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TECHNOLOGY CASE STUDY
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GEODATA INFORMATION SYSTEMS

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Executive Summary

Geodata Information Systems Pty Ltd (Geodata), a private company incorporated in Australia, has been established to commercialise a suite of survey, engineering and cadastral software solutions. The technology has been progressively developed over the past 15 years and has now reached the stage where it is being globally commercialised.

During the more recent development period, the software solutions have been applied to real projects where conventional, metes and bounds-based land cadastres have been upgraded to accurate, coordinate-based systems. This work has been undertaken both directly by Geodata personnel and by licensed surveying contractors. This report describes the experience gained on these projects and the technical and commercial benefits offered by the Geodata technology within the context of delivering the next generation of digital cadastral databases (DCDBs) that are compatible with modern global positioning technologies (GPS) and geographic information systems (GIS).

To gain an understanding of the competitive advantages offered by the Geodata technology, this report also seeks to describe the sources of stakeholder value generated by an accurate coordinate-based DCDB. Although the respondent organisations in Australia, referred to in this report, were not able to quantify the economic benefits associated with upgraded DCDBs, reference has been made to a recently published document (Appendix 2) that seeks to quantify the business case in Australia for improved spatial accuracy. This study canvassed the opinions of all key stakeholders in DCDB usage and generated the following findings for each stakeholder category: primary suppliers of information and users of cadastral information. The principal cost/benefit components in the value chain were identified as:

- Currently, over 40% of applications are not currently met by current levels of DCDB accuracy (typically, median accuracy values are 2m for urban and 20m for rural land-use areas).
- To achieve accuracies of 0.1m or less, an investment of \$3.48/parcel was perceived as acceptable at a cost to the user of \$0.69/parcel.
- Quantifiable savings to primary data suppliers ranged from \$0.02/parcel for organisations with responsibility for DCDBs areas 1M parcels to \$2.51/parcel for smaller DCDBs of <20k parcels.
- Alternatively, the mitigating benefits (i.e. operational savings) of survey accurate DCDBs were estimated at between \$300,000 and \$3,000/annum.

Consideration given to the alternative approaches to upgrading DCDBs found that:

- The optimum approach to cadastral reform involves the combined application of readjustment software to existing survey data combined with selected control point coordinates. This methodology would be applied to selected areas that, once approved, would be progressively integrated into a new DCDB to support comprehensive cadastral reform.
- Software solutions to the adjustment process needed to be easy to install, use and be compatible with existing GIS and survey platforms.
- Of paramount importance, was the ability to adjust, to an equivalent level of accuracy, associated data layers.

To meet these criteria and achieve a positive return on investment, the data input and processing costs associated with a preferred software solution, excluding the costs of re-surveying control points, needs to be less than $24/parcel.

The case studies reported on here have been prepared through detailed discussions with both customers of DCDB upgrades and those individuals that have used the Geodata software on project assignments. The case studies highlight the effectiveness and efficiencies obtained with two Geodata software products:

- ***GeoCadastre***, a Windows based cadastral process to facilitate the conversion of DCDBs generated from original survey plans and maps and associated with data having a range of accuracy, supplementary detail and functionality. The program is designed to create seamless parcel networks in a three stage conversion process. In addition, an embedded, automated "associativity" tool corrects related data layers in GIS.

- ***GeoSurvey***, a very fast and efficient survey and geometry package that will interface with most GIS and geodatabase systems. The product can manage large data sets and has the ability to import and export a wide4 range of survey data formats. It is intended to market *GeoSurvey* as a complementary data management tool in DCDB upgrades using *GeoCadatsre*.

Key insights from customers and users of the Geodata technology have confirmed that the software programs offer the following competitive advantages:

- A project undertaken over 2 years for the Northern Territory Government involved upgrading a DCDB covering 1.3M km^2 with 53,000 land parcels ranging from urban areas to pastoral leases 200 to 12,000 km^2 and native title lands up to 96,000km^2. The latter involved survey inaccuracies of several hundred metres. The application of Geodata technology achieved DCDB coordinate accuracies of 0.02m, 0.1m and 1m in urban, rural and pastoral areas at a cost to the client of $6.5/parcel.

- For a number of local government authorities in the state of Queensland, a licensed user of Geodata technology was able to upgrade DCDBs containing between 20,000 and 50,000 parcels at a cost to their client of $16/parcel. The associativity capability of GeoCadatsre as already resulted in significant savings in labour costs associated with asset management and provides an improved, lower cost interface for users through such facilities as electronic plan lodgment.

- A water utility based in NSW has been a long-term user of Geodata technology to upgrade its DCDB covering over 250,000 properties and associated pipeline assets. The attributes of GeoCadastre in preserving the integrity of original survey information has proved crucial to this organisation and the personnel requirement to manage additions (typically, the addition of up to 3,500 parcels/year) has been reduced by an order of magnitude.

The case studies in this report clearly demonstrate that the Geodata technology is a timely approach in the recent worldwide push to deliver GIS stakeholders accurate, coordinate-based land cadastres. This is particularly true for those jurisdictions (eg Australia, New Zealand, Canada, USA, South Africa and those countries in the former Eastern European Bloc) where land cadastres no longer meet the planning, legislative and management demands invoked by accurate GPS determined coordinates.

The success of the technology in delivering satisfactory outcomes for State, local government and utility organisations in Australia and New Zealand suggests that the Geodata software products have significant market potential in overseas jurisdictions facing similar land cadastre issues. This potential is discussed in some detail by reference to the current situation in the USA, the issues faced by the public and private sectors and the federal vision for a national land cadastre.

This report has been prepared by Michael Johnson & Associates Pty Ltd, an independent consulting company based in Sydney, Australia. The respondent survey work and technology assessment was funded by the Commonwealth government of Australia through the awarding of a COMET grant to Geodata.

1. Introduction

1.1 Cadastral Information

A cadastre is a parcel-based, contemporaneous land information system containing a record of interests in land (e.g. rights, restrictions and responsibilities). It usually includes a geometric description of land parcels linked to other records describing the nature of the interests, and ownership or control of those 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. planning and other administrative purposes); and enables sustainable development and environmental protection.

Central government, local government, utilities and emergency services need reliable spatial information to make necessary strategic and operational decisions. Spatial analysis and decision-making requires geographic information about the natural world (eg topography, water resources, soils and vegetation) as well as the physical features which humankind has added (transport systems, utilities and services and other structures). There are also the essential spatial administrative constructs in the form of land ownership, land use patterns and jurisdictional boundaries which require spatially accurate recording and representation. The need for determining, providing and accessing cadastral information of the appropriate accuracy is fundamental in supporting these demands.

There has been a longstanding commitment by central governments internationally towards providing core spatial information products and services – primarily for the apparatus and proper process of legislation and administration. In turn, government organisations have ensured that it is available for local government and individual citizens to access and use spatial datasets when they need them.

The area of spatial information generally is burgeoning. In 1998, the US National Academy of Public Administration reported that US$3.56 trillion of economic activity in the USA was directly related to accessing and applying geographic information.

1.2 The Evolution of Digital Cadastral Databases (DCDBs)

Most DCDBs began life as government-based spatial information output as a quickly digitised version of existing paper cadastral plans, records and maps. Many of the DCDBs were conceived, built, distributed (sold) and then incorporated into embryonic GIS in the late 1980s and early 1990s. These GIS systems have now become highly complex and multi-layered (in some cases hundreds of layers). They are now viewed by suppliers and users as a core spatial information asset which requires constant maintenance in content, form and function. More recently, they have come under increasing scrutiny as presenting spatially-inaccurate information when compared to the other available spatial information data layers which are in frequent use, and especially with spatial data captured with GPS.

DCDBs have become an integral part of the spatial information asset in Australia and New Zealand over the past two decades and have been provided by Australian State Agencies and the New Zealand government as a fundamental dataset. The adoption (purchase, installation and updating) by territorial Local Authorities (TLAs) and utilities has been widespread across the Australian/New Zealand spatial information landscape.

1.3 The DCDB Value Chain

In Australia/New Zealand the supply of DCDBs is presently dominated by state, territory or national agencies which are charged with the tasks of topographic mapping. However, more recently this role has been assumed by regional or local government or even large metropolitan utilities, e.g. water due to the perceived spatial inaccuracy of the underlying DCDB.

Smaller, so-called second tier suppliers, usually in the private sector, are also playing a key role by value-adding to basic DCDB information or customising it for individual users. Users of early DCDB material frequently amended inaccurate coordinate data by undertaking additional or remedial work themselves. Sometimes, users supply amended DCDB data back to the original suppliers in a spirit of goodwill to improve the overall DCDB system.

The trend for some DCDB users to update their DCDB layers unilaterally is believed by some industry commentators to mitigate against the option of improving interoperability – particularly if the DCDB itself is being used as the linkage. Further, a side effect of advanced complexity has been the embedding of data/process/practice within organisations to the extent that some users are reluctant to shift spatial information databases because they will need to re-adjust other spatial layers. This group regards the costs of such shifts as economically inefficient (due to disruption costs) even though spatial accuracy may be improved. This has implications for the introduction of greater spatial accuracy in DCDB as a fundamental framework layer – ***unless there are transformations that are readily available and easy to install and use, changes in spatial accuracy will not be welcomed.***

In Australia/New Zealand macro-demand for DCDB information is characterised by national and state agencies, emergency services, local and regional government and various forms of utilities. At the micro-level, the customer base includes individual firms or organisations down to the level of the sole professional practitioner: surveyor, planner or valuer. The demand side has also been driven by the technological diffusion of GIS with extremely complex spatial overlays to aid analysis and decision-making resulting in an ever expanding number of uses and users within organisations. Primary suppliers therefore have to meet the needs of a wide-ranging customer base making direct and indirect use of DCDB on behalf of their tax-payers, clients and rate-payers. These sectors include:

- Central government departments and agencies
- Local and regional government
- Emergency services
- Homeland security
- Cadastral surveyors
- Engineering and construction industry
- Scientific R&D
- Education
- Environmental management
- Agriculture, farming and forestry
- Mining and quarrying
- Property and real estate
- Transportation
- Utility and asset management

The economic dynamics of the DCDB supply/demand cycle therefore needs to define and understand the trade-offs between spatial accuracy and the accompanying costs which might or are being incurred in achieving different levels of DCDB spatial accuracy.

1.4 DCDB Spatial Accuracy

The demand for survey accurate Digital Cadastral Database (DCDB) systems is being driven worldwide by the need to take full advantage of sophisticated Geospatial Information Systems (GIS) and new technologies for defining accurate coordinates such as Global Positioning Systems (GPS). In Australia and New Zealand, this demand comes largely from a proportion of local government and utility DCDB users. For example, one utility encapsulated their accuracy requirements in terms of "***to within half a bucket*** (of an excavator) ***width***"

A recent study (July 2003), commissioned by the Australian Intergovernmental Committee for Surveying and Mapping (ICSM), where a wide cross-section of DCDB users took part in a survey of their requirements, revealed that 40% of current applications were not adequately met in terms of DCDB spatial accuracy. The cadastral information uses where respondents indicated that spatial accuracies of better than 0.5 metres are required for the following applications:

- Cadastral parcels
- Services mapping
- Some GIS applications including layer basis and analysis
- Physical change (positional) disturbance
- Utility location and management (mostly local government)
- Engineering design
- Survey and engineering plans
- Infrastructure planning

Respondents seeking this level of accuracy were in the main represented by local government and a small proportion of utilities.

Perceived accuracy is also a function of different land-use area types ranging from commercial to rural and the accuracy of existing DCDBs used by respondents, as shown in the Figure 1 below:

Land use type	Accuracy range (m)	Median accuracy (m)
Commercial	0.1 – 5	2
Residential	0.1 – 10	2
Peri-urban	0.3 - 30	5
Rural	2.5 - 500	20

Figure 1. Perceived spatial accuracy obtained from existing DCDBs in Australia

1.5 Costs and Benefits (Cost Savings) Associated with DCDB Spatial Accuracy

The same study attempted to assess the costs and associated savings associated with improved DCDB spatial accuracy by considering the economic impacts incurred through three cost categories:

Avoidance costs when organisations have to behave proactively in order to prevent problems arising from spatial inaccuracy before they occur.

Mitigating costs made up of the resources required to address the spatial inaccuracy impacts after problems have occurred. These included:

- reworking and correcting inaccurate or spatially incompatible DCDB spatial data to enable spatial matching
- engaging consultants to produce survey-accurate data
- creating and maintaining mutant and/or duplicative databases
- informing and educating staff and external users of the spatial inadequacies
- finding a cost effective way of integrating accurate GPS data with an inaccurate DCDB
- dealing with the various legal ramifications arising from spatial inaccuracies
- data loss/audit from earlier systems

Delay costs resulting from inaccuracy problems which delay the use and output of applications of information packages relying on the framework layers, including the DCDB, together with specialist and customised layers. For example:

- time and effort spent preparing reports detailing problems, contacting the supplier and waiting for remedial action
- finding a means of coping with the resulting confusion and uncertainty
- having to remedy wrong decisions, e.g. incorrect land acquisition
- delays in decision-making dependent on accurate underpinning e.g. planning applications and flow-on impacts affecting rating and building departments.

The survey generated some interesting findings regard the qualitative costs of spatial inaccuracy:

- the presence of spatial uncertainty generates additional costs particularly when the level of uncertainty is itself unknown and remedial investigation/action is required "just in case"

- the increasing difficulty of integrating multiple data sets; this becomes a serious issue for users because one "poor" layer (in terms of accuracy) can degrade the overall value of the multiple layer application

- at a transactional level, the overt costs associated with data modification and enhancement together with covert costs linked to barriers to information sharing resulting from DCDB inaccuracy

and benefits accruing from improved spatial accuracy which included the important ability to offer new or improved services as a direct result of DCDB accuracy enhancement.

In terms of quantifying the benefits (cost-savings) of survey accurate DCDBs, the ICSM study quoted respondent estimates ranging from \$3,000 to \$300,000 in operating budget savings per annum. These figures equate to between 0.1% and 25% of annual GIS budget. Using mean respondent data, the report concluded that, typically local authorities and some utilities currently incur costs to mitigate or minimise the impact of less than desirable DCDB spatial accuracy amounting to 10% of their GIS budget. The table below shows the range of savings per parcel as a function of cadastral size. However, based on other commentary made by respondents, it was further suggested that intensive DCDB users in high-price land areas, where there is considerable infrastructure investment, would achieve savings at the higher end whilst spatially wide ranging (e.g. State-wide) organisations such as utility companies predicted lower cost saving per parcel from updating the accuracy of their cadastres (Figure 2):

$ Per Parcel	>1M parcels	100k – 1M parcels	20k-100k parcels	<20k parcels
Weighted Average savings	0.021	0.36	2.90	2.51
Range of savings	0.0035 – 0.026	0.07 – 0.75	0.33 – 5.00	0.48 – 5.55

Figure 2. Cost savings from DCDB accuracy, ICSM Survey in Australia 2003

Researchers in the USA (United States Geological Survey) have advocated an empirical approach to estimating the GIS benefits from improved accuracy. This methodology links efficiency and effectiveness to:

- input complexity: number of data themes, volume of input data and land area of the cadastre
- analysis complexity: number of concurrent cadastral layers, interaction between data sets; and
- output complexity: including products of a specific application and output uses.

Applying this approach to Australian respondents, the ICSM study concluded that:

- The majority of DCDB users make use of 4-5 spatial data layers.
- The greater the number of themes overlaid, the greater the manual inputs required and the larger the potential for efficiency benefits.
- Spatially inaccurate DCDB can impose a diseconomy of scope on a range of spatial applications of DCDB users. This is due to adjustment costs incurred before full use can be made of other, more accurate, layers.
- Moreover, this study concluded that the willingness to invest in new GIS applications is often compromised by a lack of spatial accuracy and the limitations of existing DCDBs.
- DCDB users are aware that an improvement in spatial accuracy will remedy many problems associated with the use of more advanced GIS capabilities and improved integration of datasets.

1.6 Investing in Enhanced DCDB Spatial Accuracy

Research undertaken by ICSM and published in their 2003 report, asked a variety of DCDB users the investment quantum (sensible for those funding improved DCDBs) appropriate to gain different spatial accuracies. The results of this survey are shown in Figure 3 below together with respondent's comments on the reasonable charge per parcel made to users for the various accuracy categories:

Accuracy (metres)	Considered Investment	Considered Charge
	$ per parcel (mean)	
<0.1	3.48	0.69
0.1 - 0.3	1.95	0.33
0.3 – 0.5	1.42	0.28
0.5 – 1	0.85	0.20
1.0 – 5.0	0.43	0.14
>5.0	0.44	0.10

Figure 3. DCDB users' perceptions of DCDB accuracy investment and reasonable charges

This study shows that there is a comparative decline in investment value between <0.1m accuracy and >5m accuracy consistent with a rise in trade-off between accuracy categories and perceived value as one moves towards higher DCDB spatial accuracies. The downward shift between "investment' and reasonable "charge" is explained by the likelihood that users will always understate the real value of spatial accuracy enhancement to their organisation.

2. Solutions Provided by Geodata Technology

2.1 Technology Development and Commercialisation

The Geodata software technology described in this report was developed by a private company, Mimaka Ltd, whose principals are Michael Elfick and Michael Fletcher.

Michael Elfick is the principal developer of Geodata survey and cadastral software. He is a research associate with the University of Newcastle and a distinguished Fellow of the Australian Institution of Surveyors. Michael Elfick has a long history in practical surveying and software solutions for surveyors including principal surveyor on notable projects such as Sydney Opera House.

Michael Fletcher has been responsible for the software development and has played a major role in the delivery of pilot projects, particularly the DCDB upgrade for the Northern Territory government. He has participated in a pivotal way with both hardware and software development for many government and statutory authorities.

Mimaka confronted the lack of systems for processing survey data and land descriptions during the early 1990's, resulting in the development of the Geodata suite of software programs, to cost effectively convert the metes and bounds land descriptions to coordinate-based cadastres.

2.2 Intellectual Property

Geodata Information Systems Pty Ltd (Geodata) is a private company incorporated in Australia in 2000 whose purpose is to commercialise the Mimaka technology. Geodata has entered into worldwide license agreements with Mimaka on a royalty and shareholding basis.

Geodata has registered patents for the unique "panel networks process and the breakthrough "feature set transformations" process contained in the *GeoCadastre* software; both patents are defensible in Australia and the USA. The *GeoSurvey* and *GeoCadastre* names have been trademarked in Australia.

2.3 Competitive Advantage

Geodata and its associates have completed two years of product development and testing to bring the two software products GeoCadastre and GeoSurvey to a status suitable for global commercialisation. During this period, the software products have been applied to a wide range of DCDB upgrades in Australia and New Zealand and have been endorsed by academic, commercial and public sector organisations.

GeoCadastre is a Windows based cadastral process that allows conversion of metes and bounds derived DCDB data into coordinate accurate parcel networks. This unique process, involving the principal operations of data entry, parcel joining, network adjustment and creation of associative vector files, allows original survey data to be retained creating a complete and precise cadastre. The embedded, automated "associativity" tool creates correction files that allow the alignment of associated information layers within a GIS.

The adjustment program step provides the key to the process that involves a least squares iteration to analyse and recognise the original survey data. Dimensions are automatically weighted to reflect the original survey practice and accuracy. This allows the final coordinates of parcel corners to be derived from a minimum number of GPS accurate control points. The technology offers specific competitive advantages over competing techniques:

- Process speed and efficiency combined with at least a 75% reduction in field survey work to secure GPS accurate control points.
- Eliminates the need to convert input data e.g. quadrant bearings.
- Implied dimensions e.g. road widths are generated automatically as connection vectors.
- The software is interactive in that it displays the land parcel geometry on screen as the data is entered.
- Compatible with major GIS software with the additional benefit of functionality to compare data sets and create vector transition files to resolve the associatively between different GIS information layers.
- Low cost – use of the software is less than half the cost of photogrammetry and other digitising technologies; typically reducing costs from $30 to $15/parcel.

GeoSurvey

This software is built on more than 20 years of survey and systems experience. It is a very efficient Windows based geometry and design program to assist surveyors and engineers in the cost effective management of survey and design functions. Although the technology has been used successfully as a standalone package, in the context of this report, it is used in conjunction with *GeoCadastre* where it offers the following benefits:

- High degree of input and output flexibility with formats compatible with advanced surveying equipment.
- Accommodates a wide range of proprietary GIS software.
- Records cadastral data "on the fly" with edit and replay facilities.

2.4 Competing Technologies

There have been two software technologies introduced into the Australian market in recent years for the specific task of upgrading DCDBs. Whilst both technologies claim to upgrade the DCDB coordinate system, their shortcomings and inferior performance to *GeoCadastre* have been exposed through either high costs, slow performance or residual DCDB inaccuracies:

- The ACRES software product, offered by Clatworthy Consultants and funded by the Queensland Department of Mapping, attempts to improve the existing DCDB dataset by importing resurveyed parcel dimensions. The program does not incorporate the fine detail of the original survey data and on more that one occasion, *GeoCadastre* has been called upon to redeem the inadequate results produced by ACRES.

- The Spatial Adjustment Engine developed by Roger Merritt and his colleagues has been shown to be both very slow and cannot claim the accuracy demonstrated by *GeoCadastre*.

The land information upgrade undertaken in New Zealand employed an EDS software program to populate a database and subsequently generate new parcel coordinates. This approach is particularly inefficient and requires further processing to generate an image of the parcel network.

In Europe, two software products have been commercialised for improving the integrity of cadastres. These include a Swedish product, *ArcCadastre*, and another least squares adjustment engine created by the University of Delft in the Netherlands. Neither approach is suitable for converting a metes and bounds cadastre to a coordinate-based system.

In the absence of a dedicated software program similar to *GeoCadastre*, the alternative approaches to converting a DCDB to an accurate, coordinate base system involves conventional techniques such as photogrammetry, resurveying with GPS instruments, digitising existing maps or COGO data entry. Each of these solutions has inherent accuracy problems which cannot be resolved without propagating existing errors. They are also less cost effective than *GeoCadastre,* Figure 4:

Conversion Process	Benefits and Shortcomings	Cost $/Parcel
GPS Field Survey	Labour intensive but survey accurate	>100
Digitisation of maps and photogrammetry	Line work only – no survey integrity	>30
COGO in a parcel network and adjust	Includes dimensions- errors propagate	25 - 50
GeoCadastre	Cost efficient and survey accurate	15 - 20

Figure 4. Comparison of DCDB upgrade techniques

GeoSurvey has several competing products in the survey software market such as *Liscad* and *GeoComp*. However, *GeoSurvey* offers distinct benefits in providing the ability to interface with a wide range of information layers and structures in GIS. GeoSurvey software is also keenly priced in comparison with competing products, Figure 5:

Survey Software Products	Cost ($/Seat)
International	
GeoSurvey	2,243
Liscad (Leica)	6,438
PayDirt (Trimble)	11,128
GeoComp	2,670
Australian	
Terra Model	2,766
CivilCad	4,328
Foresight	715
12D	3,179

Figure 5. Survey software cost comparison

2.5 Endorsements and Alliances

This report provides detailed case histories of the successful application of the Geodata Technology in generating coordinate based DCDBs for a number of State-wide and local government organisations in Australia. In addition to these applications, the software products have been evaluated and used on live projects by the ACT Government and the New Zealand government through a project for the Dunedin municipal authority.

For many years the development of the software products has been evaluated and verified by some of Australia's leading engineering consulting firms and academic institutions including: Connel-Wagner, Qasco, CadCon (a Queensland-based licensee), Sinclair Knight Merz, Whelans, Parsons Brinkerhoff and the University of Newcastle.

Geodata is currently in discussion with the world's largest GIS software provider, ESRI, to explore opportunities for integration and marketing of Geodata Technologies. Further opportunities in the USA, promoted by an independent assessment undertaken by Fairview Consultants, is offered by the 3,700 Counties and 28,000 townships seeking solutions to private sector land tenure through coordinate based survey plans.

Recently, Geodata have appointed their first authorised distributor in the USA, IDAS located in Miami, Florida.

3. Case Histories

3.1 Methodology

Each State and Territory in Australia has its own land cadastre; there is a further cadastre covering the whole country. The cadastral surveying industry in each State/Territory is made up of three main groups:

- the land titles authority, which manages the cadastral record and provides quality checks on new data;
- registered surveyors, who provide the data for the cadastral record; and
- the state/territory government, which sets survey standards and has overall control of registered surveyors.

The reform of cadastral systems from the metes and bounds cadastre derived from existing land records has not been smooth. No jurisdictions are yet complete, few are accurate and only some interface with other information resources. This situation has arisen in part due to bureaucratic infighting, a failure to coordinate public/private sector activities and the use of inappropriate technologies to convert digitised survey plans into spatially accurate cadastres. For example in New Zealand, a project undertaken by a contractor EDS used a methodology involving the population of databases with a large number of (unrefined) coordinate datasets – this resulted in huge cost blowouts estimated at $200/parcel.

The Northern Territory represents the best of Australia's cadastres and will shortly become the first jurisdiction to have a complete, numerically defined cadastre. This is due in large part to the use of Geodata Technology to process the original dimensional data and adjusting it to fit with GPS derived control points. More recently, a number of local government areas in Queensland have employed Geodata Technology, applied through a licensed consortium of private sector surveyors (Cadcon) to generate numerically accurate, coordinate-based cadastres. These projects have been completed within budget, on time and to the specified accuracy.

These cadastral reform projects, involving the use of *GeoCadastre* and *GeoSurvey* software, have been summarised below together with exercises involving a water utility and rural council in New South Wales. Where possible the scope of the exercise and specific cadastral issues are highlighted together with the benefits delivered by the use of Geodata technology.

Respondent input to the evaluation of Geodata Technology was achieved using a combination of face-to-face and telephone interviews followed by written correspondence addressing issues set out in an informal questionnaire. In addition, reference has been made to published material covering cadastral upgrades in various jurisdictions and technical descriptions of Geodata Technology in peer review journals. A summary of respondents and literature references is provided in Appendices 1 and 2 respectively.

3.2 Case Study 1: A Legally Enforceable Coordinate Based Cadastre for the Northern Territory

3.2.1 Background

Since 1993, the Northern Territory government, Department of Infrastructure, Planning and Environment) has implemented a series of initiatives to upgrade its DCDB so that it is survey accurate. This requirement has been driven by two converging requirements:

- the need for better decision making tools by combining real world spatially compatible data sets from multiple custodians ; and
- fundamental reform of the cadastral survey and land title system.

The NT cadastre covers over 1.3M km^2 of central northern Australia but only has approximately 53,000 parcels of land. The majority of parcels are contained within the urban areas of Darwin, Palmerston, Katherine, Tennant Creek and Alice Springs. Pastoral leases and Aboriginal lands make up the majority of Territory land mass. Pastoral leases range from 200 to 12,000 km^2 and Aboriginal lands range up to 96,000 km^2. These large tracts of land are typically only part surveyed which causes unique survey coordination problems, and for which the Geodata adjustment software was been specifically developed.

When the NT cadastral spatial upgrade project started over ten years ago is was justified as part of the normal improvement to spatial systems, in particular the graphically accurate, Digital Cadastral Data Base (DCDB). Whilst it was recognised that the cadastral survey process could be turned into a digital equivalent of the current 'paper' based system, the NT did not have some of the drawbacks of its southern counterparts in many confused boundaries, adverse possession or a very large and complicated cadastre. The opportunity was therefore taken to implement significant cadastral reform by proposing a 'legal' coordinated cadastre. The ability to define the cadastre by coordinates would strengthen the government's guarantee of indefeasibility of title and provide efficiencies in the cadastral survey system.

Urban area accuracies were about 3 to 5 metres and pastoral areas are many 100's of metres in error. The decision to incrementally improve the spatial accuracy of the DCDB by adding better data as it became available was not seen as a long term solution. Development activity in some areas would take decades before new data became available and the subsequent flow on improvements to associated data sets would languish. It was decided to use the inherent rigour in existing survey plan dimensions and combine it with the upgrade of the geodetic infrastructure to the new geocentric datum to systematically roll out cadastral redefinition and coordination areas across the Territory.

3.2.2 Creating the Coordinate Based DCDB

An initial project involved converting 20,000 parcels and 10 different categories of easement in the urban areas of Darwin/Palmerston (~25 km^2) into a survey accurate cadastre that could demonstrate a correlation of <50mm with control points. Typically, the raw data involved:

- Original plans, some dating from 1880 but the majority post 1960. Recent plans were known to have an accuracy of ~20mm, whilst older documents were several meters out from GPS determined control points.

- Each plan contained approximately 10 parcels/plan; newer residential suburbs contained fewer parcels.

- The project involved making 10 control points for each 250 parcel area. During the course of the project, it was established that **70%** of these control points were superfluous and by placing the new cadastre over the control mesh, **only 3 control points/250 parcel area were required.**

- Many transcription errors in original survey plans were identified by the *GeoCadastre* software, confirming the inherent strength of the technology which relies on written numbers rather than drawn lengths.

The use of *Geocadastre* software and the preparation of the new survey-accurate cadastre involved a five-stage process:

- *A design strategy*: where the total cadastre was divided into 250 parcel areas followed by hard copy printing of individual 10 parcel plans.

- *Data entry*: each parcel required 7-10 keyed-in pieces of information plus a further 4-5 items of administrative data eg “leasehold” or “freehold”. Following parcel closure using the feedback function, any transcription errors in the original survey plans could be identified.

- *Parcel joining:* using local control point coordinates, the parcel network was joined typically involving 6 joins/parcel.

- *Adjustment*: each 250 parcel area was adjusted using ~10 geodetic control point data sets. This process took ~2 minutes of computer run time and allowed the accuracy of all parcel intersections to be determined and additional control points to be entered as a quality control measure.

- *Checking*: finally, an independent operator would check each 250 parcel area.

The experience gained on this project during 1995/96 allowed a number of process costs, associated with the use of *GeoCadastre* technology, to be determined. Using the above steps, it took **24 person hours to process a 250 parcel area**. The cost schedule for these activities is shown in Figure 6 and is based on combined labour and overhead costs of **$18/hour**:

Process Activity	**Cost/Parcel ($)**
Design strategy/printing individual 10 parcel lots	0.5
Data entry: parcel	1.0
Data entry: easement/other features	0.5
Parcel joining	1.0
Adjustment and checking	1.0
TOTAL	**4.0**

Figure 6. Labour costs for data entry using Geocadastre software

The contractor then allowed a further overhead cost of $0.5/parcel and 50% profit margin on processing costs of $2.0, yielding an overall cost to the Northern Territory government of **$6.5/parcel**. At the time that this work was carried out, alternative processes (eg photogrammetry and rubber sheeting) were investigated and costs as high as **$30/parcel** were estimated.

A feature of the Geodata technology, highlighted by the NT project, is its compatibility with surveying practice of disconnected editing. Conventionally, cadastral database systems only permit live editing. The Geodata technology, however, allows the isolation of a packet of data (i.e. an area containing a selected number of parcels) to be worked on independently and then reinserted into the database. This is achieved by a set of rigorous rules that allows the database to recognise the data and re-integrate the updated parcel information. Thus, cadastral data maintained by surveyors at a local level can interact with and benefit from the territory-wide DCDB.

Approximately 70% of the Territory has been processed to survey accuracy to date but only pilot areas have to date been loaded into the DCDB. Further, 40% of land parcels in the NT have been redefined using the *GeoCadastre* software to survey accuracy which in urban areas is conservatively +/- 0.02m, in rural areas is +/- 0.1m and pastoral areas is +/- 1m at the one sigma level.

With regard to rural/pastoral areas, typical zones or lots of 6 degree widths had been surveyed with conventional instruments that had ignored the earth's curvature over this distance. The *GeoCadastre* system allowed conversion of zone coordinates into accurate GPS derived longitude and latitude coordinates, creating a seamless parcel map for remote areas of the Northern Territory.

3.2.3 Benefits Recognised by Key Stakeholders

As a direct result of the cadastral reform process, the NT Surveyor-General will progressively declare Coordinated Survey Areas (CSAs) within which geodetic coordinates (latitude and longitude) can delimit land boundaries. The use of *GeoCadastre* software for rigorous parcel adjustment resulted in the first CSA, Palmerston (a satellite city of Darwin) being declared in 2003.

It is expected that, once all CSAs are declared across the Territory, the cost of maintaining the cadastre to government will reduce significantly. The NT government will still be responsible for maintaining the geodetic infrastructure to support coordinated cadastral survey activity. However, most field activity will be the responsibility of the private sector as part of the normal subdivision process but will require the density of current marking requirements. It is anticipated that the marking regimes can be further reduced in remote areas and in some instances the innate rigour of GeoCadatsre software in preserving the integrity of original survey plans will mean that no field survey at all will be required.

The major economic benefits promised by the spatial upgrade of the cadastre will include:

- Integration and efficiencies in the land development process by conducting all transactions in the digital media.

- Digital data transfer from government's data bases (DCDB and other spatial data sets) and the use of that data to assess, design and frame land development proposals and the final submission back to government of a land development proposal.

- Internal efficiencies will come from the automatic use of associated data (upgraded to an equivalent level of accuracy by *GeoCadatsre/GeoSurvey* software) to update the Interests and Development layer of the DCDB which can then be used by all agencies involved in the development, assessment and approval process, including those external to government.

- The key efficiency factor will be the ability to reliably integrate public and private spatial data sets, without the costs of manipulation, scaling, 'rubber-sheeting' or rigorous checking by either party at any point in the business process.

As an example, in the land development process, government need only be concerned with the mathematical fit of a land subdivision proposal into the DCDB which needs to fit exactly and be consistent with the parent parcel coordinates sourced from the DCDB. The digital survey plan will not need to show datums, adoptions and proof of definition for government to be satisfied cadastral integrity has been maintained prior to title issue. This will eliminate the cost of preparing 'paper' plans and the examination of those plans by government. NT cadastral activity is small by interstate standards with about 200 plans per annum being lodged but it estimated that this could result in a **$200,000 saving to the survey industry on official plan lodgments alone**. In addition, there will be commensurate cost savings to the NT government.

Without the catalyst of an authoritative cadastral infrastructure, no improvement to the many associated data sets can be realised and the efficiencies from automated integration will be lost. The NT government is confident that, the associativity tools and resulting upgrades of the disparate silos of spatial data maintained by multiple agencies, will result in significant cost savings.

3.3 Case Study 2: Queensland Shire Councils

3.3.1 Background

In order to meet its core business requirements and user expectations more effectively, the Queensland State Department of Natural Resources (DNR), proposed in the late 1990s enhancements of cadastral survey observations and maintenance of the spatial component of the DCDB. The DNR had recognised significant and unpredictable between DCDB coordinates and the geodetic datum arising from the different survey methods used in original compilation. This resulted in spatial information users in Queensland operating in a “two-datum regime”, causing additional work in data capture and unacceptable differences in geodetic-referenced data overlaid on the DCDB.

There are 125 local government councils in Queensland, of which, 50% are estimated to require DCDB upgrade projects. To promote this initiative, DNR has provided free access to cadastre data to maintain a survey-accurate DCDB and deliver benefits to three primary stakeholders: the DNR itself, the GIS community (in particular local government asset management), and the surveying industry. The principal benefits recognised are:

- DNR’s titling function would benefit from efficiencies in plan audit and DCDB maintenance. The statutory role would be enhanced by having a system that facilitated cadastral reform;

- The GIS community would gain from having an accurate, stable spatial representation of cadastral boundaries consistent with the geodetic datum; and

- The surveying industry would benefit from access to digital information and achieve participation in the creation and maintenance of the DCDB.

3.3.2 Creating the DCDB

In early 2000, a leading Queensland-based surveying company, CadCon, responded to tenders for DCDB upgrades using licensed Geodata software as a source of competitive advantage. The principal benefits cited by the licensee included the advanced data compilation capability of *GeoCadatsre* and its associativity attributes allowing the land parcel cadastre to be directly linked to other layers of GIS asset information.

Beginning with a pilot program of 2,000 parcels for Hervey Bay Council, CadCon proved the benefits of the *GeoCadastre* software and impressed the client with:

- the speed at which survey plan data could be accurately captured in terms of spatial coordinates and attributes

- the joining process for adjacent parcels to establish the topology; and

- the sophisticated adjustment process.

CadCon subsequently secured DCDB contracts with 3 Queensland shire councils: Hervey Bay, Maroochy Shire and Noosa Shire. The contracts were associated with DCDB upgrades involving the following parcel components, Figure 7:

Shire Council	Number of Parcels	Urban/Rural	Area (km^2)	Contract Duration (Months)
Hervey Bay	22,000	80/20	3,200	12
Maroochy Shire	54,000	70/30	5,000	6
Noosa Shire	24,000	70/30	4,000	6

Figure 7. DCDB upgrades undertaken for Queensland local authorities using Geocadastre

Typically, these assignments involved 15% field work effort with the remaining activities taking place in the office. Approximately 10% of existing control points were used whilst the remaining 90% needed to be re-surveyed for GPS accuracy. The DCDBs were divided into design areas of 5,000 parcels and then further sub-divided into 500 parcel lots to allow the definition of control point survey and data input strategies based on an analysis of survey data: age, accuracy, subordinate information, etc. The resulting DCDB accuracies achieved (as required in the tender specifications) were:

- urban parcels, 95% of all nodes within an accuracy of 0.1m
- pastoral/rural parcels, 95% of all nodes within an accuracy of 0.5m

The CadCon project work for the various Queensland local authorities reported on above was delivered under a licensing agreement with Geodata where CadCon paid a royalty rate of **$1.1 per parcel**. Typically, CadCon secured the 3 tender contracts at a charge-out rate to the client organisation of **~$16 per parcel**.

The following section summarises the experience of Maroochy Shire Council regarding the use of Geodata technology in their DCDB upgrade project.

3.3.3 Benefits Recorded by Local Government Shire Councils in Queensland

In response to questions regarding the acknowledged benefits accruing from a coordinate accurate DCDB, respondents from the 3 Queensland based local government authorities volunteered the following advice:

- Infrastructure assets such as storm water systems can be accurately placed and located on the DCDB including such fine detail as: inlets, outlets, pipes, manholes.
- Assets such as park furniture, bus shelters, nature strips, road features (e.g. roundabouts, traffic islands, etc) can now be captured by overlaying Aerial Photography with the new DCDB. This eliminates the need to send two-man team and vehicle into the field and is consequently reducing asset maintenance and procurement costs.
- Maroochy Shire Council is currently investigating the downloading of DCDB data to hand-held and in-car computer systems to allow accurate placement and location of infrastructure assets collected by field crews equipped with GPS instruments.
- Planning of parking spaces has been streamlined; officers are able to calculate lines of sight and distances from intersections and corners using Aerial Photography in conjunction with the DCDB, avoiding the cost of using field survey teams for this activity.
- The line integrity of the DCDB, preserved by Geodata Technology allows the interpolation of road lengths directly from the DCDB. Again this eliminates the need for field survey teams for the costing of road maintenance projects.
- The upgraded DCDB has halved the time required (equivalent to 6 man-weeks) to input data relating to utility features, e.g. associated with the installation of new water meters. In addition, the associativity tools allow powerful analysis to be applied to other DCDB layers such as soil condition, contours, etc.
- Councils now accept digital lodgment of Subdivision Survey Plans which are imported into the DCDB with a minimum of manipulation to achieve an acceptable ongoing accuracy.
- The coordinate-accurate DCDB, overlaid with photogrammetry images, has enabled future planning and costing of infrastructure projects such as bikeways and footpaths to be undertaken without the need for field survey activities.

3.4 Case Study 3: Hunter Water Australia

3.4.1 Background

Hunter Water Corporation (HWC) is a statutory, state owned corporation established in the State of New South Wales, Australia providing water and wastewater services to almost half-a-million people in the Lower Hunter Valley Region within five local government areas – Newcastle, Lake Macquarie, Maitland, Cessnock and Port Stephens. The total area served is 5,400 km^2. Underground assets (valued at $2 billion) total 8,000 km of pipe network serving about 250,000 properties.

Hunter Water Australia Pty Limited (HWA), a wholly owned subsidiary of HWC, that provides a range of specialist technical, engineering, storm water, catchment, environmental and operational services to HWC and, on a contract basis, to other water agencies, councils, industry and urban land developers. These areas of expertise rely heavily on accurate asset mapping and linked GIS data layers.

HWA has a long history of survey accurate cadastral mapping and in the 1970s and 1980s prepared film base sheets using data derived from field connections between the State's Trigonometric network and cadastral marks shown on Deposited Plans. Coordinates for each land parcel on a plan were generated using hand calculators and coordinates were then plotted in ink on the film base sheets. Because the location of pipe nodes (manholes, stop valves, hydrants etc) were gathered by field survey methods satisfactory agreement between the pipe network and the land cadastre was achieved.

With the advent of computers and CAD in the mid 1980s hand drafting was largely superceded. The methods used for mapping in this period were essentially an adaptation of earlier techniques: bearings and distances were shown on deposited plans and subsequently keyed into a coordinate geometry software package. ***However, this approach had a major shortcoming: once the coordinates for parcel corners had been calculated, the underlying bearing and distance information, as well as the thought processes which led to particular choices for adjusting misfits between adjoining parcels, was lost.***

3.4.2 Creating the DCDB

In the early 1990s, the NSW Lands Department used Hunter Water's hardcopy film base sheets as well as the coordinate data held on computer, in addition to other hardcopy map sheets held by the Lands Department, to create the DCDB for the Hunter Region.

At this time Hunter Water commenced implementation of a GIS to record all of its underground pipe assets. The position of most of the pipe work was digitised from hard copy sheets; recent field data was simply added to the dataset. However, the land cadastre generated by the State Lands Department revealed poor spatial accuracy between the pipe network and parcel boundaries. Consequently, HWA commenced a program to accurately map the cadastre with the requirement to achieve a spatially accurate digital cadastre defined to "the width of a backhoe bucket" ~0.6m.

3.4.3 Stakeholder Benefits

In 1994, following earlier trials of Geodata software, HWA decided to adopt *GeoCadastre* for cadastral mapping.

The most important criteria driving HWA's adoption of *GeoCadastre* proved to be its superior mathematical rigour compared with alternative approaches such as spine traversing or infilling with coordinate geometry (COGO). The *GeoCadastre* software weights survey plan information according to age and adjusts large parcel networks by least squares and coordinate variation methods to generate seamless parcel networks in accurate association with the pipe work infrastructure.

A further compelling reason for using a workflow based on *GeoCadastre* was to stem data loss and preserve the integrity of the original, surveyed asset network. Because *GeoCadastre* retains original parcel dimensions, the parcel network can be regenerated at any time to provide updated coordinates. This became critical in areas where land parcel mapping was poor, due to the age of the original survey plans, but could be incrementally improved as older lots were subdivided and new, accurate coordinates were generated using GPS field surveying techniques.

Hunter Water Australia has now used Geodata software products for over a decade. The software technology works in concert with their GIS technology as well as with their robotic laser theodolite and digital echo sounding equipment.

Each day HWA adds data from approximately five new survey plans to the DCDB, equivalent to 2,500 to 3,000 new parcels per year. The Geodata Technology facilitates the addition of, easements and the mapping of surrounding parcels to improve the overall quality of the DCDB, particularly in remoter locations where land subdivision and development is occurring.

HWA have established that maintenance and updating of their DCDB can be achieved with a resource of 0.75 man-years. This is in stark contrast to a larger, adjacent water utility (Sydney Water) that employs a resource of 20 man-years to process 50 plans/day.

The introduction of a coordinate accurate DCDB has allowed HWA to reap the benefits of other advanced, cost-saving technologies:

- Their GIS has been deployed across the maintenance workforce allowing engineers, using a field version of the GIS on a laptop computer, to quickly identify the location of valves in emergency situations

- They have also been able to implement a system of electronic ground plan generation.

3.5 Case Study 4: Gloucester Shire Council, New South Wales

3.5.1 Background

Gloucester Shire Council (GSC) is made up of 5,824 parcels covering an area of 2,918 km^2. One third of the cadastre was mapped under the “Old Systems Title” system involving deed descriptions with the remainder comprising of pre and post-1970 survey plans; the council had re-surveyed approximately 1,900 parcels.

GSC were seeking to establish a GIS but wanted to use the existing coordinate cadastre and asset layers that they had already collected. The Land and Property Information (LPI) of NSW could only supply digitised cadastre data which was not compatible with the direction that the Council had chosen to take in establishing a coordinate accurate land cadastre. After attending the product launch of Geodata and after further discussion, GSC decided to contract Geodata to set up a coordinate based DCDB using GSC’s existing information.

3.5.2 Creating the DCDB

Although yet to be completed, the new DCDB has already revealed shortcomings in the LPI’s digitised cadastre – particularly the accuracy of parcel dimensions. There are also errors with the various azimuths that surveyors have used over the years, creating problems with the merging of adjacent parcels in the new cadastre.

This situation is being resolved through the use of *GeoCadastre* software and the coordination of existing survey control points with further control points surveyed within the Shire.

3.5.3 Stakeholder Benefits

GCS believe that the new DCDB will encourage the submission of future survey accurate plans that can be incorporated into the new system, hence relating all plans to the same projection.

The new DCDB is predicted to save costs in:

- asset maintenance because their precise dimensions and location can be reliably interpolated – eliminating the tedious and inaccurate method of using scanned plans and an inaccurate DCDB.

- the wider use of aerial photogrammetry with an accurate DCDB; and

- a DCDB based on a mathematical model rather than the time-consuming manipulation of distorted images to fit the cadastre.

4. Economic Analysis of Improving Spatial Accuracy in DCDBs

4.1 The Australian Experience

A recent review of the economic case for improved spatial accuracy in Australian DCDBs conducted by the Intergovernmental Committee on Surveying and Mapping (July 20003) considered the business cases for 4 options for improvement:

Option 1**:** Gradual Coordinate based Spatial Accuracy Improvement.

This is the current approach to spatial accuracy improvement in most DCDBs where, as part of the regular DCDB maintenance process, new survey plans are used to update the DCDB with respect to changes in cadastral boundaries including the creation of new parcels and the deletion (or "retirement") of superceded parcels. Where a new survey generates more accurate coordinates for points represented in the DCDB, the corresponding DCDB points are upgraded. Some DCDB also allow for DCDB points not coordinated by the new survey but in the vicinity of the new survey to have their coordinates modified too.

Option 2**:** Selected Area Survey Observation Based Spatial Improvement.

In this approach to DCDB spatial improvement only selected area(s) will be addressed. Survey observations from cadastral survey plans defining current cadastral points and boundaries would be entered into a database together with a weighting factor that reflects the accuracy and reliability of each observation. A computerized application readjusts these observations (using least squares methods) whenever new observations are entered and new coordinates are derived as well as residuals and other statistics that indicate how accurate the new coordinates are. These revised coordinate values are exported into the DCDB.

Option 3**:** Combined Cadastral Reform and Selected Area Survey Observation Based Spatial Improvement.

This approach is similar to Option 2 (Select Area Survey Observation based approach) except that it would be developed as part of a comprehensive cadastral reform programme with the survey observation database becoming the authoritative legal record for cadastral surveys. Where cadastral surveys are approved following the establishment of this approach, the spatial accuracies, for parcels within the area under survey, would conform to legal cadastral tolerances.

Option 4**:** Resurvey Spatial Improvement

This approach is the same as Option 2 in that only selected areas will be covered by this approach. It will also be based on the adjustment of survey observations, the difference being that these will be new field measurement based observations rather than existing survey plans (as is the case in Option 2). A computerised application will adjust these observations (using least squares methods) and repeat the adjustment whenever observations from new surveys are entered. The new coordinates as well as residuals and other statistics resulting from the adjustment process and indicate the spatial accuracy of the new coordinates are exported into the DCDB.

The study referred to above presented a detailed Cost benefit Analysis for each of these four change options and concluded by calculating the Net Present Value (NPV) to fiscal jurisdictions (ie State Land Departments) of the investment costs and associated fiscal benefits; more wide-ranging economic benefits were not included. The assumptions made in the NPV calculations were as follows:

- Option 1 (the current approach in most jurisdictions) is taken as the baseline case.
- The NPV figures are based on a 10% discount rate and a 7 year investment period.
- The cost/benefit data assumes a 5 year program of DCDB spatial accuracy improvement involving 1M largely urban parcels.
- Costs and internal savings were derived from the DCDB reform program undertaken in New Zealand.
- For Option 3, a special Cadastral Reform levy is charged (estimated to generate $18.8M over 7 years).

The cost assumptions for each scenario are shown in Figure 9:

DCDB Upgrade Option	Application Software costs	Additional Survey Control Costs	Data Capture Costs and Adjustment
Option 2	6 x GIS single user licences @ $3k 2 x Specialist GIS user licences @ $6k	$365/new control point	$10/parcel
Option 3	$9.8M over 2 years	$365/new control point	$24/parcel
Option 4	$9.8M over 2 years	$365/new control point	$250/parcel

Figure 9. Principal Costs Associated with DCDB Upgrade Options

Data capture costs are one of the most significant expenditure items in all three non-baseline options. Hence, data capture cost variations on budget estimates are likely to have a significant impact on the financial position of DCDB upgrade projects. This revealed in the NPV calculations for each DCDB upgrade option, Figure 10:

DCDB Change Option	NPV (Fiscal) $M
Option 1	0
Option 2	-0.7
Option 3	31.5
Option 4	-257

Figure 10. NPVs Associated with DCDB Upgrade Scenarios

The results confirm indicative assessments of the change options in that:

- Option 4 is very expensive
- Option 2 is very risky unless funding arrangements can be guaranteed or the scope of the areas to be covered is limited; and

- Option 3 is the most attractive from an investment perspective. The NPV delivers significant fiscal and economic benefits and funding is dependent on the volume of new cadastral survey (and title) transactions lodged.

The experience in the use of Geodata technology in Australia to date has been largely consistent with the criteria associated with Option 3. This report has demonstrated that the use of Geodata software, through a licensed contractor, has allowed the total data capture costs, additional survey field work and profit margin to be restricted to **$16/parcel**. The cost assumptions used in the ICSM model suggest that the investment benefits from using GeoCadastre and GeoSurvey are likely to be **even more NPV positive** than suggested in the value for Option 3, Figure 10. This augers well for the application of the Geodata Technology in other jurisdictions seeking to upgrade the spatial accuracy of their digitised land cadastres using selected area improvement combined with cadastral reform.

4.2 Opportunities in the USA

The original subdivision pattern for the cadastral boundary framework in the USA can be broken into four distinct groups:

- The Eastern states were originally settled in an “ad hoc” manner with settlements being made by chartered trading companies and merchant adventurers. The authority of these companies came from European thrones and sponsors. These groups held land in common ownership and as the colonies grew, land distribution was made to individuals or groups. Each parcel is defined by the metes and bounds of its surround together with dimensions connecting some corners to adjacent parcels. Parcels may be of any size or shape and each survey may be oriented differently with respect to true north. The definition may be a written legal “description” and or the information shown on a plat (the US name for a cadastral plan defining one or more parcels). This means that the original subdivision pattern is similar to that of the settlement in the eastern states of Australia.

- Texas has a similar type of “Chaotic” pattern, but the original pattern was developed under Spanish law.

- Hawaii incorporates some British common law principles with traditional boundaries from the original inhabitants.

- The remainder of the country (about 40 states equivalent to ~ 80% of the country) was originally subdivided under the Public Lands Survey System (PLSS) devised by Jefferson after the revolutionary war. In 1785, the first public domain was established as land held by the government. The purpose of the PLSS was to inventory the land and subdivide it into orderly lots for distribution. The PLSS is nominally one mile by one mile area called sections. Thirty six sections combined in a six mile by six mile block forms a PLSS Township.

When land was originally allocated in the USA, measurement techniques were often very crude and the actual dimensions and shape as marked on the ground frequently do not agree with the dimensions on the parcel subdivision network or “plat”. In general, regardless of the nominal dimensions on the plat or in the land description , the original marking defines the actual land allocated and this may be more or less than that stated on the plat. As elsewhere in the world, with the advent of GPS, it is again becoming increasingly important that position based cadastral references correlate as closely as possible to the position on the ground.

In most states in the USA, cadastral surveyors are licensed and work to set standards. As in Australia, they are liable for their work and this has maintained standards despite a lack of overall control by land administration authorities; in some areas the record systems of surveying companies is more complete than that of the local authority. The day to day administration of land subdivision is carried out at the town and county level. The degree to which this is diligently undertaken depends very much on the local authority. Very few places have a "torrens" system of land registration. In some authorities the public record system is fairly complete, while in others it is almost non-existent. Many authorities employ a surveyor to examine new plans of subdivision before they are accepted.

Currently in the USA, there is a nationwide project, The National Integrated Land System (NILS), involving collaboration between the public and private sectors, working at both state and county level, to develop a common data model for the collection, management and sharing of survey data and land record information. The Federal "vision" is for the creation of an accurate, complete and seamless cadastral network for the whole of the USA. This will be achieved through the provision of a base framework into which data, generated at a county level, flows.

This is an enormous undertaking and will probably evolve over a long period of time. However, the current cost of title insurance and title uncertainties associated with most development projects (particularly in inner cities) provides ample justification for spending substantial sums in system reform.

Currently, there is no suitable software for managing the subdivision patterns in either those Eastern States outside the PLSS or those that have a subdivision pattern which hangs off the PLSS. In their discussions with ESRI, Geodata have demonstrated that the Geodata technology portfolio provides a user friendly interface for disconnected editing and workflow that efficiently and effectively carries out the surveying function with mathematical integrity in addition to contributing to the upgrading of the national cadastre.

ESRI believe that the Geodata Technology will provide them with their promise to customers to ***build a bridge between the Survey and GIS communities.*** ESRI believe that the value proposition to stakeholders in land records Is strong and that Geodata Technology provides an ***economic alternative that satisfies both legal and cadastral surveying demands.***

Appendix 1: Case Study Respondents

Respondent Name	Affiliation	Case Study Reference
Mike Elfick	Mimaka Pty Ltd	1
Mike Fletcher	Mimaka Pty Ltd	1
Roger Lee	Geodata Information Systems	
Gary West	Surveyor General, Northern Territory Government	1
Terry Gadsby	Department of Infrastructure, Planning and Environment, Alice Springs, NT	1
Roland Maddocks	Department of Infrastructure, Planning and Environment, Alice Springs, NT	1
Adrian Perry	GIS Manager, Hervey Bay City Council	2
Mandy Lewis	Data Integrity Manager, Maroochy Shire Council	2
Max Ainsco	GIS Manager, Noosa Shire Council	2
Peter Todd	Department of Natural Resources and Mines, Queensland State Government	2
John Gillespie	Director, CadCon	2
Peter Bartlett	Principal Surveyor and Manager Asset Mapping, Hunter Water Australia	3
Julian Schneider	GIS Manager, Gloucester Shire Council	4

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