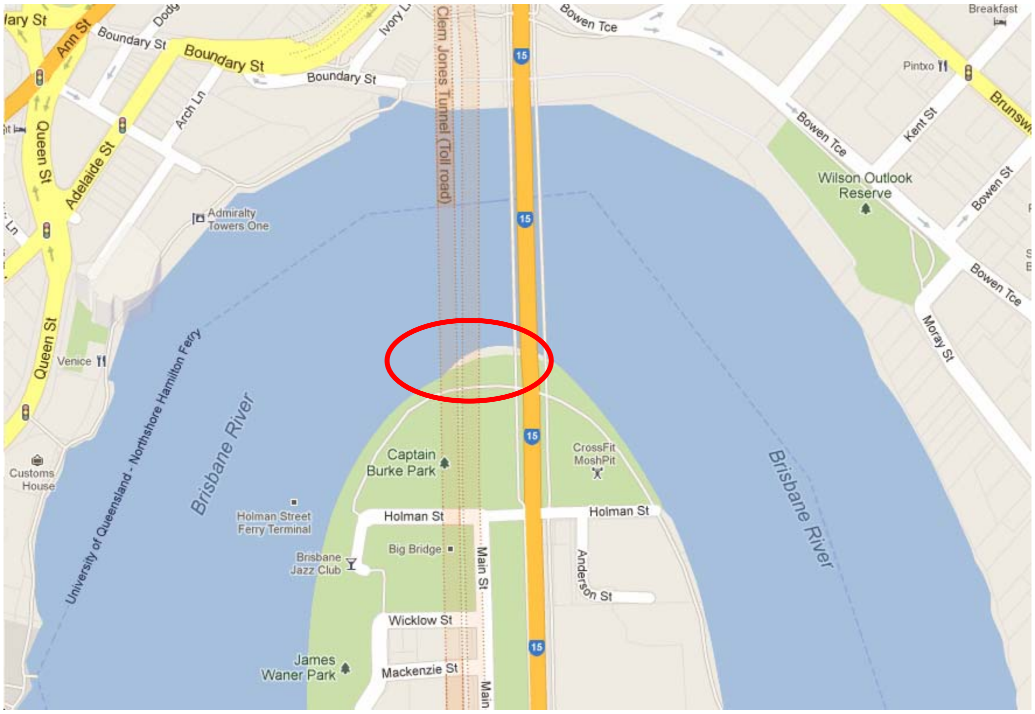


Figure 5-23: Google Map location of the volumetric ambulatory boundary

The volumetric ambulatory boundary was created as volumetric Lot 837 on SP192733 within the standard format lot 259 on 10th November 2006. Individual volumetric lots were created where it intersects base lots, and because the tunnel continues to the other side of the river, therefore in addition to this plan, there is one volumetric ambulatory lot underneath the river (SP190809) and one on the other side of the river (SP211459).

<u>Infrastructure/Utility Networks</u>

As the original standard lot was bounded by a riparian boundary, the subsequent volumetric lot was created as bounded by the same riparian boundary. Riparian boundaries are defined and administered by Part 7 section 63(1) of the Surveying and Mapping Infrastructure Act 2003. Sheet 3 of 5 on SP192733 contains the table of measurements between stations C and D where the spline curve is fitted to create the riparian boundary.

<u>Plan of Survey</u>

The part of the volume of Lot 837/SP192733, which is not the riparian boundary, is constructed with vertical faces on the sides and triangulated top and bottom of the bounded volume (Figure 5-24). The volume exists between an approximate RL of -34m to RL around -55m relative to the Australian Height Datum (AHD).

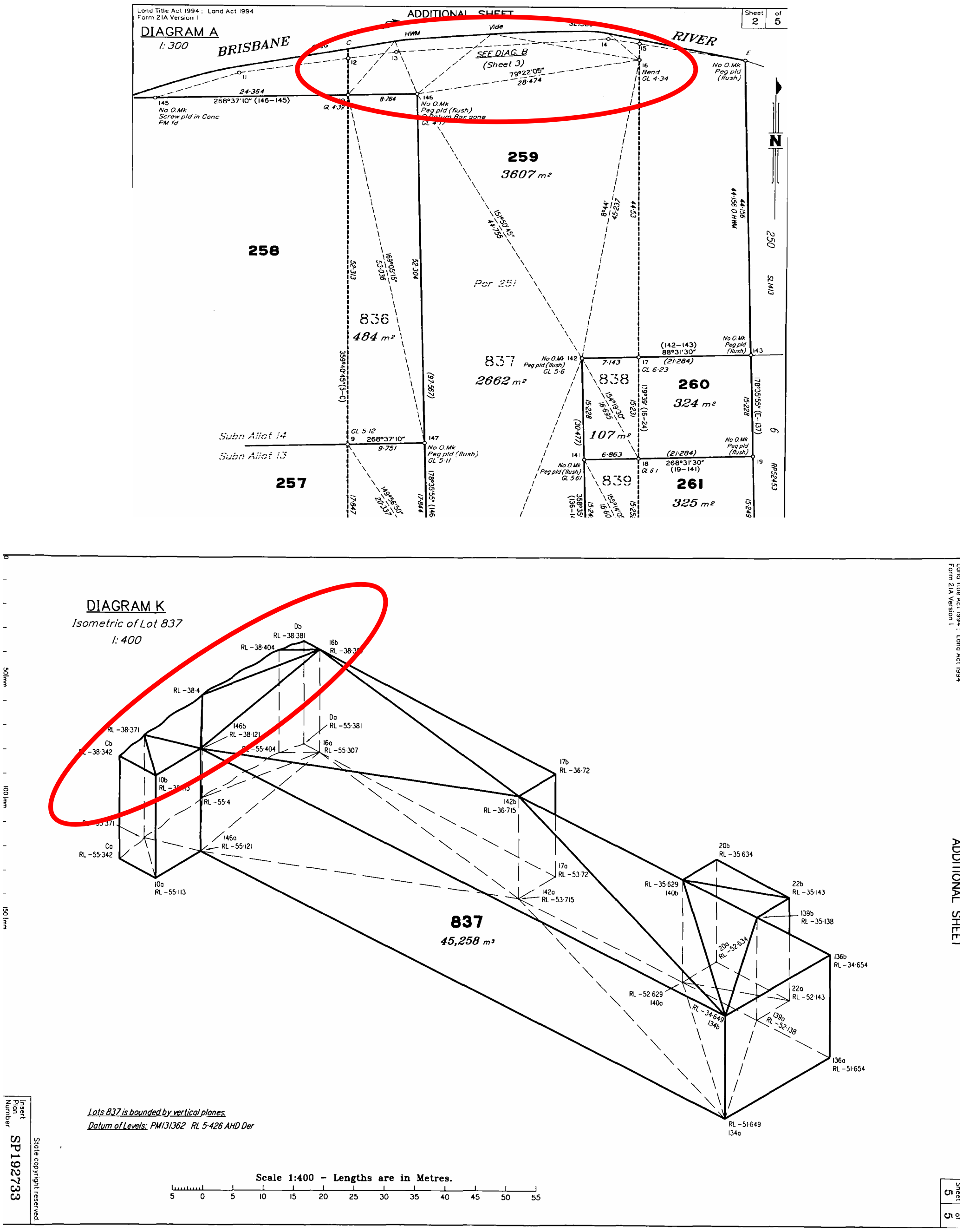


Figure 5-24: (Top) Plan showing the original 2D ambulatory boundary and, (Bottom) Isometric drawing of the same volumetric ambulatory parcel

(Source: DNRM QLD)

Registration of rights/tenure

The title for the standard Lot 259 is Estate in Fee Simple (freehold land) whereas the tenure for the volumetric Lot 837 is created as a perpetual lease for the whole of the Clem 7 tunnel (Tenure Reference number PPL 0/234528). As in the previous case, mixed private and public rights have been registered in strata. The standard lot is registered as a freehold, whereas the volumetric lot has a registered tenure to the State Government. In SP211459, the tunnel volumetric lot is created underneath the river and the surface parcel exists as unallocated state land in the cadastre.

Digital Cadastral Database (DCDB)

As with the previous two cases, since the DCDB does not yet support 3D data, the volumetric parcel is stored as a 2D footprint only, on a different layer to the base lot (Figure 5-25).

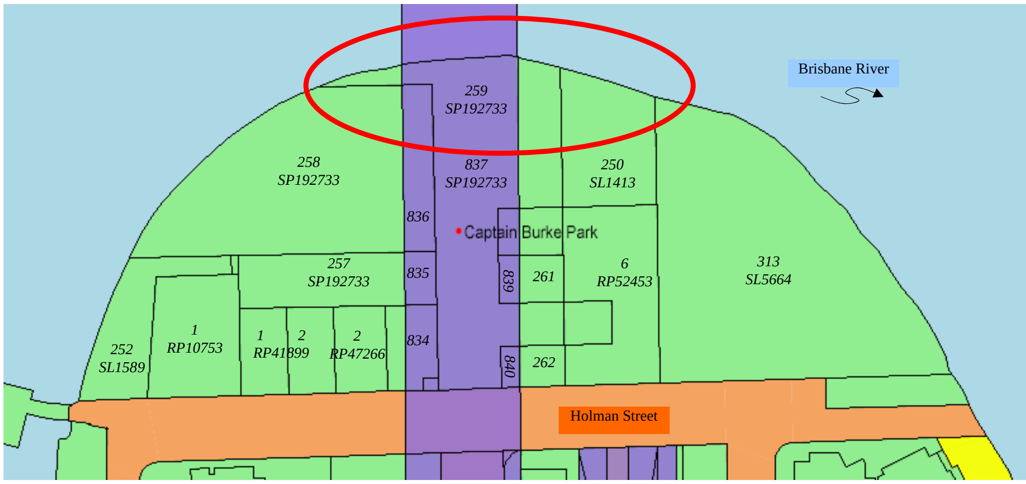


Figure 5-25: SmartMap view of the DCDB of the ambulatory volumetric lot

(Source: DNRM QLD)

5.3.4 Volumetric Doughnut

General 3D situation

This case is on Morala Avenue, Gold Coast (Figure 5-26 and Figure 5-27) and it presents two independent unique features: (a) it registers airspace without the feature being constructed, and (b) it registers geometrically unique figures resembling a doughnut or a torus. In a 3D database, this would be difficult to store, manipulate and validate, however, in the present 2D cadastral database, the volumes have been registered individually and the outline of the volumes stored in the DCDB as concentric circular shapes.

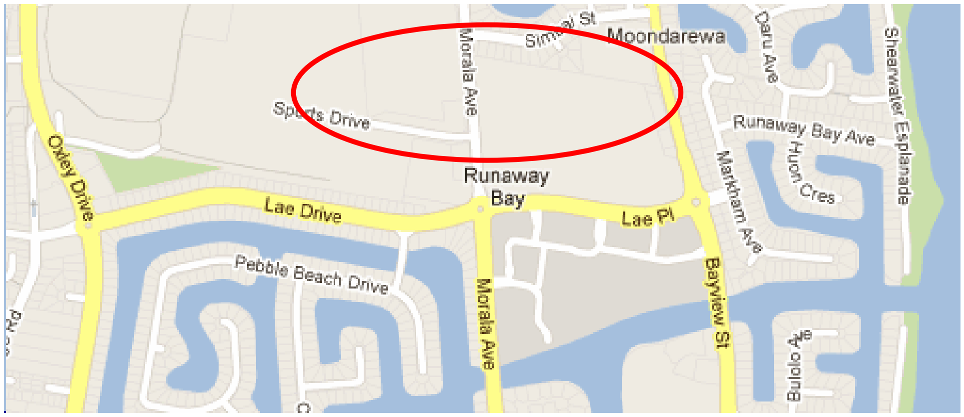


Figure 5-26: Google Maps view of the location of the case

Figure 5-27: Google Street View of the pole on Morala Avenue

<u>Plan of Survey</u>

Three concentric hollow cylindrical volumes were created on SP116505 to enable the construction of a Telstra telecommunications active repeater facility on Morala Avenue, Gold Coast (Figure 5-27). The standard format Lot 4 and volumetric lots 1, 2 and 3 on SP116505 was created on 3rd December 1998.

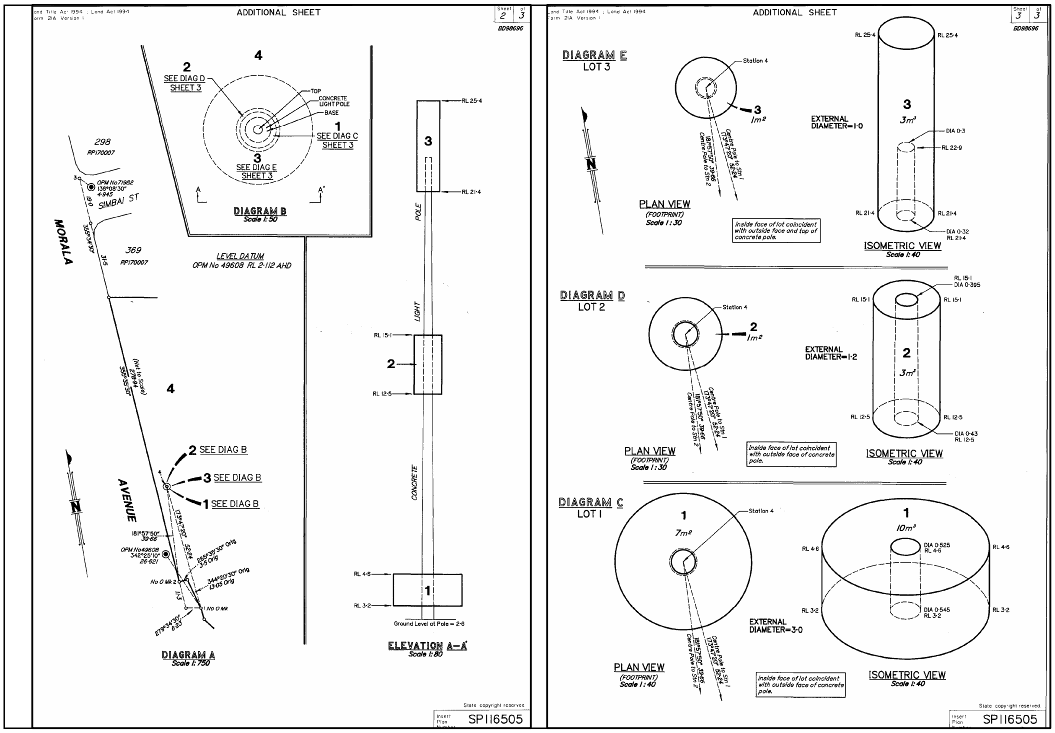


Figure 5-28: (Left) Plan showing the three volumetric lots and their relative vertical position, (Right) Isometric drawings of the three lots

(Source: DNRM QLD)

Figure 5-28 (left) shows the relative positions in the vertical space of the three lots. Figure 5-27 shows that the pole itself is created as a slender tapered concrete structure without the bulges as shown at different levels on Figure 5-28. Statements on Sheet 3 of 3 on SP116505 (Figure 5-28 Right) demonstrate that the actual pillar is constructed at the interior faces of the three figures. Thus, the three volumetric lots seem to be constructed to protect the space for securing access rights until actual construction can take place, or for securing permissions for construction.

Registration of rights/tenure

The title for the volumetric lots is created as a term lease of 20 years expiring on 28/02/2019 to Telstra Corporation for the exclusive purpose of constructing a telecommunications repeater facility. The lessee can not use it for any other purpose and has an obligation to maintain it as detailed in the lease. The base parcel is leased to several sports facilities for varying periods.

Digital Cadastral Database (DCDB)

The outlines of the three volumetric lots are stored in the DCDB in different layers to the base lot (Figure 5-29). If the DCDB could store 3D data, it would be difficult to geometrically store and represent this volumetric lot in the database. As identified, there is a hole in the middle in the bottom two figures of Figure 5-28 (Right) and a partial conical hole in the middle of the top cylinder of Figure 5-28 (Right) where the supporting pole tapers. There is also a problem of referencing the cylinders to the centre where the position of the centre is unknown. The concentric circular outline would create an additional problem in 3D data storage as they spatially encroach upon each other in 2D and would trigger validation errors in databases; however this can be overcome by storing them in different layers or running validation rules specifically designed for such cases.

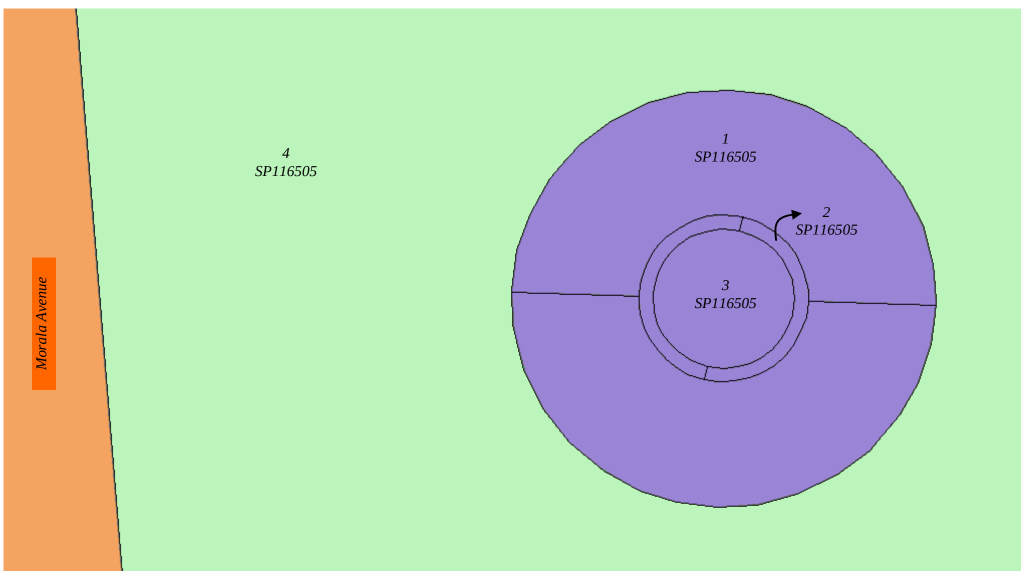


Figure 5-29: SmartMap view of the data stored in the DCDB of the three volumetric lots

5.3.5 Volumetric Road

General 3D situation

In the previous section, air space was registered for a feature to be constructed in the future. In this case, air space is registered for a road parcel that is unlikely to be built as it is along the face of the Meriton-Soleil building starting at level F (Figure 5-31 right), whereas the ground level is two storeys below at the base of level D (Figure 5-33a).

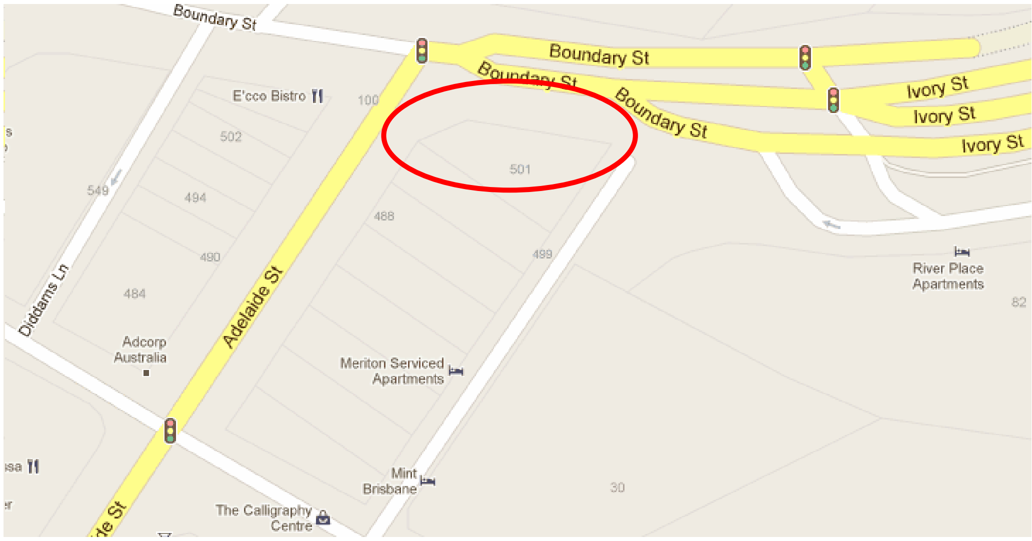


Figure 5-30: Google Map view of the location of the volumetric road in Brisbane

The road parcel is taller than the 76 storey building and fronts Boundary Road at the intersection of Adelaide Street and Boundary Road in Brisbane City (Figure 5-30). The top of the road parcel has a reduced level of 250.5m, while the tallest point in the building is 242.575m (sheet 39 of SP217742).

<u>Building Units</u>

The plan SP217742 that creates the volumetric road is a volumetric format plan (VFP) while the plan SP217743 that created the building units as shown in Figure 5-33c is a building format plan (BFP).

<u>Plan of Survey</u>

The volumetric parcel for the road is created in the volumetric format plan (VFP) SP217742 (Figure 5-31). The building units are created in the building format plan (BFP) SP217743 (Figure 5-32) and other similar plans.

<u>Registration of rights/tenure</u>

The base lot is registered as Estate in Fee Simple (freehold title) with title reference number 50861048. The building has registered building units (Figure 5-33c) and is governed by the Body Corporate and Community Management Act (1997).

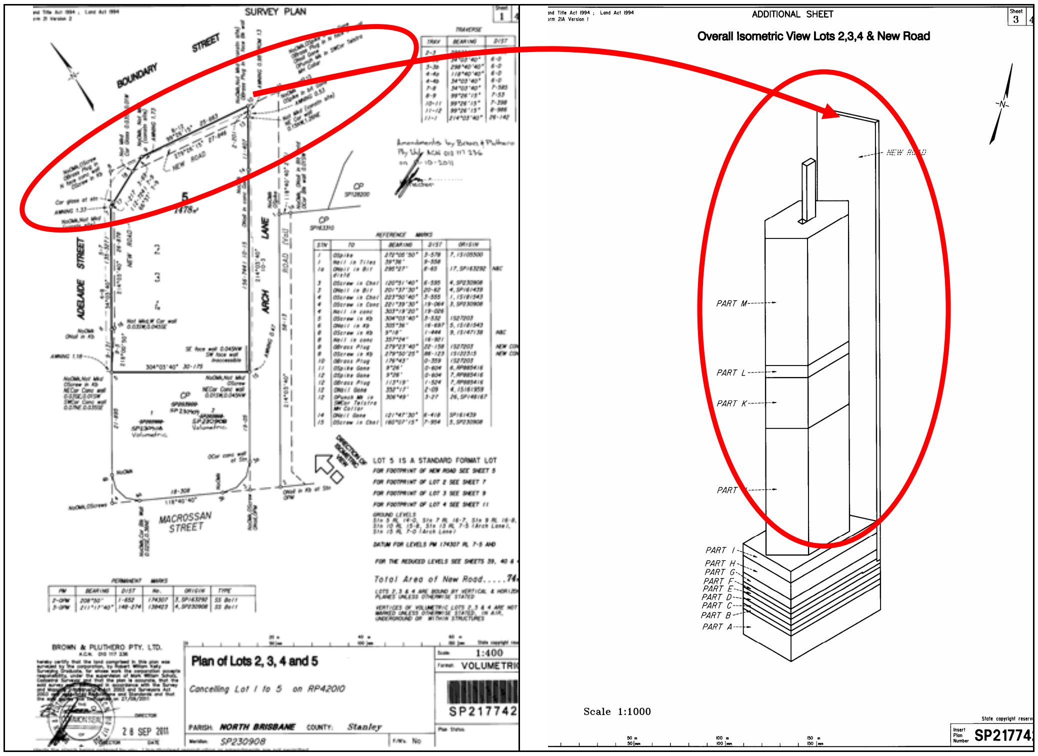


Figure 5-31: (Left) Volumetric road footprint and (Right) isometric view

(Source: DNRM QLD)

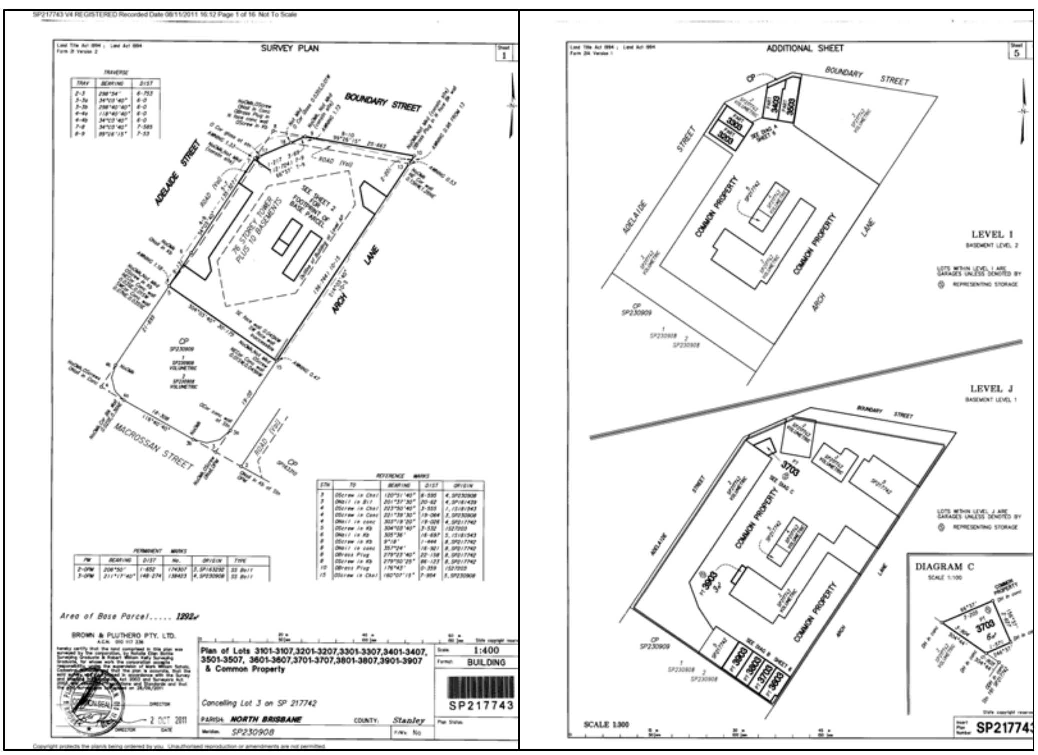
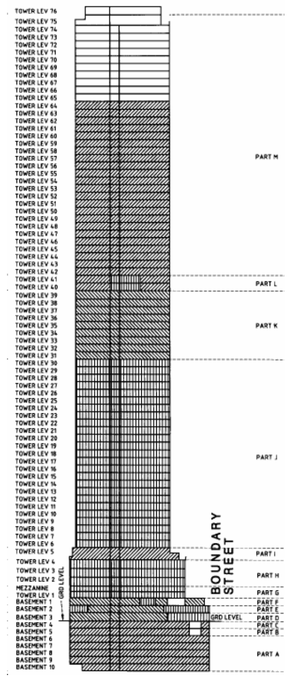
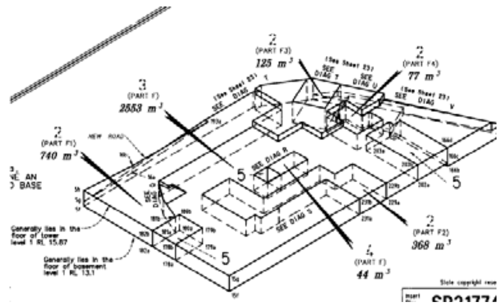


Figure 5-32: (Left) Building format plan, and (Right) Example of layout of units and common property in a level

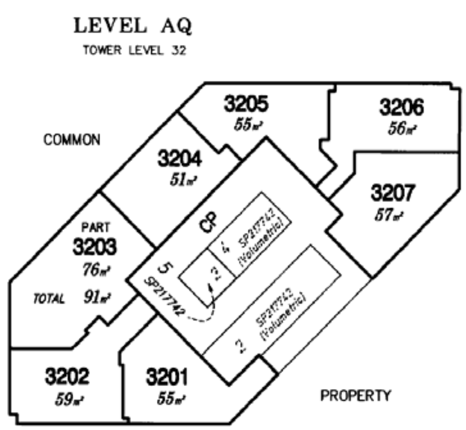
(Source: DNRM QLD)



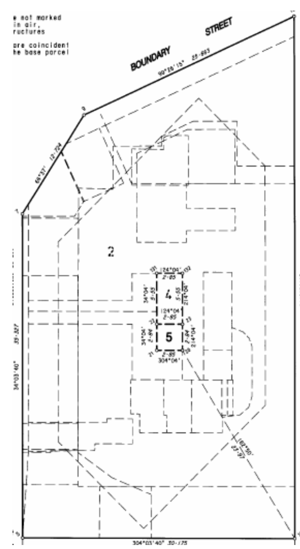
(a) Lateral view (VFP)



(b) Isometric view of each level (VFP)



(c) Building unit footprints for each level(BFP)



(d) Outline of building footprint (VFP)

Figure 5-33: Building Format Plan example with different views and footprint information

(Source: DNRM QLD)

<u>DCDB</u>

As in the other cases the DCDB stores the outline of the footprints of the volumetric lots and the building footprint lot at ground level in separate layers than the base lot (Figure 5-34). The DCDB does not store the geometry for each of the building units in a building, but stores the attribute information tied to the standard 2D lot.

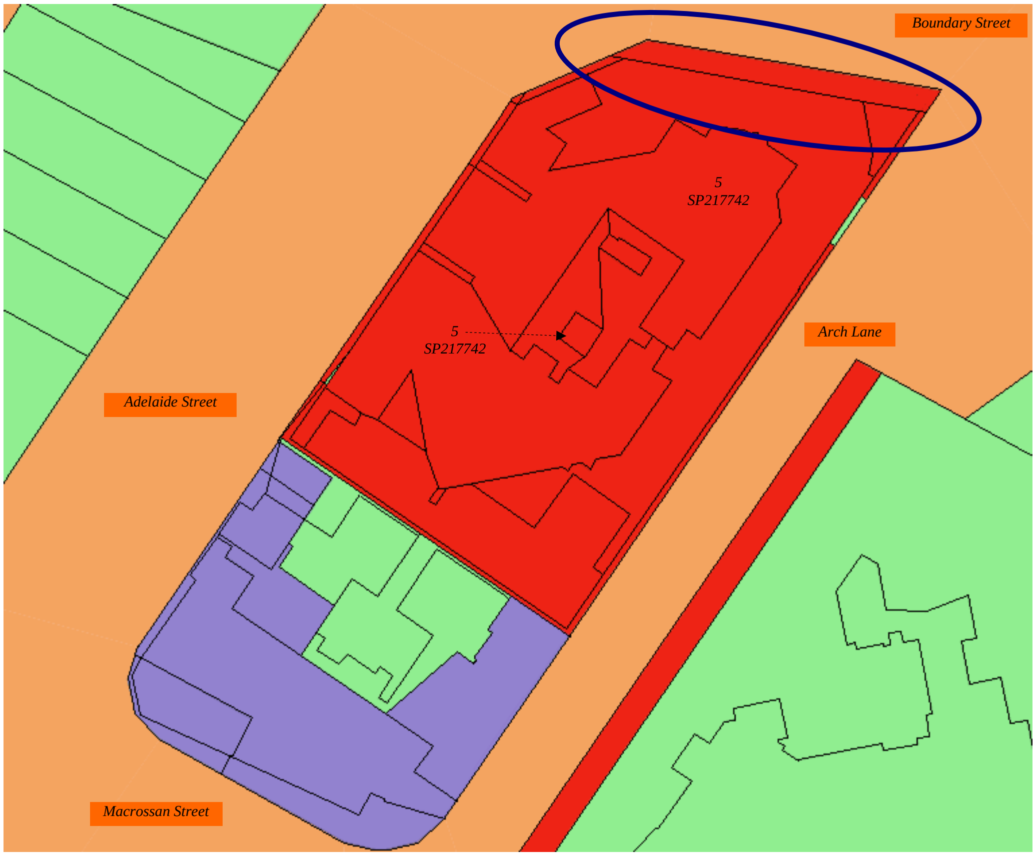


Figure 5-34: SmartMap view of the DCDB for the volumetric road

(Source: DNRM QLD)

5.4 CONCLUSION

This chapter presented the results of the case study of the cadastral jurisdictions of Queensland. The case studies reveal a high degree of variation and complexity in the development and application of 3D cadastre. The legislative framework in the cadastral jurisdictions of Queensland is supportive of 3D cadastre. The registration of 3D titles is dealt with in a similar manner as 2D, which has created an opportunity for a natural progression from 2D to 3D cadastre.

Registration of rights/tenure has often become more complex in the way they are addressed and multi-level rights can co-exist with 2D rights. Multiple processes and functions are adopted to ensure the registration of rights is logical; for example, in the volumetric encroachment case in the Gabba Stadium, the road is considered a cadastral parcel, closed volumetrically and a lease created.

Discussions on the specific construction of complex 3D parcels identified the characteristics of 3D cadastre implementation in Queensland. The cadastral database is capable of storing 2D spatial data and does not store 3D data in the spatial database. There is no automated process for the digital lodgement of 3D data, and automated validation of the geometry of this data continues to be problematic.

The next chapter is the discussion, which brings together the information in Chapters Four and Five. It highlights the findings of these two chapters, identifies common issues, and proposes a number of possible institutional and technical strategies for improving future 3D cadastre implementation.

CHAPTER 6

DISCUSSION

6.1 INTRODUCTION

In Chapter Four, results from the survey of cadastral jurisdictions across Australia were analysed and in Chapter Five, a case study analysis was performed for selected cases in Queensland. This chapter summarises the findings of the two previous chapters and integrates the results to identify key issues in the implementation of 3D cadastre. Based on these, future implementation strategies are developed for 3D cadastre.

6.2 SUMMARY OF FINDINGS

6.2.1 Summary of Questionnaire Study

The aim of the survey of all cadastral jurisdictions of Australia was to explore the status of 3D cadastre in the national context. It further provided a means to gain an understanding of the various institutional and technical issues relating to 3D cadastre which were common to all jurisdictions.

In the cadastral jurisdictions of Australia, 3D cadastre is supported by existing legislation which allows the creation and registration of 3D objects in the cadastre. Most states have adopted a strategy where 3D parcels remain constrained within a 2D surface (base) parcel.

Most cadastral jurisdictions also allow natural ambulatory boundaries to be registered in the cadastre. However, the Australian Capital Territory (ACT) did not have examples of marine ambulatory boundaries as it is landlocked. All Australian jurisdictions allow the registration of 3D air-space, but some jurisdictions do not allow disconnected 3D multi-part parcels of a single lot to be registered in the cadastre.

All jurisdictions allow the creation of 3D curved surfaces provided the 3D shapes are able to be defined geometrically or mathematically. Network parcels can also be registered in the cadastre and are usually registered as volumetric parcels (QLD), easements (QLD, NSW) or as non-spatial registered easements (SA).

Building units or apartments are registered as individual properties in all jurisdictions of Australia and they are treated similar to 2D parcels for registration and transfer of rights. However, no jurisdiction stores 3D data spatially in their DCDB, and the ownership and other rights are stored as attributes attached to the base parcel in some jurisdictions. Common properties in individual blocks of units or apartments are managed by the Body Corporate or the Owners Corporation and may either be unallocated, unregistered space left between registered properties (ACT) or registered space owned by everyone in the unit block (all other jurisdictions).

Parcel boundaries are defined by bearing and distance and not by coordinates, but cadastral corners may be connected to permanent survey marks which may or may not contain horizontal coordinates as in Queensland. Volumetric plans or stratum plans show elevation information that are referenced to a permanent mark or benchmark based on the Australian Height Datum (AHD). Building format plans or strata plans do not show Z-coordinates in most of the states. There is no formal mechanism for the collection of temporal data, however versioning of the DCDB or registered timeshares, or ambulatory boundaries provided temporal data if needed. Also, since the cadastral database can store most parent-child parcel relationships, including transaction histories, these aspects of temporal data are stored automatically for future use.

The primary RRR issues that were of concern to QLD and ACT were to ensure the unique definition of 3D property rights. For NSW, the three major RRR issues included better representation of 3D RRR interests, asset relationship to 3D strata and 3D city modelling.

The software used in DCDB data updates were mostly a mix of proprietary software, open source or customised programs. However, none of the software and databases allowed the storage of 3D content. Plans containing 3D building content were called building format plans in Queensland and strata plans in other jurisdictions. Similarly, plans containing volumetric lots were called volumetric format plans in Queensland and stratum plans in other jurisdictions. In Queensland, isometric drawings are part of a volumetric format plan which is not a requirement in other jurisdictions.

6.2.2 Summary of Case Study

The aim of the case study was to undertake a detailed study in a single jurisdiction to identify specific issues and characteristics of 3D cadastre. A detailed analysis of the

3D cadastral implementation arrangements in Queensland provided a better understanding of the issues at an operational level.

From the legislation identified as supporting both 2D and 3D cadastre in Queensland, it was determined that the legal framework for cadastre in Queensland has created an environment where there is no difference from a titles registry point of view in the way 2D and 3D titles are created. The legislative framework has been supportive of the implementation of 3D cadastre as evidenced by specific legislation that allow 3D objects to be created as well as fostering a non-restrictive environment.

Documentation regarding policies, standards and guidelines demonstrate that the Queensland cadastre has an adequate policy framework for cadastre development. Comprehensive guidelines exist on how to prepare volumetric and building format plans, thus assisting field surveys of 3D information and to standardise plan preparation. There are very few restrictions on the kind of 3D objects that can be surveyed provided they fulfil the requirements of the Registrar of Titles Directions for the Preparation of Plans (2008).

Queensland cadastre supports and registers many different types of ownership and tenancy rights. All the tenure types registered in Queensland were identified together with an explanation of some of the regularly used tenure types. In this regard, 3D parcels are registered and treated similarly to a 2D parcel. Complexities exist in registering 3D parcels that continue beyond the extents of the 2D base parcel. Examples of current 3D implementation processes were discussed for representative cases. It was found that cadastre in Queensland allows complex 3D shapes to be created and registered in the cadastral system and even allows 3D airspaces to be registered.

In Queensland, the Department of Natural Resource and Mines (DNRM) acts as the custodian of cadastral data. As with most cadastral jurisdictions, there are inter-institutional and intra-institutional interactions for the completion of a cadastral transaction. The external institutional arrangement in a cadastral survey was discussed with the aid of a UML use case diagram. An explanation of the internal interactions during the life-cycle of a plan within the DNRM was provided to give a detailed picture of the internal and external institutional arrangements.

Cadastral data is stored in various databases identified during this life-cycle. Currently, the digital cadastral database of Queensland stores 2D spatial data only and when plans containing 3D content are lodged, the spatial content of the 3D parcel is stored as an outline in the database on a separate layer.

6.3 INTEGRATING THE RESULTS

Gable (1994) argues strongly in favour of combining research methods generally, and more specifically for combining qualitative and quantitative methods. This research uses a similar methodology and uses the case study to complement the survey of cadastral jurisdictions. The findings are integrated according to the mixed methods approach and the results interpreted and discussed as illustrated in Figure 6-1.

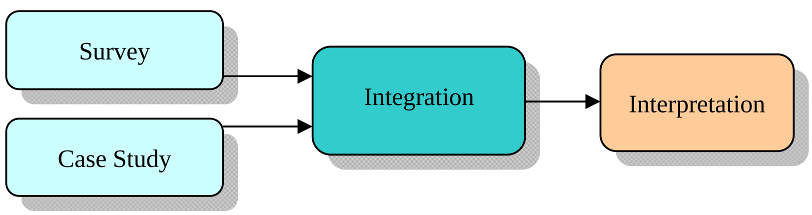


Figure 6-1: Integrating survey and case study

The survey of cadastral jurisdictions in Chapter Four provided an understanding of the status of 3D cadastre in all the states and territories of Australia. The data was analysed quantitatively and the findings were descriptive in nature. A complementary case study was performed in Chapter Five on selected representative cases in Queensland.

This research utilised a mixed method approach by combining the survey of all cadastral jurisdictions of Australia, which uncovered a wide spectrum of issues, with a case study that dealt with detailed issues for one particular jurisdiction. Based on the two complementary studies a number of issues relevant to the implementation of 3D cadastre were identified (Table 6-1).

Table 6-1: Identification of significant 3D cadastre issues and their source

Issues	Survey	Case Study
Generic and 3D specific legislation	☒	☒
3D data capture policy	☒	☒
Spatial referencing guidelines	☒	☒
Technical guidelines		☒
3D registrations	☒	☒
Mixed 2D/3D rights	☒	☒
3D parcel registration	☒	☒
3D parcel construction		☒
3D geometry validation		☒
3D data capture	☒	☒
3D data representation	☒	☒

The responses to the survey were a valuable source of information regarding the status of 3D cadastre in Australian jurisdictions. The case study provided an in-depth explorative analysis of the current implementation arrangements of 3D cadastre in Queensland. As expected, the case study identified issues at a greater level of detail than the survey.

The issues were classified into six classes: legislative support; policy and standards; operational arrangements; registration of rights / tenure; data geometry; and database representation. These classes were analysed in the case study in detail and most of the component issues were discussed in the analysis of survey results.

According to Williamson et al (2010), advanced Land Administration Systems are based on the following frameworks:

"***Juridical Framework****: the legal status of stratified properties and particularly the RRRs of their owners*

Cadastral Framework*: the capacity of the plans of the entity to be stored in and relates to other parcels in the land administration system, particularly the land survey system*

Technical Framework*: the system architecture (computer hardware, software, and data structures) supporting cadastral registration*"

In this research, the Juridical and Cadastral frameworks are combined into a single Institutional Environment to simplify the analysis in a technical and non-technical environment (Figure 6-2). A description of each of the six classes is discussed below.

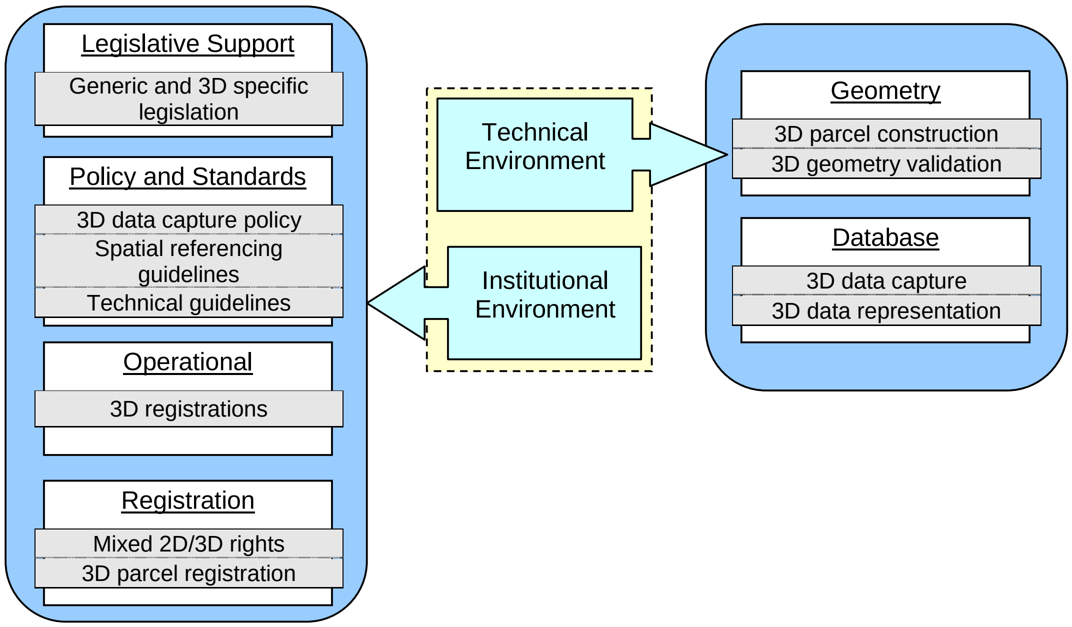


Figure 6-2: Classification of 3D cadastre issues

6.3.1 Legislative Support

Currently each cadastral jurisdiction in Australia has a generic legislative framework to support the existing cadastre. 3D cadastre has been supported within the same framework; however, there is no 3D specific legislation in any of the jurisdictions. In Queensland 3D parcels can be surveyed and paper plans prepared under the guidelines of the Registrar of Titles Directions for the Preparation of Plans (2008), while this can be registered under the current 2D specific Land Act (1994) for public land or the Land Title Act (1994) for freehold land. 3D cadastre can be implemented by the creation of a 3D parcel as well as registration of its rights. Creation of a 3D specific legislation will assist to guarantee the entitlements of a 3D title holder, protect their rights, create explicit rights, be acceptable as security for financial institutions, allow land transactions and subdivisions, avoid possible litigations, and as clarification for legal professionals.

6.3.2 Policy, Standards and Procedure

Policy and standards assist to regulate and clarify the legislative framework in a jurisdiction. Guidelines further assist to standardise the implementation of specific legislation and policies in a day to day operational environment. From the case study, guidelines for the implementation of general cadastre processes were identified in Queensland, while responses for the identification of similar documents in other jurisdictions were inconclusive. While 3D cadastre is being implemented within the current legislative framework, specific policies regarding 3D data capture and registration were limited and require further development.

6.3.3 Operational Arrangements

The operational arrangements and processes for registration of the existing 2D cadastral objects are identified and well defined in each jurisdiction. The current implementation of 3D cadastre occurs under the same operational arrangements. However, for the implementation of a full 3D cadastre, and with changes to the legislative and policy framework, the operational arrangements may need to adapt to provide more specific support required for 3D cadastral registration. For example, organisations may need to dedicate database resources, modify validation strategies and change business processes to accommodate 3D cadastral objects in the system.

6.3.4 Registration of Rights / Tenure

All jurisdictions allow the registration of 3D rights under the existing cadastral arrangements. However, 3D objects do not exist in their own right in the current cadastre and are tied to the base surface parcel for registration in the cadastral system. Building objects or volume objects should be able to be registered in the cadastre with a dedicated tenure type with storage of both spatial and non-spatial data in the database. As jurisdictions progress towards a full implementation there will be stages where mixed 2D and 3D rights co-exist. The 3D cadastral database should be able to handle a mixed 2D/3D implementation as well as a full 3D implementation.

6.3.5 Geometry

Cadastral jurisdictions of Australia represent 3D geometry on paper plans and store the outline of the 3D object in the cadastral database, but not the 3D geometrical object itself as the database is not 3D capable. Geometrical complexities are one of the major technical issues in the implementation of a 3D cadastre and include issues of 3D geometrical construction and validation. Existing implementations of 3D cadastre in Australia include the storage and representation of non-spatial building units and volume parcels in the cadastral database. This has created an environment where the cadastral system is supportive of 3D parcels until a full implementation of 3D cadastre can be realised. As a result of the supportive environment, complex 3D situations are constantly being encountered and represented in paper plans with titles support for registration of rights.

6.3.6 Data Capture and Representation

The existing digital cadastral databases in the various Australian jurisdictions are 2D databases. In a full 3D implementation, databases should be able to store 3D geometric data, perform database validations, 3D queries, 3D manipulations and 3D visualisation. A 3D database would also support application areas such as disaster management, 3D city modelling and 3D asset management.

6.4 IMPLEMENTATION STRATEGIES

In this section, possible strategies for the improvement of the on-going 3D cadastre implementation are suggested. These strategies are non-exhaustive and are representative of the possible approaches that are required to realise a full 3D cadastral implementation. Based on the discussions and identification of issues in Section 6.3, eleven issues in six classes were identified. Based on the issues identified, six implementation strategies are proposed (Table 6-2) and discussed below.

Table 6-2: 3D Cadastre implementation strategies

Class	Issues	Implementation Strategies
Legislative Support	Generic and 3D specific legislation	Legislative support for 3D cadastral objects
Policy, Procedure & Standard	3D data capture policy	Creating more comprehensive policy, standards and guidelines
	Spatial referencing guidelines	
	Technical guidelines	
Operational Arrangements	3D registrations	Build industry skills and capacity in 3D cadastre operations
Registration of Rights/ Tenure	Mixed 2D / 3D rights	Registration of 3D objects
	3D parcel registration	
Geometry	3D parcel construction	Research and implement a specific geometry
	3D geometry validation	
Data Capture & Representation	3D data capture	Build 3D capable database
	3D data representation	

6.4.1 Legislative Support for 3D Cadastral Objects

All Australian jurisdictions have generic legislation that allows 3D cadastral objects to be captured and registered in the cadastral system. While most of the suggestions below are currently being implemented in the existing cadastre, legislation that is specific to 3D needs to be formalised.

The legislation should specifically support the:

- Creation of 3D cadastral parcels;
- Registration and transfer of rights in 3D;
- Transaction of 3D cadastral objects such as subdivision and amalgamation; and
- Creation of secondary interests such as 3D leases, easements, covenants.

Formalised legislation creates a supportive environment for 3D data capture, protects the rights and interests of the title owners and reduces the risk of litigation. To achieve this, current legislation needs to be reviewed and based on the findings the legislative framework may require modification. However, changing the legislative framework is no trivial task, so a temporary alternative to the amendment of the existing legislative framework would be to modify the policies and standards by the relevant government authority to facilitate these suggestions.

6.4.2 Creating more comprehensive Policy, Standards and Guidelines

Policy documents and standards for 3D data capture are inconsistent and incomplete in all jurisdictions of Australia. Guidelines for 3D data capture exist in Queensland; however, the responses from the survey could not identify 3D specific policies in other cadastral jurisdictions. Policies and standards usually reflect the existing legislation and are often an expansion and explanation of the legislative requirements.

Directives and guidelines generally originate in the jurisdictional department coordinating the cadastral activities to provide more detailed operational support. These guidelines have the advantage of being accepted by the industry and gradually grow to be the current accepted practice.

In the absence of a legislative support, and as a stopgap measure while legislation is being developed, 3D cadastre can be supported through guidelines, standards or policies. Even when the legislative framework provides support for 3D cadastre, these policy documents provide the necessary level of clarity and operational instructions to be useful for the industry.

Policies, standards and guidelines are required in 3D cadastre for the following:

- As clarification of existing legislation, for example, how to capture a particular 3D situation;
- Explanation of various legislation for specific purposes so that all legal implications pertaining to a particular issue may be assessed quickly, for example, how to deal with a volumetric ambulatory boundary; and
- As technical advice, for example, how to create isometric drawings

The advantages of having such documentation include: improved standardisation of work; better quality control mechanisms and quality expectations; and as stopgap measures for deficiencies in existing legislation. Further, these documents can be used as a test platform prior to the amendment of legislation to include 3D specific content.

6.4.3 Build Industry Skills and Capacity in 3D Cadastre Operations

The organisational interactions during a cadastral transaction were identified by the Queensland case study in Chapter 5. From the case study it was observed that because a significant group of people were involved in a single cadastral transaction, any organisational capacity building effort would need to be well coordinated and effective.

The following key group of people and training activities are identified:

- Surveyors are responsible for field data capture and data representation, so initial training and awareness creation must involve them;
- Educational institutions create future spatial industry professionals, so including 3D cadastre topics in the curriculum will create better prepared professionals; and
- Training and awareness creation of key personnel involved with cadastre processes such as titles office, plan auditors and database administrators.

Organisations such as DNRM, local governments, titles office, educational institutions, and surveying firms need to ensure that appropriate time and financial resources are allocated for awareness of the institutional and technical developments in 3D cadastre processes.

6.4.4 Registration of 3D Objects

All Australian jurisdictions register 3D objects in their cadastral systems. However, complete 3D objects are not stored spatially and do not exist in their own right in the database.

In a full 3D cadastre implementation, 3D lots should exist independently in the cadastral database similar to a 2D lot. This would ensure that the cadastral database is complete, and properties in strata can be queried or visualised in the database.

To store 3D objects in the database the following conditions should be satisfied:

- 3D cadastral objects must exist as an individual entity in the cadastre;
- These objects must be able to be defined and identified unambiguously; and

- The registration of 3D objects must ensure that there are no encroachments or overlap of rights.

The existing hybrid approach of registering 3D rights but storing partial geometry in the database does not support 3D functionalities such as 3D validation, query, visualisation, and manipulation. Registering 3D rights and storing 3D geometry as an individual entity will ensure the completeness of a 3D cadastral fabric.

6.4.5 Research and Implement a Specific Geometry

All cadastral jurisdictions in Australia represent 3D objects on a 2D paper plan. Queensland requires that isometric drawings be part of the volumetric plan submission. 3D geometric issues are quite complex and significant research is ongoing currently to identify an appropriate geometry for cadastral purposes.

Some of the requirements of such geometry are:

- Topologically valid;
- Capable of being stored in the database with minimum resource requirements; and
- Facilitate querying, data manipulation and visualisation.

Selecting appropriate representation geometry will create opportunities for implementing automated validation. The existing approach of creating 3D geometry through surface triangles or wire-frame representations works well for the current level of sophistication; however it does not meet the requirement of a full 3D implementation.

6.4.6 Build 3D Capable Database

The current digital cadastral database in all cadastral jurisdictions is a 2D database. To implement a full 3D cadastre, the database must be able to store, view, query, manipulate and validate 3D data.

The requirements of a 3D capable database include the capacity to:

- Store the construction geometry of a 3D cadastral object;
- Perform topological validations;

- Perform database checks such as 2D/3D and administrative adjoining parcel information;
- Uniquely identify 3D property extents to prevent boundary encroachments and litigations; and
- Query, manipulate and support visualisation of 3D data.

The creation of a database capable of storing 3D cadastral data will support the implementation of full 3D cadastre. It needs to be able to transition from the existing database without loss of information. The transition to a 3D database must also minimise disruption to the daily operation of cadastral transactions.

6.5 CONCLUSION

This chapter summarised the findings of the questionnaire survey of all cadastral jurisdictions of Australia and the case study in Queensland. The results were then integrated and issues relevant to the implementation of 3D cadastre were defined. The legislative support that facilitates 3D cadastre appears to be adequate but may require further refinement to support increasing complex developments occurring.

Further work appears to be required in developing policies, standards and operating procedures to further streamline and improve the efficiency of lodgement of 3D cadastre and 3D rights. Issues in the areas of digital lodgement and validation will require significant efforts to improve the capture, validation and storage of 3D cadastral data.

The final chapter is the Conclusion and Future Research. It discusses the achievements of the research based on the objectives initially defined. It further discusses the contribution of the research and identifies themes for future research.

CHAPTER 7

CONCLUSION AND FUTURE RESEARCH

7.1 INTRODUCTION

This chapter summarises the outcomes of the research regarding 3D cadastral implementation in Australian jurisdictions and Queensland in particular. Further, it reviews the achievement of research aim and objectives and suggests directions for future research.

7.2 RESEARCH AIM AND OBJECTIVES

As discussed in Chapter 1, the central research problem for this study was:

"In Australia, although 3D cadastral objects are currently being registered, our understanding of the complex 3D cadastre issues and the varying jurisdictional implementation arrangements is incomplete, and is therefore limiting our ability to implement institutional and technical improvements."

In this context, an understanding of the implementation arrangements provides a background for the identification of issues to assist in the improvement of the current processes. Thus, to address the research problem, the following research aim was formulated:

"Identify the key issues and characteristics that are impacting 3D cadastre developments across Australia and Queensland in particular, so that strategies for improving its institutional and technical implementation can be identified."

In order to achieve the research aim, four research objectives were defined. The four objectives were addressed in Chapters Two, Four, Five and Six respectively. Chapter Two reviewed the relevant institutional and technical 3D cadastre issues and identified the research gap. Chapter Three framed the research approach and formulated a mixed methods approach to analyse survey and case study data. The advantages of utilising a mixed method approach were the ability to study the research problem at varying levels of detail, and the ability to integrate the results through triangulation. Chapter Four presented the results of the survey of Australian jurisdictions and identified the current status of 3D cadastral implementation. Chapter Five analysed five cases in Queensland to identify specific institutional and technical issues and characteristics of the 3D cadastral implementation. Chapter Six summarised the results of the survey and the case study, and then formulated possible implementation strategies to support the ongoing implementation of 3D cadastre.

The achievements of the objectives of the research are reviewed and discussed below.

7.2.1 Objective 1: Review Existing Theory and Practice

Objective 1 of the dissertation was to "*review the existing institutional and technical issues and characteristics relevant to the implementation of 3D cadastre in Australia and internationally*".

In Chapter Two, the theoretical framework of 3D cadastre was presented, key terminology discussed and key issues and characteristics identified. A brief review of six international cadastral jurisdictions was undertaken. Characteristics such as registration of apartments, fragmentation of base parcels for network subsurface parcels, transferable ownership rights, easement rights dominating ownership rights creating easements for network objects, selling air rights were identified. A review of 3D cadastre issues including data geometry, representation, database, validation, data modelling, and 3D registration was undertaken. It was observed that although there are several methods to define 3D geometry for 3D object creation and representation, these are not implemented in cadastral jurisdictions because they are still being examined for optimal storage, validation and topological requirements. Cadastral jurisdictions have not yet adopted a defined 3D geometry type that supports automated validation, so data validation rules for these are yet to be developed. In the cadastral jurisdictions of Australia, each state has developed its own terminology and processes which has created issues with standardised efforts such as the national ePlan model. In Australia, 3D cadastre is being implemented; however there is a gap in research in understanding the complex institutional and technical 3D cadastre issues at the national and sub-national level. In summary, the first objective has been achieved and has served to highlight a gap in existing research.

7.2.2 Objective 2: Status of 3D Cadastre in Australian Jurisdictions

Objective 2 of this dissertation was to "*study the current status of 3D cadastre in the cadastral jurisdictions of Australia*".

Cadastral jurisdictions in Australia have implemented 3D cadastre in various ways. Chapter Four of this research analysed the similarities and differences in the 3D cadastre implementation in Australia. A survey of the eight cadastral jurisdictions was conducted by the author in association with ICSM between October and December 2010.

The results of the analysis revealed that various legislative frameworks exist in the cadastral jurisdictions of Australia to support the registration of 3D objects in the cadastre. This has enabled the real property market to create complex volumetric and building format plans to support the registration of 3D rights. Most states have adopted a strategy where 3D parcels remain constrained within a 2D surface (base) parcel but also permit 3D ambulatory boundaries to be registered in their cadastral system. Network parcels are registered in the cadastre, and are usually registered as volumetric parcels, easements or as non-spatial registered easements. Building units or apartments are registered as individual properties in all jurisdictions of Australia and are treated similar to 2D parcels for registration and transfer of rights, however, no jurisdiction stores 3D data spatially in their DCDB, and the ownership and other rights are stored as attributes attached to the base parcel. All jurisdictions allowed strata ownership to be different to the ownership of the base lot, which was owned under the community management schemes such as body corporate or owners corporate. The survey achieved the objective of providing an insight and current status into the differing arrangements across the eight jurisdictions. Many of the 3D cadastre developments were similar; however it was evident that some states have progressed further than the others.

7.2.3 Objective 3: Status of 3D Cadastre in Queensland

Objective 3 of the dissertation was to "*undertake a detailed study in one Australian jurisdiction to identify specific institutional and technical issues and characteristics of 3D cadastre implementation*".

This research used a case study approach to analyse the 3D cadastral implementation issues based on an institutional and technical framework. Five representative cases were studied in detail in Queensland. A detailed analysis of the 3D cadastral implementation arrangements provided a better understanding of the issues, and complemented the findings of the survey of the Australian jurisdictions.

In Queensland, the Department of Natural Resource and Mines (DNRM) acts as the custodian of cadastral data. As with most cadastral jurisdictions, there are inter-and intra-institutional interactions for the completion of a cadastral transaction. It was found that the institutional setup was mature and capable of transitioning to a full 3D implementation without significant changes to the institutional interactions. Registration of rights of both 3D and 2D parcels were treated similarly, which has fostered a supportive environment for the development of a 3D cadastre.

Standards and guidelines on the preparation of plans containing 3D content exist in Queensland and this assists surveyors to collect 3D information and to standardise plan preparation. It was found that there were very few restrictions on the kind of 3D objects that can be surveyed and that Queensland supports and registers many different kinds of ownership and tenancy rights. Cadastral data is stored across a number of databases however most are not capable of 3D data storage.

Overall the study found that 3D cadastre is being implemented effectively in Queensland although a number of technical and institutional issues should be addressed to improve operational and strategic imperatives. It is therefore considered that this objective has been successfully addressed through the case study approach.

7.2.4 Objective 4: Identification of Issues and Formulating Strategies

Objective 4 of the dissertation was to "*frame possible strategies to support the ongoing implementation of 3D cadastre in Australia.*"

Chapter Six integrated the results obtained from the survey of the Australian jurisdictions in Chapter Four and the detailed analysis of 3D cadastral implementation in Queensland in Chapter Five. This enabled the identification of common issues and the formulation of implementation strategies for the ongoing 3D cadastre in the jurisdictions. Eleven 3D cadastre issues were identified and classified into six component classes: legislative support; policy, procedure and standards; operational arrangements; registration of rights/tenure; geometry; and data capture and representation. Based on these findings, six implementation strategies were formulated and a brief discussion was provided on each. Thus, the objective to frame possible implementation strategies has been achieved.

7.3 CONTRIBUTIONS OF THIS RESEARCH

This research has reviewed the current theory and practice of 3D cadastre. There is ongoing research in 3D cadastre internationally; however, there has been limited research in Australia even though it is considered internationally to be a leader in 3D cadastre developments. This research has assisted in collating and better understanding the institutional and technical issues in 3D cadastre implementation in the Australian context.

The survey of cadastral jurisdictions regarding 3D cadastre implementation was the first of its kind in Australia and has provided a comprehensive baseline of the current status of 3D cadastre in the jurisdictions of Australia. The findings of the survey have provided insights into the current status, implementation practices, issues and strategies in Australia.

The findings of the case study have identified the range of complex 3D cadastre issues that exist. The case studies have provided an understanding that a "*one size fits all*" solution will not be possible in the case of defining and registering rights across private and public lands.

The identification of issues and implementation strategies has documented a non-exhaustive list of issues that require the further attention of jurisdictions in implementing 3D cadastre. Finally, this research has contributed to the body of knowledge in the area of 3D cadastre through a mixture of both quantitative and qualitative research approaches.

7.4 FUTURE RESEARCH

The following issues are identified as possible areas for further investigations and future research in the context of 3D cadastre.

7.4.1 3D Cadastral Data Model

Cadastral data is currently stored in 2D-capable databases which are limiting the full benefits of 3D data for validation, management and visualisation. Current developments of ISO 19152 LADM have created opportunities for the creation of a 3D specific cadastral data model. Further research is needed to create a database model capable of storing, manipulating, validating and visualising 3D cadastral data.

7.4.2 3D Digital Lodgement

Digital lodgement of cadastral data is currently being developed and tested with partial implementation. Due to the phase-wise progress of the process, 3D cadastre data lodgement for input into a 3D database is currently not well advanced. This provides an opportunity to research 3D digital lodgement within the context of both existing and future processes.

7.4.3 Validation Strategy for 3D Cadastral data

Current validation of 3D cadastral data is performed manually. Validation rules for 2D cadastral data have been developed for data entry through digital lodgement as well as for data in the digital cadastral database. With the implementation of 3D cadastral databases and 3D digital lodgement, validation strategies for 3D geometry, registration rules and 3D database process need to be investigated.

7.4.4 Visualisation

Currently, 2D data is visualised in paper plans and through the front-end of the digital cadastral database. With the ability to store 3D data in a cadastral database and digital plans, there is a need to develop visualisation processes that support 3D cadastre operations.

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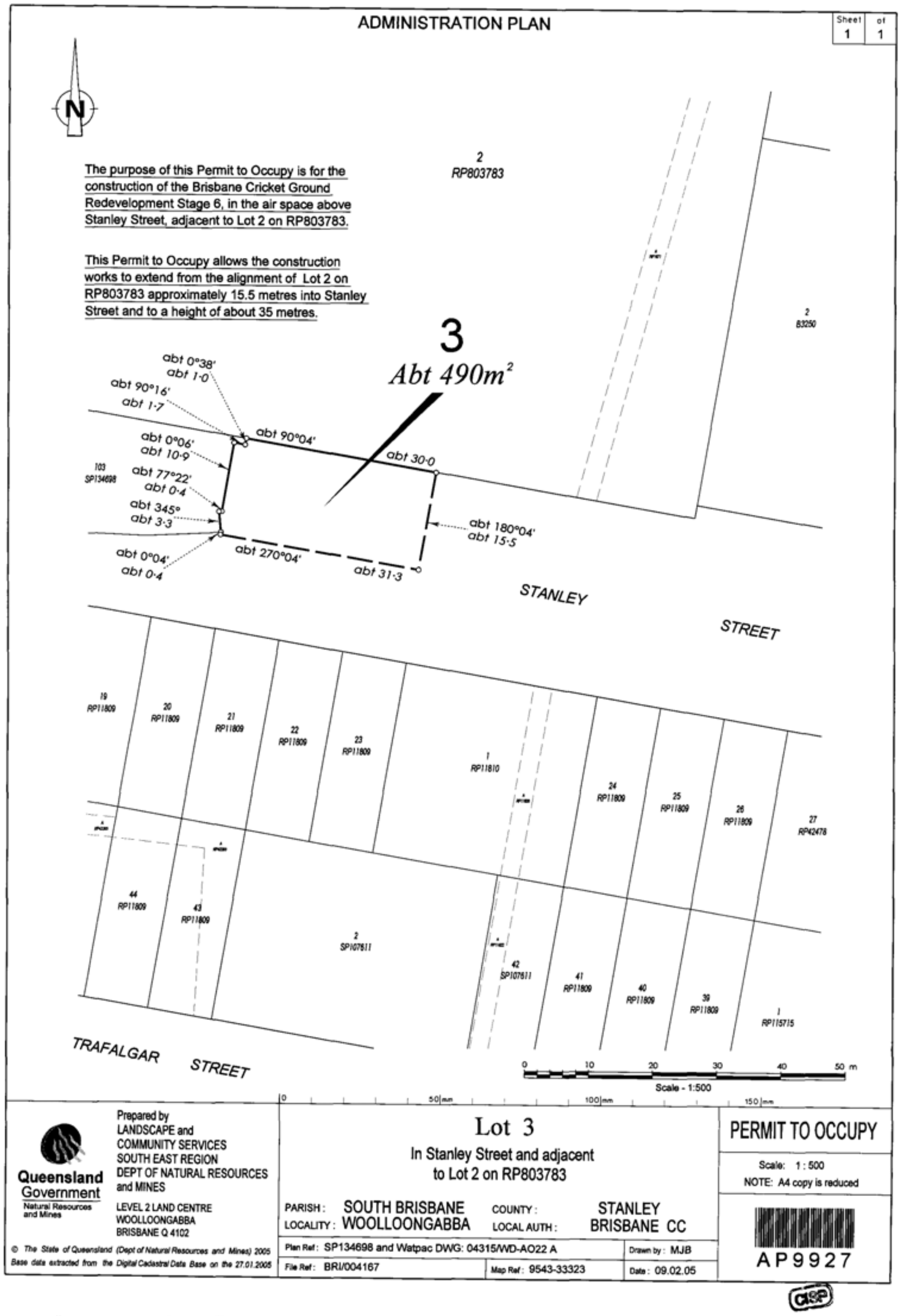
APPENDIX 1

EXAMPLES OF PLANS OF SURVEY

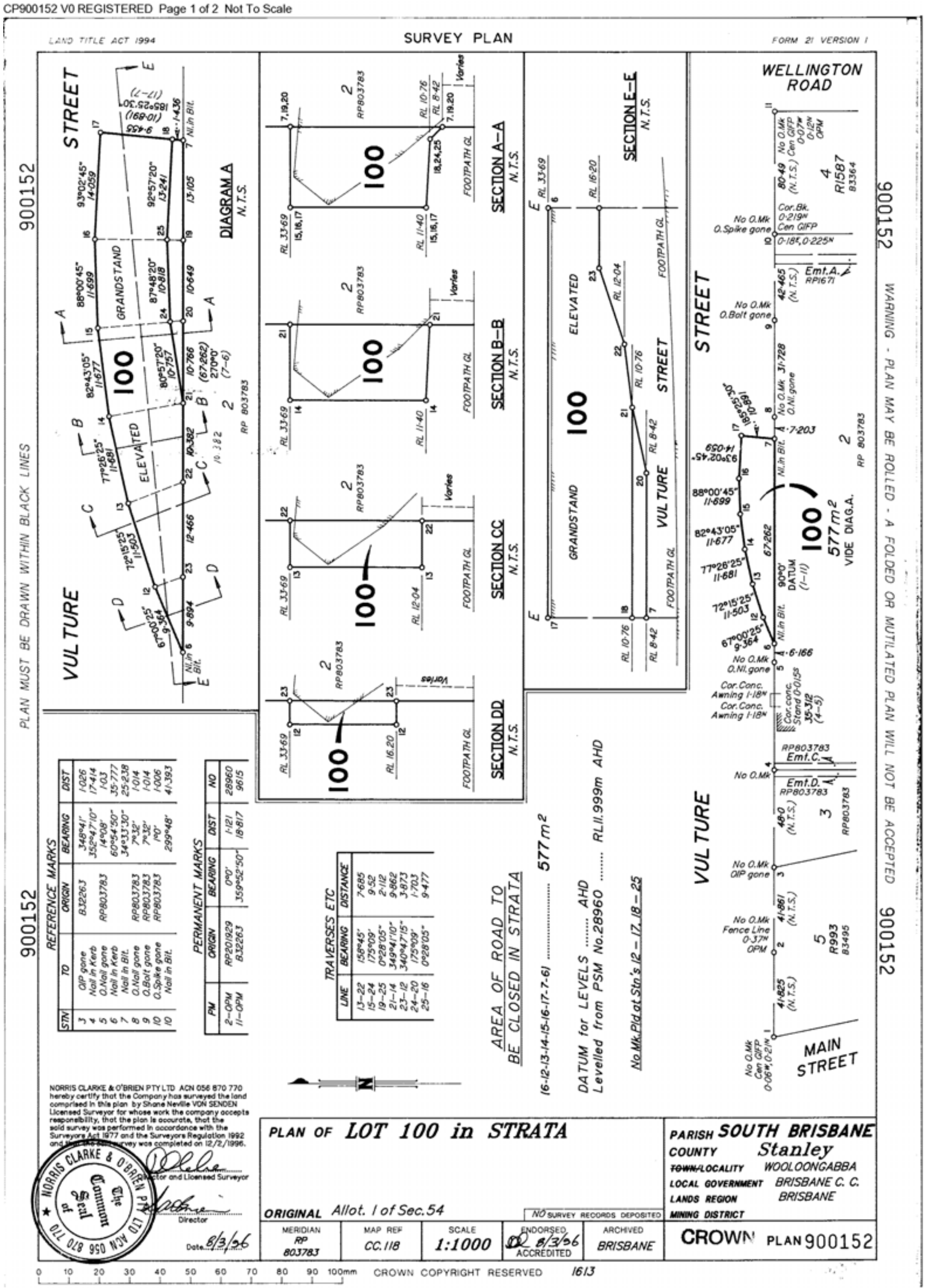
AP9927

AP9927 V0 Page 1 of 1 Not To Scale



CP900152

CP900152 V0 REGISTERED Page 1 of 2 Not To Scale



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APPENDIX 2

QUESTIONNAIRE

Karki Sudarshan

From:	Priebbenow Russell
Sent:	Wednesday, 6 October 2010 1:00 PM
To:	Thompson Rod; Karki Sudarshan
Subject:	FW: 3D cadastre questionnaire
Attachments:	3D-Cadastres_questions final.doc

FYI

Regards

Russell

Dr Russell Priebbenow
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From: Priebbenow Russell
Sent: Wednesday, 6 October 2010 12:58 PM
To: Hirst, Bill; Dione Bilick; Don Grant - NZ; Garry West - NT; John.tulloch@dse.vic.gov.au; Paul Harcombe - NSW ICSM; Peter Kentish - SA; Peter.Murphy@dpiw.tas.gov.au
Cc: Susie.Salisbury@ga.gov.au
Subject: 3D cadastre questionnaire

Sudarshan Karki, an employee of the Queensland Department of Environment and Resource Management, is carrying out research towards a Masters Degree at the University of Southern Queensland on the subject of 3D cadastres. Through that work, and in consultation with Peter van Oosterom of the Delft University of Technology, he has developed the attached questionnaire on 3D cadastres. He proposes to use the data from the questionnaire in his research, and in publications arising from that. He will acknowledge ICSM and the jurisdictions providing the data. This questionnaire will also form part of a global survey that is being conducted by FIG (http://www.gdmc.nl/3DCadastres/).

Bill Hirst has agreed to this being circulated through the PCCR, which will also result in the data being available for use by ICSM.

Please complete the questionnaire and forward it to Bill Hirst and Susie Salisbury by 31 October 2010.

Regards

Russell

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Questionnaire 3D-Cadastres: Status October 2010

This questionnaire is an attempt to gather information regarding the status of 3D cadastre in Australia and New Zealand. The response from this questionnaire also feeds into by the FIG Working Group 3D-Cadastres 2010-2014. The purpose of the survey is to make an Australia and New Zealand-wide inventory of the status of 3D-Cadastres at this moment (October 2010) and the plans/expectations for the future. By sharing this information, it should be possible to improve cooperation, learn from each other and support future developments:

- Two example sets of partial/preliminary answers are included from Queensland and The Netherlands, to support the questions and to be of help when formulating the answers for your jurisdiction.
- If a certain question is not relevant to your jurisdiction or if you have unsure of what to respond, please do not spend too much time on this (and leave the field blank). We might call you back to clarify some of the answers if needed.
- The questionnaire is grouped in a number of blocks. This is not an indication of priority and often some question could be applicable to multiple blocks.
- Please complete this questionnaire and send it to Bill Hirst (bill.hirst@act.gov.au) and Susie Salisbury (Susie.Salisbury@ga.gov.au) before 31 October 2010

1. General/applicable 3D real-world situations

This part of the questionnaire refers to the applicable 3D real-world situations to be registered by 3D parcels (as distinct from what may or may not be recorded in any database or registry). It also addresses the types of 3D geometries, which are considered to be valid 3D representations for these parcels.

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
1.1. Are all 3D parcels constrained to be within one surface (2D) parcel?	Yes, but this is not guaranteed for all time (i.e. the 2D parcel can be subdivided without requiring the 3D parcel to be subdivided).	Rights referring to the use of a limited space will be registered in the cadastre on a 2D parcel. However the right registered might refer to a construction or space on several 2D parcels. Yes.	
1.2. Are ambulatory1 boundaries permitted?	Yes, because 3D parcels are broken at surface parcel boundaries.	Theoretically they are, because the database representation may become invalid when situations have been like that (i.e. in conflict what is registered) for many years.	
1.3. Is it allowed to have 3D parcels not related to physical constructs or objects?" (e.g. airspace, subsurface volumes)	Yes.	Normally the rights to establish 3D parcels (apartment rights; right of superficies; right of long lease) do refer to constructions. But this is not a restriction.	
1.4. Are disconnected parts of a single 3D parcel allowed?	Yes.	No (also not in 2D).	
1.5. Limitation – e.g. must the 3D parcel be	Anything is permitted as a	No. Apartment unit boundaries are generally	

[1] An ambulatory boundary is a boundary of a land parcel which follows the movements of a natural feature such as a river. Its position determined at points of time (when a survey is carried out), but between such "fixes", the definition of the property is the position of the real world natural feature.

described by a boundary definition?	volumetric parcel, provided it can be described unambiguously and an isometric drawing supplied. Unit boundaries (building format lots) are generally described as Floors, Walls and Ceilings. Other subsidiaries such as car parks need dimensions or reference to physical objects.	described as Floors, Walls and Ceilings. Other subsidiaries such as car parks need dimensions or reference to physical objects. It is possible to show which volume is affected with the right by indicating boundaries on a drawing added to the deed registered in the public registers. But no guidelines exist for these drawings. In case of apartments it is mandatory to register in the public registers a drawing indicating the boundaries of the apartment units. These drawings are made in 2D (for each floor level), and therefore do not give any 3D information on the dimension of the units.	
1.6. Are curved surfaces bounding the 3D parcels allowed?	Yes.	Yes. As no legal requirements exist nor guidelines are given; this is allowed. Currently practiced when the constructions have these types of shapes.	
1.7. Must the curved surfaces (if allowed) be cylindrical sections, or any other constraint?	No. 2D boundaries can be described by radius etc.	No. No restrictions.	
1.8. Any other constraints – e.g. all surfaces must be horizontal or vertical?	No.	No.	
1.9. Is there generic legislation (law and/or regulations) for 3D descriptions of parcels? If so please, mention law and article(s).	Land Title Act 1994, supported by Registrar of Titles Directions for the Preparation of Plans	No.	
1.10. Do you have example descriptions of typical 3D parcels; either ‘prototype’ or ‘operational’?	Yes		
1.11. Is there a formal model for the 3D parcels (UML style); e.g. based on ISO TC211 series?	No.	No.	
1.12. Are natural resources (groundwater, mining rights) considered as 3D	No.	No.	

parcels?			
1.13. Are polluted areas considered as 3D parcels (as legal restrictions are associated to these spaces: above and below surface)?	No.	No.	
1.14. Are spatial plans considered as 3D parcels (as rights or restrictions are related to them)? Sometimes also called spatial development plans, zoning plans or physical plans (land use, urban, regional, environmental,...)	N/A	No.	
1.15. Any other geometric issues?			
1.16. If rights (such as mining rights) are registered as 3D parcels or strata titles, does Isometric drawing have to be supplied?	N/A		
1.17. How are records maintained for either uniform height zoning (like mining regions) or variable height zoning (like airport surrounds)?		[2]	

2. Infrastructure/utility networks

This refers to the situation where an infrastructure network is considered to be defined within the cadastre. for example in some jurisdictions, an underground network might be privately constructed for the purpose of leasing space within it for other organisations to run cabling. In this case, a network, or part of that network may be considered to be a real estate object.

	Australia/Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
2.1. Do you register network parcels? (e.g. subterranean conduit networks)	Yes in some cases. Where a network exists on private land, and there is not a statutory right of access to place and maintain the asset, then the land is acquired or a right is acquired by way of an easement.	No. However we do register the ownership of networks, and therefore the networks itself as legal objects. The property rights in land (e.g. right of superficies or easements) are still related to the surface parcels that overlap with the network.	
2.2. If so, can the network structure be traced in the	No (The networks are broken at the surface parcel boundaries, and may not be	Yes. As physical objects.	

[2] The shaded portion represents questions that were in addition to the FIG questions

database(s)?	defined below roads etc.)		
2.3. Does the jurisdiction have private networks? If so please, mention law and article(s).	Yes (Overhead cable networks). Privately constructed road tunnels fall into this category.	Yes.	
2.4. If so, are they registered as 3D property parcels?	Yes in some cases.	Yes (see 2.1).	
2.5. Do you have example descriptions of typical 3D parcels for networks; either 'prototype' or 'operational'?	Yes	Yes.	
2.6. If the network (legal) objects break at the surface parcel, how do you deal with intersecting networks or vertically parallel networks?	The DCDB does not record network objects as a network.		
2.7. Any other geometric issues?		Networks are registered as lines.	
2.8. What is the minimum cross-section size of a network parcel?	None specified		

3. Construction/building units

This refers to 3D properties that are related to constructions and apartment (condominium) buildings. The individual units are often defined by the actual walls and structure of a building, rather than by metes and bounds. E.g. "unit 5 on level 6 of … building".

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
3.1. Do you register 3D construction/building units?	Yes.	Yes.	
3.2. If so, what are the most important types? E.g. apartment units, or also other buildings or even more general constructions (infra related; such as bridge, tunnel or even other, such as windmills,..)	Most common are building units, and may be for residential or commercial purposes.	Most apartment units.	
3.3. Does the jurisdiction have generic legislation (law and/or regulations) for construction or building units? If so please, mention law and article(s).	Land Title Act 1994, supported by Registrar of Titles Directions for the Preparation of Plans	Dutch Civil Code, Book 5, Article 106, Cadastre Act, Article 20.	
3.4. Do you have	Yes – these are	Prototype (they are	

example descriptions of typical 3D parcels; either 'prototype' or 'operational'?	stored in the DCDB, but with no graphical extent (just the unit number and the surface area of each unit).	not registered in 3D).	
3.5. What would be typical 3D boundaries in an apartment complex: middle of the wall and floor/ceiling, or walls, floors/ceiling as neutral/shared 3D space?	Typically the unit is defined to the middle of the walls/ceilings.	In general the unit boundaries will be defined in the deed to the middle of the walls/ceilings.	
3.6. Is common property inside the building registered? If so, how?	Yes. They are registered as community titles under the Community Management System (CMS) and usually is shown as Lot 0 in the DCDB.		
3.7. Who owns the common property inside the building?	The body corporate.		
3.8. Who owns the land on which the apartment is built?	The body corporate.		
3.9. Any other geometric issues?	Where the main part of a lot is defined by the structure, other parts of the lot (e.g. the car park) can be defined as a 2D "part lot"	Apartment units are related to one or several surface parcels.	
3.10. What is the lot numbering convention for units in a building?	Each unit is given a lot number within the "building unit plan". The numbering scheme is specified in the Registrar's Directions.		
3.11. What is the process for re-building or re-establishing extents and rights in case of damage to units/buildings?	The interest is considered to remain defined in 3D space as if the construction remained. Any change to the building configuration would need to be dealt with by reconfiguring the 3D space (subdivision and/or amalgamation)		
3.12. How do you deal with a mezzanine floor situation in a building?	There is a second level created for the lot with a "void " in part of the level		

4. X/Y Coordinates

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010

4.1. Do the plans of survey guarantee X/Y coordinates? (and are they relative or in an absolute spatial reference system?)	No.	Yes of 2D parcels.	
4.2. Are the cadastral database coordinates authoritative?	No. The DCDB cadastral point positions at any time are the best estimate based on survey information and control point data. As such, point positions will change with time.	Yes.	
4.3. If not, what is the authoritative source of X/Y coordinates?	None.		
4.4. Do you have parcels defined by the walls of a building (with no recorded geometry)?	Yes – "Building Unit Plans". Units usually defined by centre of floors, walls and ceilings.	Yes. Apartment units; building units established with right of superficies.	
4.5. What is the spatial reference system for X/Y Coordinates?	N/A		
4.6. Any other X/Y coordinate issues?			

5. Z Coordinates/height representation

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
5.1. Are the Z coordinates of 3D parcels relative to local ground?	No. Relative depth only used for volumetric plans or complex features. Most building unit plans do not have Z value as extent of units defined by the physical building.	No guidelines.	
5.2. Are Z coordinates reduced to a standard datum (absolute)? If so, what is the spatial reference system for the Z coordinate?	Yes. Australian Height Datum		
5.3. In principle is it possible to store both relative and absolute Z coordinate?	No		
5.4. Is the earth surface (height) explicitly stored (in the DCDB or other accessible register)?	No, but may be shown on volumetric plans.		
5.5. What is the	Surface elevations		

source of elevation for the 2D surface parcel?	are not recorded in the DCDB.		
5.6. Any other Z coordinate issues?			

6. Temporal Issues

	Queensland 2010	The Netherlands	Your Jurisdiction 2010
6.1. Are temporal limits part of the definition of a parcel (2D or 3D)?	No. All parcels are unlimited temporally. for example, a 1 week timeshare apartment is treated as a 1/50 share in the apartment. The registering authority does not specify which week of the year it applies to.	No.	
6.2. Are moving parcels allowed?	No – apart from ambulatory boundaries. These are not represented as a curve in time.	No.	
6.3. Are there any limitations on the range of temporal limits? (e.g. only on 3D apartments).	N/A.		
6.4. Are there any attempt to integrate 3D space and temporal representations, into a single 4D space/time representation?	No	No.	
6.5. In the case of tidal boundaries, what happens to the 3D ambulatory parcel if the 2D land parcel changes extent due to the movement of High Water Mark?	This is not determined yet.		
6.6. Any other temporal issues?			

7. Rights, Restrictions and Responsibilities

This section covers a broad range of RRRs including administrative controls, as opposed to simple registered or unregistered interests.

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
7.1. Range of RRR on 3D parcels.	Same as 2D although may involve responsibility for common property and right to use subsidiaries such as car parks (e.g. exclusive use areas).	No specific rules.	

7.2. Are there any limitations on the range of rights? (e.g. subterranean parcels must be owned by Govt).	No.	No.	
7.3. Any other RRR issues?	Now possible for a Unit complex to be part of a community title. Thus owners have shared responsibilities outside the unit land parcel.		
7.4. Are there RRRs that are only allowed in 3D (and not valid for 2D)	No.	No.	
7.5. Is there specific legislation (laws, regulations) defining 3D RRR types? If so, provide details, e.g. references to documents/ articles.	Yes. Queensland Government, Land Title Act 1994.	No.	
7.6. Can 3D sub-surface/above-surface parcel be owned by someone other that the person owning the land parcel?	Yes.		
7.7. What applications do you foresee for 3D cadastre?	Ensuring unique definition of property rights, to serve complex property markets, 3D city models, prevention/detection of encroachments etc.		

8. DCDB (The Cadastral Database)

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
8.1. Does the DCDB contain representation of 3D parcels (in any form)?	Yes. (But not in all jurisdictions).	No. Attribute values of parcels may indicate a 3D situation (i.e. pollution; mining; right of ease; underground construction).	
8.2. If so, how are they represented (in the DCDB)?	As 2D polygons in a layer above (below) the base layer.	Always related to the 2D parcels and represented through the geometry of 2D parcels. Exceptions are the networks (line representations).	
8.3. If so, how are they presented on cadastral "maps" (including screen presentations)?	As polygons is a contrasting colour to the base parcels.		

8.4. Are there possibilities to store geometry of 3D parcels in the DCDB?	No.	No.	
8.5. Is it possible to manage a 3D topological structure in the DCDB?	No.	No.	
8.6. Are constraints/rules defined for valid 3D objects (closed volume, no overlap, no gap in 3D)? What about rules for a mix of 2D and 3D representations?	No constraints are enforced in the DCDB between 3D objects and other 3D or 2D objects.	N/A.	
8.7. How can internal and external user query and visualize the 3D content supporting rotating, slicing, transparency, perspective (3D web/view service, 3D pdf documents,..)?	Only as a 2D map with the presence of 3D parcels indicated in colour.	Not.	
8.8. What Spatial DBMS software do you use? Any 3D capabilities included and used?	Ingres. No 3D capabilities at the moment.	Oracle. No 3D used at the moment.	
8.9. Do you have any validation rules for 3D representation in the database?	These are still being specified.		
8.10. What (GIS/CAD) software is used for updating, editing, analysis, and visualization of the cadastral data? Any 3D capabilities included and used?	Microstation, 3D capabilities not used at present.	Fingis (future Intergraph Geomedia). No 3D used at the moment.	
8.11. What web software is used for remote data access/distribution and visualization? Any 3D capabilities included and used?	None		
8.12. Is your DCDB organised as Multi-Layers or Object Oriented or some other data model?	Object-oriented (but with layer as an attribute).		
8.13. How do you query 3D objects in your DCDB?	As all other objects, (but with only the 2D footprint returned).		
8.14. Is it possible	Yes.		

to query neighbourhood parcels to a 3D object, vertically as well as horizontally?			
8.15. Any other DCDB issues?			
8.16 Do you maintain a Point Identifier Database (PID) for all the vertices of the cadastre?	Yes		
8.17 If yes, what is the convention for numbering the PIDs in 2D and 3D?	Points are uniquely numbered in terms of the X/Y coordinates. Where 2 points share the same X/Y, they are given an alphabetic suffix (a, b, …)		
8.18 If yes in Q8.16, do you store the relationship of linestrings joining the PIDs?	No. This is not a topological issue; the PIDS are stored in a Points database and the lines forming a parcel are in the DCDB, so the relationships themselves are not stored in the table.		

9. Plans of Survey (including field sketches)

	Queensland 2010	The Netherlands 2010	Your Jurisdiction 2010
9.1. Do the survey plans carry 3D parcel representations where those parcels are defined by reference to a structure (building format plans)	No	No, but in theory it would be possible.	
9.2. If so, how are they represented?		Fully depends on the surveyor.	
9.3. Do the survey plans carry 3D parcel representations of parcels defined independently of any structure (volumetric plans)?	Yes.	No, but in theory it would be possible.	
9.4. If so, how are they represented?	As a tabulation of corner positions, associated with plan, and isometric views (on paper). Each floor is represented on a separate diagram. Heights (AHD) are given for corners of	Fully depends on the surveyor.	

	non horizontal surfaces.		
9.5. Is there specific legislation (regulations) describing the requirements for Plans of Survey in 3D? If so, please give link to the relevant documents.	Yes. Registrar of titles directions for the preparation of plans. Queensland, Australia, 2003.	No.	
9.6. Is sketch level allowed (low geometric quality, but in principle enough to indicate the 3D object)?	Yes.	Yes.	
9.7. Is it possible to define a 3D parcel by referring to other 3D real world objects/ topography (and not specifying coordinates)?	Only in the case of a building unit plan.	Yes.	
9.8. In what format are the 3D parcels submitted for registration; attached to legal document in a single pdf (which has good 3D capabilities) or in an extension of (city)GML for 3D parcels, or….?	At present, on paper, but will be submitted in “LandXML”.	As drawings registered in the public registers. Not on the cadastral map nor cadastral surveys.	
9.9. Are the 3D parcels somehow checked for spatial validity; e.g. volume is closed, does not overlap with neighbour volume (and also no unwanted 3D gaps)?	Visually at present.	No. Mostly relate to existing physical constructions or constructions to be built.	
9.10. Do you have examples of (prototype or production) 3D survey plans available?	Yes		
9.11. Are any reference objects visible on the survey plan (e.g. real buildings, roads, that is 3D topography)?	No.	No.	
9.12. What form of 3D data acquisition is used (CAD, terrestrial surveying, sketches, stereo/oblique images, laser scanning,…)?	Terrestrial surveying		
9.13. What software do you use for creating and processing survey	SIP (Survey Information Processing) Capture		

plans? Any 3D capabilities included and used?	Tool		
9.14. Can 3D parcels be subdivided, consolidated or nullified?	Yes.		
9.15. Is there any existing technical circular or directive to assist Surveyors in 3D data collection in the field?	Not exclusively. However, various documents exist on Preparation of Plans etc to assist Surveyors.		
9.16. Any other survey plan issues?			
9.17 How are the 3D vertices captured and numbered by surveyors for a curved surface?			

10. Other Issues

Please include at 10.4 any other issues that may be of interest in an international context. for example, in some foreign jurisdictions 3D parcels can only be separated by horizontal planes.

	Your Jurisdiction	
10.1. Country (State, Province)		
10.2. Your name, function/position and your organization		
10.3. Contact details: address email, telephone		
10.4. Other issues		
10.5 Consent for research[3]	Do you consent to this questionnaire to be used for research work?	

[3] The questionnaire has been developed by Sudarshan Karki, an employee of the Queensland Department of Environment and Resource Management, as part of research he is carrying out towards a Masters Degree at the University of Southern Queensland on the subject of 3D cadastres. He proposes to use the data from the questionnaire in his research, and in publications arising from that. He will acknowledge ICSM and the jurisdictions providing the data. This questionnaire will also form part of a global survey that is being conducted by FIG (http://www.gdmc.nl/3DCadastres/).

APPENDIX 3

ACTS AND REGULATIONS FOR LAND ADMINISTRATION IN QUEENSLAND

1	Aboriginal Land Act 1991
2	Aboriginal and Torres Strait Islanders (Land Holding) Act 1985
3	Aboriginal and Torres Strait Islander Communities (Justice Land) Act 1984
4	Aboriginal and Torres Strait Islander Communities (Justice Land) Regulation 2008
5	Acquisition of Land Act 1967
6	Acquisition of Land Regulation 2003
7	Acts Interpretation Act 1954
8	Body Corporate and Community Management (Accommodation Module) Regulation 2008
9	Body Corporate and Community Management (Commercial Module) Regulation 2008
10	Body Corporate and Community Management (Small Schemes Module) Regulation 2008
11	Body Corporate and Community Management (Standard Module) Regulation 2008
12	Body Corporate and Community Management Regulation 2008
13	Body Corporate and Community Management Act 1997
14	Brisbane River Tidal Lands Improvement Act 1927
15	Building Units and Group Titles Act 1980
16	Building Units and Group Titles Regulation 2008
17	Environmental Protection Act 1994
18	Evidence Act 1977
19	Evidence and Discovery Act 1867
20	Evidence Regulation 2007
21	Fair Trading Act 1989
22	Fair Trading Act 1989
23	Forestry Act 1959
24	Forestry Regulation 1998
25	Forestry State Forests Regulation 1987
26	Housing (Freeholding of Land) Act 1957
27	Housing (Freeholding of Land) Regulation 2006
28	Information Privacy Act 2009
29	Information Privacy Regulation 2009
30	Infrastructure Investment Asset Restructuring and Disposal 2009

31	Land and Resources Tribunal Act 1999
32	Land and Resources Tribunal Rules 1999
33	Land Court Act 2000
34	Land Court Regulation 2010
35	Land Court Rules 2000
36	Land Legislation Amendment Act 2003
37	Land Sales Act 1984
38	Land Sales Regulation 2000
39	Land Tax Act 2010
40	Land Tax Regulation 2010
41	Land Valuation Act 2010
42	Land Act 1994
43	Land Regulation 2009
44	Land Title Act 1994
45	Land Title Regulation 2005
46	Local Government (Aboriginal Lands) Act 1978
47	Local Government (Aboriginal Lands) Regulation 2001
48	Local Government Act 2009
49	Marine Parks Act 2004
50	Mixed Use Development Act 1993
51	Native Title Queensland Act 1993
52	Neighbourhood Disputes Resolution Act 2011
53	Oaths Act 1867
54	Place Names Act 1994
55	Place Names Regulation 2005
56	Property Law Act 1974
57	Property Law Regulation 2003
58	Public Records Act 2002
59	Public Records Regulation 2004
60	Queensland Boundaries Declaratory Act 1982
61	Right To Information Act2009
62	Standard Time Act 1894
63	Statutory Instruments Act 1992

64	Statutory Instruments Regulations 2002
65	Survey and Mapping Infrastructure (Survey Standards) Notice 2010
66	Survey and Mapping Infrastructure (Survey Standards-Requirements for Mining Tenures) 2011
67	Surveyors Act 2003
68	Surveyors Regulation 2004
69	Survey and Mapping Infrastructure Act 2003
70	Survey and Mapping Infrastructure Regulation 2004
71	Sustainable Planning Act 2009
72	Sustainable Planning Regulation 2009
73	Transport Infrastructure Act 1994
74	Urban Land Development Authority Act 2007
75	Urban Land Development Authority Regulation 2008
76	Water Act 2000
77	Water Regulation 2002
78	Work Health and Safety Act 2011
79	Work Health and Safety Regulation 2011