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COORDINATION OF THE NORTHERN TERRITORY CADASTRE

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ABSTRACT

A process to alter the existing conventional cadastre of dimensions and monumentation to a Coordinate Based Cadastre is presented. This process is being implemented in the Northern Territory. It is opportune due to the technological changes and advances being experienced in the areas of GPS measurement and computer based geographic information systems. It is timely to introduce this change as part of the conversion to a geocentric datum.

INTRODUCTION

The Northern Territory is progressively coordinating all the land parcels using the existing cadastral survey data together with the Territory Geodetic Network (TGN) plus additional control. This process brings together all of the available evidence as to the location of boundaries in an area and provides a basis for determining the most likely position on the ground for each corner. At sometime in the future areas will be "proclaimed" and after that date a coordinate will define each corner absolutely. The process could be likened to that in an alignment survey in NSW but on a broader scale.

MANAGEMENT CONCEPTS

What is a Coordinate Based Cadastre?

Coordinates can be used either as an additional piece of evidence to aid in the definition of boundaries, or they can be used to define the absolute position of parcel corners.

Where a new subdivision has been connected to the geodetic network, then those boundaries can be relocated to a high degree of accuracy even if all the existing marks were destroyed. A coordinate used in this way is simply a dimension from a known point and can be used to compute a connection from any other point in the geodetic network. So, in the first instance, coordinates can be used to aid the redefinition and to take the place of reference marks.

This use of coordinates can be taken a stage further if the coordinates are used as the definition of the corners themselves. In South Africa they are used this way and the intention in the Northern Territory is to move to such a system.

MAPNET

In the late 1970s and early 1980s a Digital Cadastral Data Base (DCDB) was developed by the Northern Territory Government. "MAPNET" was developed mainly through the digitising of the graphical presentations of the cadastre but there was inadequate funding for it to be survey accurate. It is a useful tool. However with positional errors of up 3 or 4 metres in urban areas it is not accurate enough for service authorities and progressive upgrading causes them severe operational problems. In the pastoral areas positional errors in the order of kilometres are not uncommon.

With the commonplace usage of GPS and DGPS which enables positional accuracy for services, there is a need and expectation that boundary coordinates be of a similar accuracy.

Why form a Coordinated Cadastre?

The cadastral system in Australia evolved at a time when it was relatively easy to measure lines but very difficult to find the exact location of a point on the Earth's surface. The accuracy specified in regulations for marking of land and the definition of boundaries is a reflection of the measurement technology of the era.

The availability of GPS and the expected technical development of this type of equipment is going to have a considerable impact on all aspects of surveying and in particular the cadastral sector. *There now is less work in the fixing of a position than there is in measuring a boundary* and the cadastral system will have to adapt to take advantage of this new technology.

The current methods of boundary definition have provided an effective guarantee of title over a long period of time. However, computer based geographic information systems are "position oriented" and there is a need for the cadastral system to be in a form compatible with all other geographic based data sets.

To change to a coordinate based cadastre will be at least as significant as the change to Torrens Title in the 1860's. Torrens Title provided a system for guarantee of title and *a coordinate based cadastre is a system to guarantee the position of the land itself.*

With the changing nature of the workplace experience in boundary re-definition in rural areas is being lost. All new subdivision work is also coordinate based.

There is a demand for coordinate data building up as the general public as GPS becomes more widely used by the general public. Already, pastoralists in the Northern Territory are using it to locate remote boundaries for fencing purposes. Apart from datum uncertainty, potentially huge errors may occur by misuse of the MAPNET displayed coordinates.

The technology is now available to build a "survey accurate" cadastre from the original survey data in an economical manner. The process coordinates evidence of the original marking and maintains the integrity of the original surveys.

Where are the Current Boundaries?

In the Northern Territory cadastral boundaries have in general been measured with great care and as a result there is little difficulty in re-establishment by measurement from existing survey marks providing that the marks still exist. While GPS holds the promise of providing an accurate and rapid positioning system, it is important that the coordinates to be derived for each parcel corner represent the position on the earth's surface of the actual "legal" corner. There is no point in moving to a coordinated system unless it provides a certainty of boundary position equivalent to that available at present.

COORDINATION - URBAN AREAS

Background

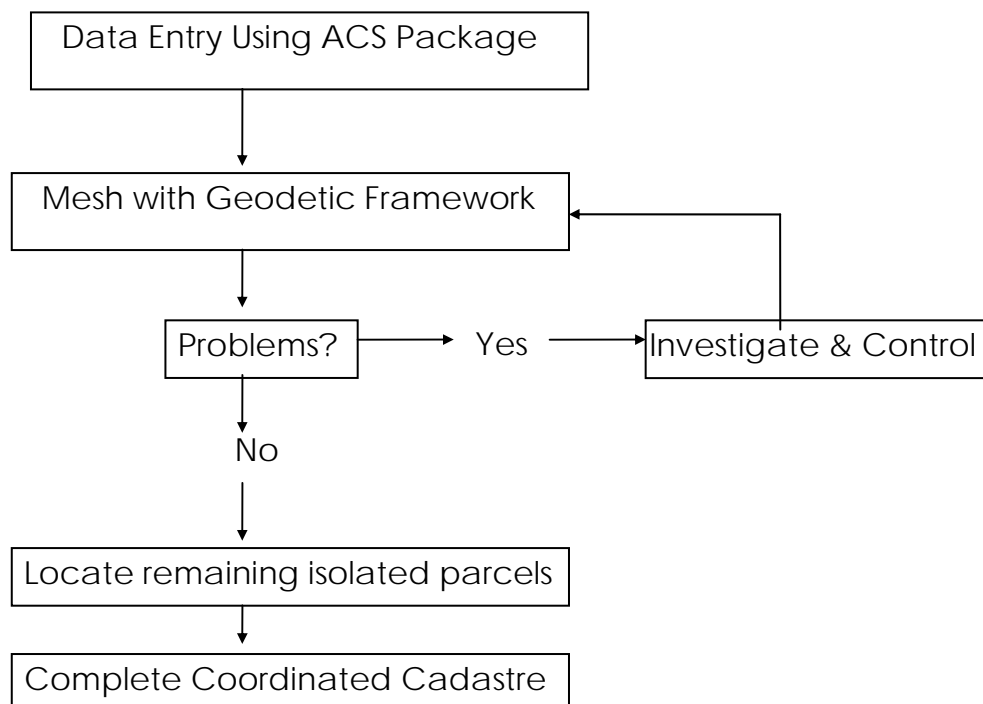
The intention of a subdivider is displayed on the subdivision plan and while a purchaser may buy the land as marked, there is an expectation that the dimensions of the parcel are close to those shown on the plan. Considerable weight should be given to trying to adhere as closely as possible to the original subdivision design provided that there is sufficient land available.

The problem that every surveyor faces when redefining an old boundary is what to adopt as evidence to the original marking. Clearly, the subdivision plans are documentary evidence as to the original intention and survey marks such as old pegs, reference marks etc., give evidence as to the location of specific corners and the quality of the survey work. Other physical objects such as old fences and structures can also be used to provide guidance if the original marking is gone.

As time progresses and evidence of the original subdivision marks are lost, there is a tendency to favour the adoption of "monuments over measurements" and the original subdivision pattern becomes irregular and disjointed. Surveyors often select a solution which will minimise the chance of litigation rather than try to define the true location of a boundary. Most resurveys are carried out under tight cost constraints and therefore are limited in area and in the amount of detailed investigated. The use of all available data to build a coordinated cadastre which truly reflects the correct position of a corner is a logical extension to the existing system.

Conversion to a Coordinated Cadastre

In general, the approach to be adopted will be to use dimensional data together with selected control points. This has the potential to provide accurate good use of data from the current record system. In the Northern Territory this is an invaluable resource.



The Territory Geodetic Network (TGN) provides the Geodetic framework for the controlling the coordinate base. Its datum is GDA94 which has been formally adopted by the NT government.

The dimensional data is derived from the lodged cadastral plans and is entered and manipulated using the ACS software package.

A key issue is the balance which is applied between the adoption of the position of existing survey marks and the adoption of dimensions shown on documents in order to guarantee quality assurance and consistency in the results.

At one extreme one could simply adopt all survey marks and distribute excesses and shortages between the marks found. This would result in irregular street frontages and road widths and distortion in parcel dimensions especially in older subdivisions.

For practical reasons it is better to work on a group of between 100 and 300 parcels at a time. All data for each area is first entered, then assembled and adjusted to a local origin. This provides a check as to the internal consistency of all the plan data for the group. A selected number of survey marks can then be coordinated and used as absolute control. The adjustment is then re-run to compute geodetic coordinates for the parcel corners and assess the accuracy of the plan data.

Depending on the weights allocated to connections to the coordinated marks, this process can be used to maintain original dimensions and street widths wherever possible and distribute small errors in the connections to control points. The method is like fixing boundaries by "occupations" where the subdivision pattern is shifted until a "best fit" is achieved with the occupation pattern.

The solution adopted will probably lie somewhere between these two extremes and will depend on the guidelines adopted for the transition process. These guidelines will have to take into consideration the legal definition as to what people actually own and the weighting to be placed on the existing dimensional data.

The process of mathematically joining and adjusting all of the dimensional data for an area is not only a comprehensive way of analysing the documentary evidence, but it also allows the surveyor to analyse the likely quality of marks found as physical evidence of boundary position. Many local anomalies can be only be explained by looking at the complete picture.

What is the Existing Data Quality in the Northern Territory?

This will vary from place to place and will to a large extent depend on the age of surveys. However, except for some locations, most areas are a mixture of old and new work and by working with blocks of 200 to 300 parcels at a time some definite trends emerge.

The cadastral pattern is often complex with a great deal of "connectivity" between the parcels which creates a very redundant data set. Under these circumstances, errors can be isolated *provided that all of the data is used*. Perhaps these points can be best illustrated with some examples.

The first example was with the Town of Batchelor. The data set comprised 16 cadastral plans and 190 parcels and 35 coordinated points. After joining, four of the coordinated points were

used as control and the area adjusted. The remaining points were then used as a check to see how well the coordinated cadastre fitted with the physical marks in the ground.

After the adjustment which held the original parcel dimensions very closely, the standard error of the residuals on the test points was 19mm and the largest error being 38 mm (see table below). Many of the points were below 5 mm and at this stage no study has been carried out on those points with the larger errors. The size of these residuals would change if different control points were selected or if more points were used.

Comparison of Control Coordinates with Cadastral Values

Control Points with fixed values

Pt.	East	North	Pt.	East	North
17	5260.462	4773.023	55	5521.564	5074.034
24	5084.228	4941.635	27	5150.760	5143.455

Coordinated test points and differences to Cadastral Values

Control Values				Differences(mm)				Control Values				Differences(mm)			
Pt.	East	North		East	North			Pt.	East	North		East	North		
21	5176.731	4853.140		7	2			32	5312.626	5013.904		2	9		
22	5163.513	4865.783		4	2			23	5097.445	4928.993		4	0		
31	5242.690	5080.812		2	1			34	5293.488	5008.271	25	11			
35	5313.032	4995.620		5	9			37	5460.796	5011.963	6	10			
39	5441.846	4998.462		4	4			40	5524.972	4944.250	12	7			
41	5523.974	4943.811		12	5			42	5506.854	4936.272	3	3			
43	5528.626	4778.962		4	10			45	5510.341	4778.555	4	0			
46	5583.863	4761.901		4	28			47	5602.150	4762.308	1	26			
48	5729.766	4783.424		5	18			49	5748.457	4765.528	1	17			
50	5742.382	5039.972		27	8			52	5724.268	5031.992	23	0			
53	5597.434	5153.339		30	14			54	5534.208	5087.248	0	1			

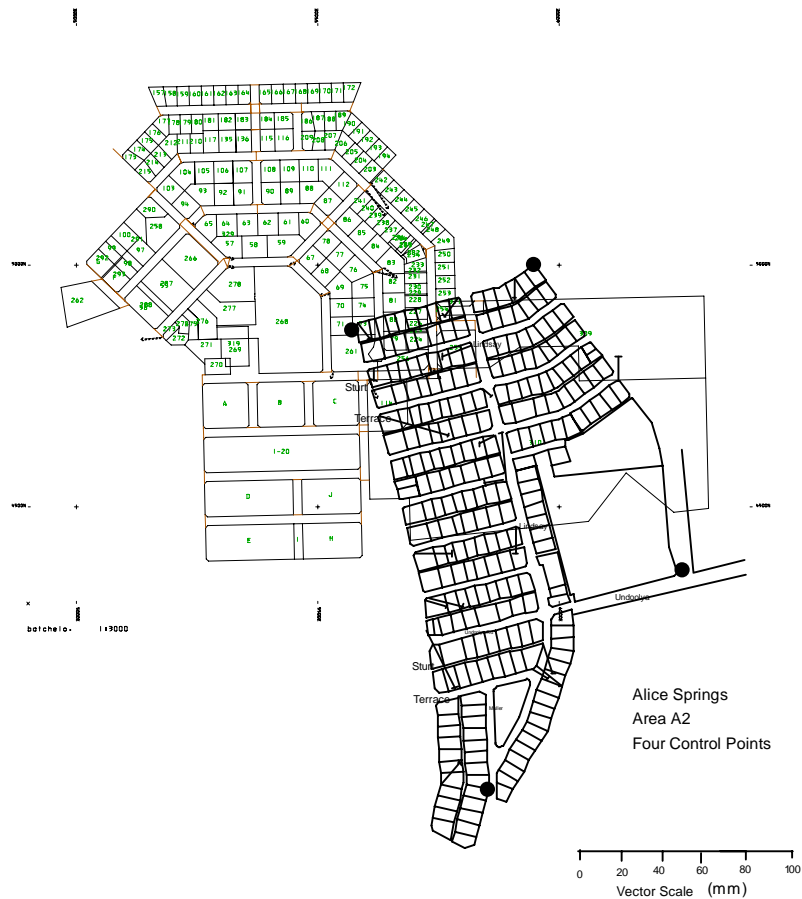


Figure 2

The second example is from Alice Springs in Central Australia. It is an urban area in flat terrain and most of the survey plans are dated between 1945 and 1975. As part of their work towards creating a coordinated cadastre the Department of Lands, Planning and Environment have coordinated by precise traverse all the remaining old reference marks and have also fixed points by GPS using Leica equipment in "rapid Static" mode.

Initially, four GPS points were used as control and these gave differences of less than 100 mm for most points with an obvious trend towards the south end of the area which indicated that one of the old reference marks was unreliable. The area was then readjusted using the traverse values and a more suitable mark used for the most southern point. As shown by figure 2, the residuals on the reference marks were less than 30mm for most points and the difference between plan dimensions and those computed from adjusted coordinates was less than 10mm. There were three reference marks which exhibited large residuals and it is likely that these were either badly placed originally, or have moved in position due to road works or other disturbance. Effectively the process has determined the most likely position for the parcel corners after considering all the available data and has computed the connections to the actual position of each of the reference marks left by the original survey.

The above two examples show that the cadastral framework can be used to generate a coordinated cadastre with limited control and that the framework itself can be used to select control points which best represent the plan data. The coordinates which are generated can be made to reflect the shape of the original subdivision pattern, or fit closely to later boundary

marks depending on the number of control points and the weight allocated to their position. It then becomes a management decision as regards the form that the derived coordinated cadastre will take. To very closely follow the positions of all available survey marks is both costly and may not really reflect the original subdivision boundaries. By accepting the fact that any marks found will have errors in position and will not necessarily be exactly on the boundary, it is possible to closely adhere to the original subdivision geometry in most cases.

In time, the coordinates for each old area will tend to stabilise and at that stage these values could be proclaimed to uniquely define the parcel corners. Once an area has been proclaimed then all of the old historical plan data becomes redundant and the boundaries are defined by coordinate values of the corners. This may be likened to the "curtain principle" of the Torrens Title.

COORDINATION - RURAL AREAS

Background

The rural areas provide different types of problems to the urban areas. Parcel sizes vary from less than a hectare through to leases of thousands of square kilometres. There are many isolated parcels and often surveys are for parts of boundaries rather than encompassing whole parcels. Whereas the urban plans have a high degree of "connectivity", this is not true for rural boundaries.

Mostly the surveys are from the era of theodolite and steel band and onward. Marking is generally still in existence, often in the form of steel pegs and steel pins. Where boundaries have been fenced the original marking often remains in tact. Connections to trig points are not uncommon but there is little in the form of absolute control.

Dimensions on survey plans are good, but azimuth control is a problem despite regular sun observations. There is a need for more absolute control to stabilise each adjustment area.

The older plans (A, B and OP series) show measured angles, azimuth observations and measured lengths. On long line surveys there is no point in entering every distance shown as this will simply complicate the data entry and adjustment process without improving the quality of the final adjusted coordinates. A better approach is to mark up the key points along each boundary and only enter the total bearing and distance between each key point.

The key points to look for are the bends in the boundary, the points which connect on to adjacent surveys and any point which has been coordinated or connected to a geodetic mark. On some boundaries the surveyor may read bearings to a nearby trig station from several points along the boundary. From these a connection can be calculated to the trig point and if more than two bearings are read, then it is possible to estimate the accuracy of the connection.

Operational Procedure

Once a region has been selected, all the survey plans are assembled. Images of all plans have recently been captured onto CD which assists in this task. A cross reference table is built up showing each plan and the plans that it is connected to. New plans show reference to adjacent older plans but not always vice versa, so the cross reference table can be built up to give a complete picture of the connectivity of the area as well as ensuring the plan search data is complete. It is also useful in planning the joining process.

An initial "first pass" field survey is undertaken using GPS. Points selected are preferably easy to access by vehicle, and tend to follow features such as main roads, stock routes and railway and pipeline corridors. Marking is best restricted to the adoption of existing charted survey marks. Most such marks can be allocated a simple unique identifier based on the numbering on the plan of its placement. The best marks are steel pegs or concrete posts shown on lodged cadastral plans.

For example a bend in the Hugh River Stock Route may be required for control. Inspection of search (plan A833) indicates a concrete post placed in 1971. In the field a concrete post stamped "86" is found in good condition, stable and apparently undisturbed. Using an offset tape both nearby reference marks are found undisturbed at the distances indicated on the plan. The mark is clearly suitable to be used as a control mark in the long term. Existing documentation and recording is adequate and its precise location will be available for any future work. The mark requires re-tagging to clarify its unique identity (A833.86) but usually no further action is required. Should this mark be unsuitable or difficult to re-establish it is often best to visit the nearest suitable stable existing mark rather than spend resources establishing a new mark.

GPS measurements should be for an appropriate amount of time (dependent on baseline length and equipment). It is best to have observations to two base stations simultaneously or be enclosed in a traverse loop. Experience has demonstrated that errors in point identification and instrument setup height are infrequent and if unidentified are insignificant.

In this type of work it is unnecessary and impractical to recce each point. The point is selected, measured and documented in the one visit. The advantage of this methodology becomes a commonality of reliable survey marks in both cadastral and geodetic frameworks. There is minimal additional fieldwork to connect cadastre to the geodetic framework, and minimal calculation. Because the marks have been located from the search there is minimal new documentation (identifier, description, location and history). The result is that during the course of coordinating the cadastre the geodetic control has been greatly densified at no extra cost.

Assembling the Parcels

Having the geodetic control file in place the parcels can be assembled using the ACS cadastral software. The key points on each plan are marked and for older plans bearings and distances along the boundaries are derived by use of the measured angles and by summing the measured distances between key points. As the cadastral software will rotate each survey on to the azimuth of the adjacent plans as it is connected, any suitable bearing can be used as a starting bearing. The adjustment will consider the bearings in a survey as "direction sets" and will apply the necessary geodetic corrections before using this data.

Plans of partial boundaries (that is they do not close the parcel) are given a special parcel code.

The surveys are joined in loops and each loop is completed before progressing to the next. It is best to start with a section which has the most control and run the adjustment after building each loop. In this way errors do not accumulate and the results of each addition are checked progressively.

Where there is a lack of connectivity or errors become apparent, decisions can be made for specific additional control. Logistical factors to consider include method of access, whether it be by motor vehicle, helicopter or boat. In the "Top End" the wet season must also be considered.

Once the framework has been completed and adjusted to a satisfactory level, then the remaining surveys are added to complete the framework. Isolated parcels which have been located by GPS or tied into the geodetic framework at time of survey can be added directly to the data base, provided the parcel has been oriented in some way. A typical example would be that of a microwave repeater station survey.

"Native Title" boundaries which have been fixed by GPS traverse and other means can be entered using the Geometry package and converted to parcel files. An example of this process is in the Hermannsburg area west from Alice Springs.

Accessing the Accuracy

When comparing the plan measurements to the geodetic control it is useful to consider distances separately from angles and azimuth.

Distance Comparisons

- (a) Steel chain and theodolite. This method comprises approximately half the surveys and by regulation needed to be good to 1:5,000 in country with slopes not exceeding 4 degrees. From experience it was expected this work would be better than this and commonly as good as 1:10,000. Where there were unclosed boundary lines most blunders would be due to the omission of a lay of the chain (ie 500 links).
- (b) Invar Chain and theodolite. The survey of the SA-NT border is an example where particular care was taken prior to the introduction of EDM. There are very few surveys of this type. The expectation was that this type of work would yield accuracies of better than 1:25,000.
- (c) EDM and theodolite. This group accounts for most of the remainder of surveys and was expected to yield better than 1:30,000 especially since constrained centring is commonplace.

Angular Comparisons and Azimuth Control

Methods (a) and (c) above would be equivalent. Most rural theodolite work in the NT has been with Wild T2 type theodolites. However most angles on long line surveys are measured under poor sighting conditions due to heat shimmer so that both random and systematic errors accumulated. Good azimuth was difficult to achieve and that can provide a significant source of error especially on long lines which make up the majority of rural land boundaries. The GPS technology directly addresses this so that we can now easily measure good azimuth and control long lines. Method (b) would be better controlled but is still subject to the same types of errors.

- (d) GPS controlled. This represents a small but growing number of surveys and is expected to yield in the order of anything better than 1:40,000 when comparing data in the conventional manner. Azimuth is excellent.

Inspection of the results confirmed the above expectations and in many cases the comparisons proved better than the estimates. Blunders and unacceptable differences could quickly be isolated and usually results in additional control being required.

BENEFITS OF THE COORDINATED CADASTRE

Initially the coordinates of the land parcels will be used to upgrade the MAPNET data base and will facilitate their location. The move to adopt coordinates for the legal corners of parcels will require legislative changes for the NT Government. However the cadastral coordination process allows a complete framework of the cadastre to be built up and an estimate made as to the accuracy of the coordinated points.

Surveyors may wish to extract geometry data from it along with the collection of existing plans as part of the "search process" before carrying out a boundary definition. Plans provide a visual record of previous surveys and the geometry data provides a numerical record of the boundary dimensions. In some instances GPS is replacing chainmen and can lead to one man field parties. There is increased productivity in establishing datum and it can eliminate random searching for marks.

As digital data becomes available the checking and charting process for new plans can be modified for instead of simply making comparisons on a line by line basis it will be possible to consider the new survey as a whole and see how it fits to the existing framework and the effect on the framework by the adoption of the new survey dimensions. Examining surveyors or draftsmen will join in the survey and get a report on how every joined parcel and line fits with the existing framework. An adjustment of the local area can then be carried out to see how the new dimensions affect surrounding parcels.

CONCLUSIONS

Surveyors have been developing coordinated cadastral data for some years. Nearly all computer based calculation systems are coordinate based and methods of working with miscloses as practised in "pre-computer" days have virtually been abandoned. Most survey firms have extensive record systems holding coordinates for cadastral corners in their local area. It is inevitable that cadastral systems will be coordinate based in the future and the transition from the current dimension based system will require careful thought and planning if we are to maintain the reliability and quality of the existing system.

The existing geometric data can be effectively used to help generate coordinates for existing parcel corners provided that the appropriate systems are put in place. The software must be designed to efficiently process cadastral data and it must be able to correctly handle the miscloses which exist in nearly all of the older survey plans.

The use of all documentary evidence such as plans and written boundary descriptions will facilitate the initial coordinate production and also produce values which are likely to be very close to the intended position of each parcel corner.

REFERENCES

West , G.C. “Coordination of the Pastoral and General Tenure Boundaries in the Northern Territory” *Internal Report, Department of Lands, Planning and Environment, March 1994.*

Elfick, M.H. “A Cadastral Geometry Management System” *The Australian Surveyor, March 1995, pp 35 -40.*

Elfick, M.H. “Coordinating a Metes and Bounds Cadastral System” *Australian and South East Asian Survey Congress July 1995.*

Menzies, T. “ Northern Territory, Existing Digital Cadastral Database - October 1994” *The Australian Surveyor Sept ember 1995 pp 242-243.*

Maddocks, R . “Boundary Coordination in Rural Areas, South Alice Springs Region” *Pilot Project Report, Department of Lands, Planning and Environment, September 1995.*