The State of the Qld DCDB: An Accuracy Assessment in the Mackay Region

Luke Cimpa, Australia

Key words: Cadastre, positional uncertainty, DCDB, Accuracy Assessment

SUMMARY

A Digital Cadastral Data Base (DCDB) used for land development, asset management and public interpretation of land boundaries, is expected to be provided to an accuracy that allows the end user to visualise their parcel of land, typically against aerial imagery. Non spatial specialists are unaware of the limitations and accuracies that are created through map digitisation and field measurements, which were prone to error when initially captured. In Queensland, upgrades to the DCDB have been driven by land development and government entities, resulting in a patchwork of land parcels which range in accuracy based on the capture method. In the Mackay Region a large area of parcels has been captured and updated to a higher standard.

This project's main objective was to assess areas not yet captured and identify areas of priority and discrepancies against the existing DCDB. By coordinating reference marks from surveys plans, categorised by their accuracy, applying standard statistical tests and direct distance comparisons, conclusions were made on the accuracy of the areas chosen to be assessed. The results indicate that all areas perform at a percentage greater than the assigned accuracies with some areas showing no need for further upgrade though the limitations in assessing the data could require further in depth comparisons. This analysis provides a quick overall evaluation, giving an opportunity to prioritise and allot resources better for future updating, which can be replicated by other organisations and even refined to smaller areas to gain an understanding of future needs of the DCDB.

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1. INTRODUCTION

Following a standardised process by using the best available cadastral maps, the Queensland spatial cadastre digitisation project was completed in 1992. By using existing cadastral maps, the variation of positional accuracy ranged from 0.1 metres to 250 metres. The Queensland State Government partners with local governments to assist the improving of the urban accuracy due to the importance of the state's land information systems (Queensland Government, 2023). This aligns with the Intergovernmental committee on Surveying and Mapping strategy, Cadastre 2034, outcome of '*A digital cadastre that is 3-dimensional, dynamic and survey accurate'* (ISCM, 2015). Following the efforts of the creation of the DCDB and the datasets, local authorities have partnered with state governments to improve the dataset and its overall positional accuracy. This has been due to the need of increased costs created by inaccurate digital cadastres when planning for projects and site assessments where cadastral survey wouldn't be an appropriate method of identifying the location of the cadastre. Professionals not involved in the geospatial industry are at risk of not being able to identify and gauge the accuracy of the DCDB and rely only on the assumption that the available data is suitable for their purposes and the expectation that the data is of centimetre accuracy (Carruthers & de Belin, 2021; Paudyal, 2007).

The DCDB is a multipurpose data base that holds information relevant to professionals in a variety of industries. Land administration, future land development, asset management, land taxation, land use, land tenure, and land valuations are among some uses of the DCDB which are reliant on accurate, reliable data to inform. The ability of survey technology to have an increased method of measurement accuracy is vastly superior, but due to the DCDB having been updated using the only available methods at the time, unless there is an effort to update using the advantage of technology the accuracy will always be at the level of its earliest capture (Thompson, 2015). To update the whole data sets and increase its overall PU to a level that is suitable for its many purposes, there needs to be a commitment from Government and professional industries to do so, and a way to complete without accumulating unnecessary time and cost. Efforts made by State Government Departments to upgrade the DCDB using desktop methods such as imagery should not go to waste when evaluating areas of the DCDB that need prioritisation of upgrade.

The study aims to evaluate the positional uncertainty values of the DCDB in Queensland using the Mackay Region as a case study area. The aim is to determine areas where the DCDB does or doesn't meet the assigned accuracy or areas where the upgrade process has applied a conservative value. This aim should answer two research questions, how reliable is the DCDB in the Mackay region? What areas can be prioritised for upgrading and what areas can be left as they are?

The paper is structured as follows: Section 2 discusses the current practice on assessing the DCDB using direct and indirect methods. Section 3 discusses material and methods which includes the discussion on the study area that will contain the land parcels for the assessment and the history of the DCDB update in the region; and the research methods used for the assessment. Section 4 discusses the results of the parcel accuracy assessment detailing each of the accuracy types assessed. Section 5 provides a discussion of the results and any findings and limitations of this study. Finally, a conclusion summarising the project, an answer to the research questions, and the potential for future work is presented in section 6.

2. LITERATURE REVIEW

Comparisons between digital cadastre data and field measurements have been completed ad hoc mainly in part when survey work has been completed as part of urban development and improving the DCDB would aid in future land development. This is mirrored by other organisations such as local government, mining companies, and public and private utility organisations (Butler, 2018). Methods used to upgrade portions of the cadastre, which assess the quality concurrently, have been either by a direct method, or an indirect method. An assessment on multiple methodologies for positional accuracy assessment and whether sample size of control points and spatial distribution would affect the outcome of whether positional accuracy requirements could be met have been completed and form a good base for a methodology (Ariza-Lopez & Atkinson-Gordo, 2008).

2.1. Indirect methods

Indirect methods of assessing the DCDB have been completed using high-resolution satellite imagery processes and techniques. The method involves updating cadastral databases that have been created from maps and field survey techniques. Ground control points are placed in the area to orthorectify the imagery and overlay with the maps creating a data set that can assess the positional accuracy of the parcels and update identified areas of interest (Dansena, et al., 2022). Where there has been a defined link between the topography and the digital maps that are able to clearly identify any boundary changes this method has been used to meet and acceptable RMSE requirements (Sengupta, et al., 2016; Čeh, et al., 2019) . This method can be completed at a reduced time and cost to an organisation compared to areas where direct methods are planned to be used and the density of vegetation and buildings limits the advantages of GNSS technology (Benduch & Pęska, 2016) . Any errors found when processing and orthorectifying images can be attributed to the multiple steps that are required as part of the process like scaling of images or error in the limits of the camera.

The benefits of utilising indirect methods such as satellite imagery and orthorectified photography are suited for large datasets and have been used to assess and update maps with varying degrees of success. The reliance on the number of checks that can be done on the georeferencing along with the locating of natural features and fence lines only cannot guarantee an accurate assessment (Butler, 2018).

2.2. Direct methods

The literature, when concerning direct methods of assessment of a digital cadastre aim to use field data from existing survey plans and use a mixture of computing methods such as least squares adjustments, rubber sheeting transformations and direct scaling of plan measurements to relate to field GNSS measurements. Carruthers & de Belin (2021) applied survey accurate coordinated reference marks gained by measuring and connecting the original plans to the existing DCDB models, and then applying a least squares method. This resulted in an improved DCDB model when comparing the updated model to the previous datasets. RTK GNSS methods when following technical standards of measurement allow the reduction of mean errors when determining boundaries in the field and measuring markers to gain the coordinated horizontal positions (Benduch & Pęska, 2016).

Even with two differing methods of assessment and updating of cadastral databases, the analysis of the methods relates. A root mean square error (RMSE) analysis was the predominant tool to measure the accuracy of the differences in the original dataset to the upgraded dataset. Results showed easting and northing differences along with standard statistical analysis of the mean, maximum and minimum, and standard deviations (Fetai, et al., 2022).

Assessing the parts of the DCDB which haven't been part of any upgrade process using survey control and direct bearing and distance entry from survey plans, or via least squares adjustments, can show areas of potential upgrade that can be identified in a faster, more cost-effective manner that could lead to a more focussed effort in upgrading the DCDB. Thoughts around the accuracy of the DCDB is that the position in an urban environment be no more than a shovel width (Grant, et al., 2018). The high cost associated with upgrading digital cadastral databases and their associate accuracies has been identified previously when attempting to adjust a whole of region area, so by upgrading sections of parcels at a time is more achievable (Merritt & Master, 1999). Most methods of assessment of PU have been part of a more refined project to assess and then update a specific area of interest. This research differs from previous research by assessing areas of the DCDB to identify those areas of interest and make a plan that allow for funding and resources to focus on areas that really need the improvement using a direct method of analysis.

3. MATERIALS AND METHODS

3.1. Site Selection

The Mackay region is located on the eastern coast of Queensland approximately 970 kilometres north of Queensland capital city Brisbane as illustrated in Figure 1. The region covers an area of over 8000km^2 with land ranging from coastal communities, rural sugar cane farms and National Parks along the Clarke ranges to the west (Mackay Regional Council, 2017). The main accumulation of urbanisation and land parcels are on the coast of the region with most land development occurring here and spreading west out towards rural areas. There are small and large localities scattered through the region leading to small areas of land development when heading west towards the Eungella Township, similarly, spaced out north from the main city centre towards the boundary of the Whitsundays and Sarina to the south (Mackay Regional Council, 2017). There are a variety of land types and parcel shapes and sizes that form these towns leading to a mixture of new and aged cadastre information (State of Queensland, 2024).

The need for a more accurate representation of digital cadastral information to inform for land development, project planning and asset management for the Mackay Regional Council, led the DCDB for the region to be progressively updated since 2001 (Mackay Regional Council 2024, pers. comm., 13 February). The DCDB has a PU assigned to each individual parcel and the accuracy assigned is relative to the coordinate of each parcel corner in the database which is in the state coordinate system of MGA2020. As of the 30/01/2024 there were approximately 92% of the region parcels that have been updated by direct bearing and distance entry and plotting by manual collection of reference marks and utilisation of a least squares adjustment or direct calculation and entry of bearing and distances from survey plans (Mackay Regional Council 2024, pers. comm., 13 February). Approximately 67% of the parcels have been assigned an accuracy of 0.1m. Analysis of the total area of the region that has been updated provides a different picture as to the total area of the region that has been updated. Based on an export of the parcel areas, there is approximately 8538km² of land parcels and of that area only 36% has been adjusted. This has left 5432km², or 64% of area left unadjusted (Natural Resources and Mines, Manufacturing and Regional and Rural Development, 2024). This is obvious when viewed in the below map where the orange shaded area shows the completed adjusted survey areas, leaving large rural areas still to be updated (see figure 1).

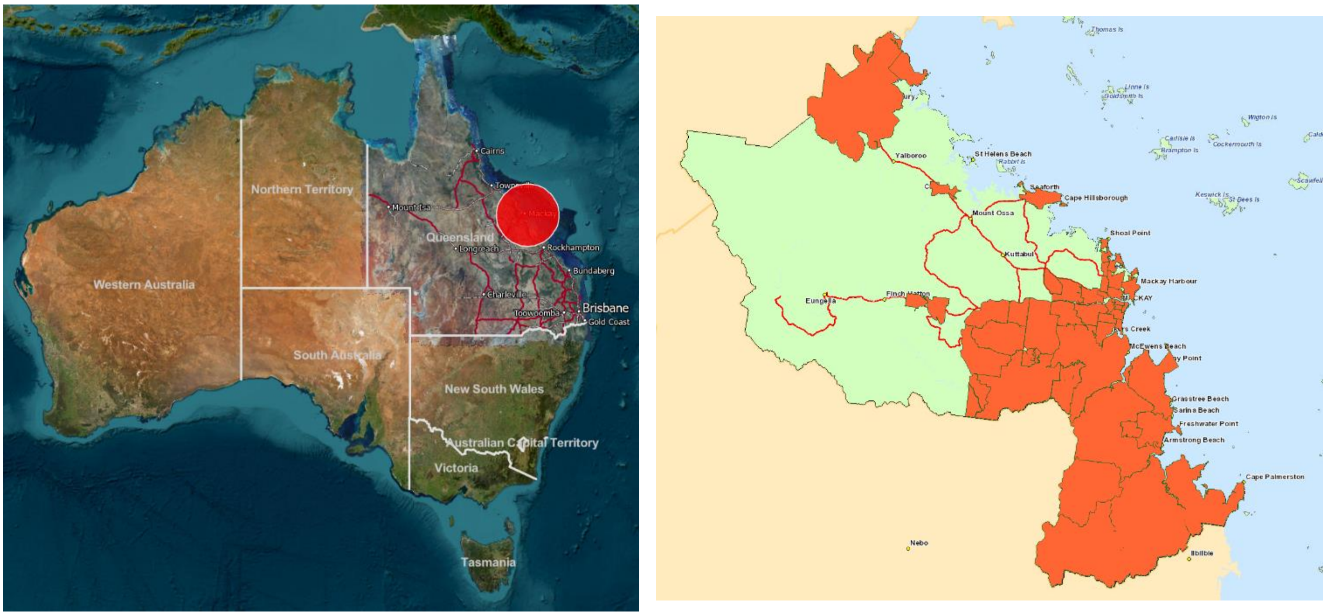

Figure 1 Location of Mackay in Australia, Qld Globe & Highlighted areas of existing DCDB adjustment, Mackay Regional Council Mapping (MADI)

The steps followed for obtaining and then measuring the DCDB and the coordinated parcel points follow figure 2 and are then explained in further detail below.

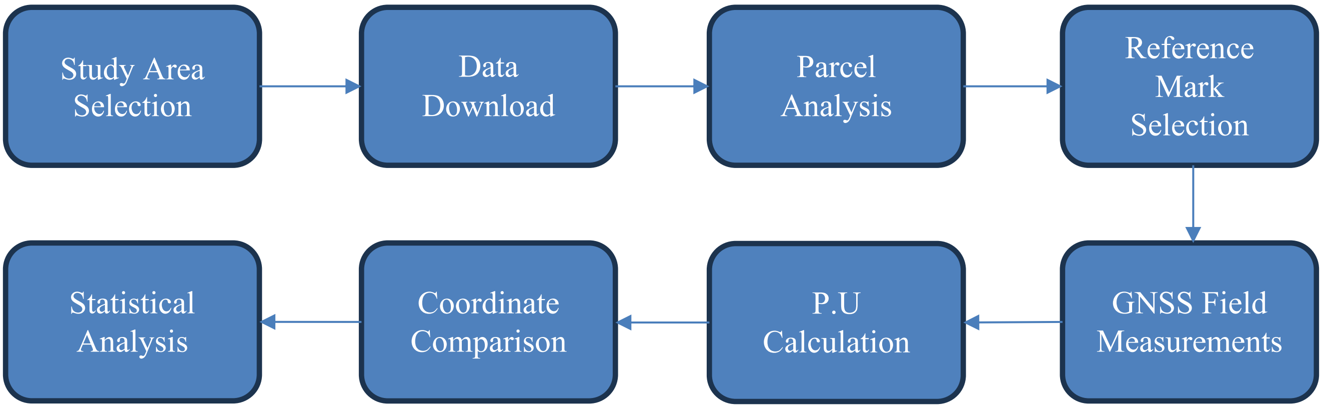

Figure 2 Flow Chart of Research Methods

3.2. **Data Sources**

The methods chosen to assess the DCDB by comparing against measured cadastral reference marks from registered survey plans in the Mackay region, were adopted considering the current technical standards for classifying uncertainties. The areas assessed inside the study area were selected as a subset of the whole region. The data chosen hasn't been adjusted or updated by techniques which are outlined in the ICSM Special Publication Guideline for Control Surveys by GNSS (ICSM, 2020), which has been used to update portions of the Mackay region by the Mackay Regional Council. Detailed examination of the methods employed is presented in the following sections.

3.3. **Study Area parcels and reference marks selection**

The data for the DCDB was imported into 12d Model, a surveying and civil software package, using a shapefile of the Mackay Region land parcels. Using attached attributes the data was then categorised into 21 models based on the accuracy of the parcel and coloured separately to distinguish between the models. The data was then exported into an excel spreadsheet which listed Lot and Plan, locality and accuracy type. Table 1 details the number of respective parcels in each accuracy type and the accuracy code was used as a reference for the source of the data which is explained in figure 3. Planning around the number of parcel points to be assessed and areas of focus were gained from this information.

Of the 21 parcel accuracy categories there were 13 chosen for assessment. 8 of the 21 were excluded due to the method of obtaining the parcel accuracy. Bearing and Distance Entry Controlled and Bearing and Distance Plot Controlled ranging from 0.1m to 5m have been previously updated by the Mackay Regional Council since 2009. Another 4 categories were excluded due to the nature of the parcels being either inaccessible or not having suitable survey plans allowing for searching reference marks.

Table 1 List of DCDB accuracy types in the Mackay region

DCDB Assigned Accuracies	Parcel Count	Accuracy Code
B&D ENTRY CONTROLLED - 0.1M	42334	B
B&D PLOT CONTROLLED - 0.25M	8528	B
B&D PLOT CONTROLLED - 0.3M	4831	B
B&D PLOT CONTROLLED - 0.5M	846	B
B&D PLOT CONTROLLED - 1.5M	25	B
B&D PLOT CONTROLLED - 1M	577	B
B&D PLOT CONTROLLED - 2M	218	B
B&D PLOT CONTROLLED - 5M	145	B
PARISH MAP 1:100000 CONTROL - 57M	186	I
STANDARD 1:10000 CADASTRAL MAP - 6M	724	S
STANDARD 1:100000 CADASTRAL MAP - 56M	29	S
UPGRADE ADJUSTMENT - 0.25M	3	C
UPGRADE ADJUSTMENT - 0.5M	8	C
UPGRADE ADJUSTMENT - 10M	29	C
UPGRADE ADJUSTMENT - 1M	399	C
UPGRADE ADJUSTMENT - 2M	1015	C
UPGRADE ADJUSTMENT - 5M	2153	C
UPGRADE IMAGERY - 25M	535	A
UPGRADE IMAGERY - 50M	2	A
UPGRADE PHOTOGRAMMETRY - 2M	18	T
UPGRADE RECTIFICATION - 2M	143	R
Grand Total	**62748**	

Code	Description
S	Derived from Standard cadastral mapping at various scales
P	Derived from Provisional cadastral mapping at various scales
O	Derived from Orthophoto standard mapping at various scales
I	Derived from Parish maps, standard 1:100000 control
B	Bearing and Distance Plots, geodetic control
R	Position upgrade, Rectification, geodetic control
T	Position upgrade, Photogrammetry, geodetic control
A	Position upgrade, Satellite imagery
C	Position upgrade, Imagery, Geodetic Control, Graphical Adjustment
N	Bearing and Distance, Geodetic/Imagery control, Internal Adjustment
X	No value

Figure 3 Accuracy Code Descriptions from QLD Interchange Format Department of Resources, 2021

Due to most land parcels of each accuracy type being in the same or neighbouring locality choosing parcels for analysis was done by applying an even random spread over the extent of the accuracy area. Attempts were made to split the area into quadrants and locate reference marks equally in each quadrant though this was dependent on the age of the survey plan associated with the land parcel and the type of survey plan. Previous assessment methodologies attempted to define a sample size, and it was determined that there needed to be a balance struck between the size and the costs associated with field sampling (Ariza-Lopez & Atkinson-Gordo, 2008). Rural areas have a higher likelihood of older survey plans with less reference marks, so the areas chosen for searching were around built-up areas of land development. Due to the parcels belonging to private land the reference marks that were chosen for measurement were found along the road frontage of the parcels. Using reference marks to compare between the DCDB and the true boundaries was used due to the marks forming a connection that identifies the boundary on the ground (Hanus, 2013). A minimum of two (2) reference marks from each plan were chosen to calculate a meridian swing from the plan datum to the datum GDA2020, which is the reference datum for the DCDB. All reference marks on the survey plan that correspond to a parcel corner of the DCDB were calculated from the DCDB with an approximate meridian swing to allow for easier locating. The calculated points then were exported into a spreadsheet for field searching with GNSS.

3.4. Reference Mark Position Acquisition and Application of Uncertainty

Ascertaining the positional uncertainty of the reference mark follows a process detailed in the ICSM Special Publication Guideline for Control Surveys by GNSS (ICSM, 2020). It was intended that for each reference mark the positional uncertainty would be at least 3 times greater than the positional uncertainty applied as the parcel accuracy. To keep consistency in the method of collection by GNSS the same technique was applied whether the accuracy was 0.25m or 57m. A search for Datum quality Permanent Survey Marks in the vicinity of the parcels was conducted to assist in planning the required measurements, and where there was suitable internet connection or a lack of Datum PSM, the use of Network CORs stations were also incorporated as a suitable base station.

The field method for measuring the survey plan reference marks followed the steps from the Standard for Australian Survey Control Network (SP1) (ICSM, 2020), Figure 4 illustrates the process, and were:

- Set over reference station with tripod, tribrach and optical plummet;
- Set tripod or bipod over reference mark;
- Occupy mark for 3 minutes; and,
- Repeat process after moving reference station with half an hour between occupations.

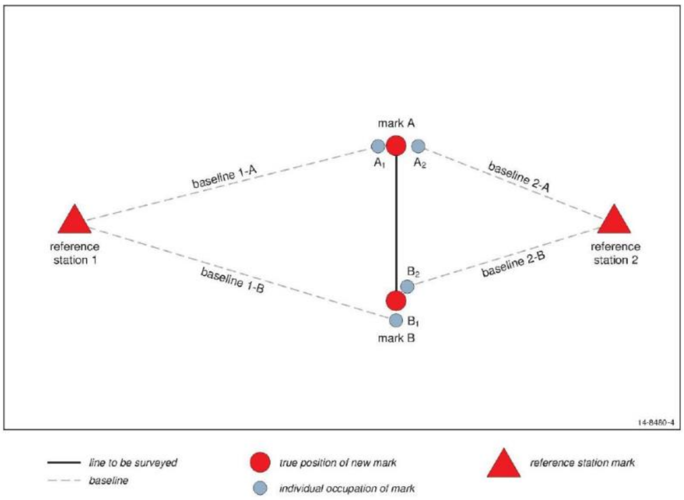

Figure 4 Example Network from SP1 Guideline for Control Surveys by GNSS

Once field work completed all measured data downloaded into 12d model, the evaluation of the GNSS survey points followed the next steps and calculations to get the estimated positional uncertainty. Once the PU has been calculated and met the requirement of being better than three times the PU of the parcels, the averaged coordinate of the reference mark is then entered into 12d model.

3.5. DCDB Coordinate Comparison

All reference marks for the survey plan once averaged were entered into 12d model and the bearing and distance between the reference marks was found. The plan bearing and distance was then found and the combined height/point scale factor was applied to the plan distances between the reference marks to get the distance comparison and the bearing swing was noted. Checks between all reference marks were completed to test whether the differences in distance and bearing were consistent for all marks on the survey plan. This determined the bearing swing that was applied to the survey plan when calculating from the reference mark back to the parcel corner. Once a final bearing swing was chosen, the parcel corner was calculated by using the plan bearing and distance, applying the bearing swing and the combined height/point scale factor, thus creating a point representing the corner of the boundary parcel in MGA2020 coordinates to be compared against the DCDB parcel corner.

4. RESULTS

4.1. Accuracy Assessment and Statistical Tests

To assess and visualise the differences between the parcel points that were calculated from the field measured reference marks and the parcel points that are represented by the DCDB, a coordinate comparison of the eastings, northings and horizontal distances were compiled into an excel spreadsheet. The results were displayed by visual analysis showing the differences in coordinate location and the statistical analysis shows discrepancies in the data (Fetai, et al., 2022; Govind Kumar, et al., 2013). The differences were displayed using a scatter plot to identify if there were any consistencies in the direction of the differences of the values, or

whether the differences were independent of each other based on the technique to create the parcels in their PU category. Statistical tests were calculated to give more understanding of the strength of the data (RMSE) and the confidence interval of the data.
Table 2 shows how each of the areas assessed compares against the assigned accuracy as a snapshot of the results from a horizontal distance perspective. These values show what percentage better the DCDB is performing when comparing using the direct measurement method of coordinating reference marks from survey plans and getting the horizontal distance difference to the coordinates of the DCDB.

Table 2 Percentage Comparison of horizontal difference

Accuracy Type	Accuracy Value	Mean Value	Comparison	Points Measured
Standard 1:10000 Cadastral Map	6.0m	2.40m	60%	18
Parish Map 1:100000 Control	57m	4.381m	92.31%	14
Upgrade Imagery	25m	4.361m	82.56%	26
Upgrade Adjustment	0.25m	0.075m	70%	3
Upgrade Adjustment	0.5m	0.205m	59%	4
Upgrade Adjustment	1m	0.203m	79.7%	26
Upgrade Adjustment	2m	0.217m	89.15%	33
Upgrade Photogrammetry	2m	0.155m	92.25%	12
Upgrade Rectification	2m	0.178m	91.10%	16

Appendix A shows more detailed statistical results for each individual analysis area with the value n being the number of points compared. The analysis of these results is discussed in greater detail in the discussion.

5. DISCUSSIONS

This research projects aims were to evaluate the PU values of the QLD DCDB in Mackay and to determine areas where the DCDB does or doesn't meet the assigned accuracies. The evaluation of the PU values was mostly completed and further work could be done to evaluate the areas which were outside the scope of this project and to evaluate areas already adjusted to assess if any changes have been made as part of the regular updating process. The assessment as to whether there were areas that do or don't meet the assigned accuracies was completed for the chosen areas giving a good insight into the region and future projects for updating.
Of the nine (9) areas assessed, four (4) were assigned the technique 'Upgrade Adjustment' and ranged in PU from 0.25m to 2m. The statistical results for these areas met the assigned PU and were significantly better. Any upgrading of the cadastre by any other means would unlikely give a better accuracy. The only accuracy for this technique that further work could be completed on would be the 2m Upgrade Adjustment parcels due to the higher statistical

values for the mean and 95% confidence intervals than the other parcels assigned a 2m accuracy with a different method.

There were three (3) definitive areas that while within the assigned accuracy of the DCDB, they display high RMSE and Confidence interval values. The Standard 1:10000 Cadastral Map 6m, the Parish Map 1:100000 Control 57m, and the Upgrade Imagery 25m are areas that show the greatest need for updating, whether it be by direct method, or indirect method as an overall upgrade.

The techniques for these areas, specifically the Cadastral Map and the Parish Map, lead to the assumption that the accuracy applied to these areas are based on the original techniques applied to creating the digital cadastre in the area, where accuracies are varied over larger areas that were initially surveyed to a topographic standard (Pullar & Donaldson, 2022), and due to their rural nature have not been prioritised for any form of updating. The consistency of the error with Cadastral Map method, the Parish Map method, and the Upgrade Imagery are curious due to the Upgrade Imagery area having been subject to upgrade by aerial imagery, but as the literature suggests, this method is prone to error and reliant on accurate ground control.

Other data that was able to be analysed and compared against were 3 of the parcel values that were assigned 2m positional uncertainty. There were 3 differing techniques for this PU which allowed for a check on whether there were similarities in the results and whether a different technique gave a different answer. The results show that two of the methods, Upgrade Photogrammetry and Upgrade Rectification had consistent values using a similar number of parcel points for the assessment. The Upgrade Adjustment had more than double the number of parcel points that were used to assess the PU which may have caused the larger values.

5.1. Limitations

- The data available for the assessment had limitations due to the accessibility and nature of cadastral survey plan reference marks (Hanus, et al., 2018).
- Parcel points selected for assessment were adjacent to the road reserve, excluding those at the side or rear of parcels.
- Most marks on survey plans are located along the road frontage, excluding potential issues with the DCDB away from the road frontage.
- Reference marks chosen were largely from newer survey plans with easier-to-find walk-on reference marks like nails, screws, and permanent survey marks.
- Older parcels in rural areas had more difficult-to-locate reference marks due to the age of the survey plans and their listed reference marks typically being iron pins.
- Choosing these marks risked taking more time in the field due to using the DCDB to calculate an approximate coordinate, potentially creating a search area of up to 57m.
- Other parcel categories were unable to be assessed due to the remoteness of the parcels and the lack of survey plans containing reference marks.
- Many parcels were National Park plans with no connections to reference marks, evident in the Upgrade Adjustment 10m category.
- Instances were found where parcels with higher PU were adjacent to parcels with lower PU, raising questions about the appropriate PU assignment.

- The upgrade process assigning values was not investigated in this research project but could be valuable for understanding the creation and application of these techniques and values.

6. CONCLUSIONS

The digital representation of the cadastre in the Mackay region has been progressively updated to a point where approximately 92% of the parcels have been updated using a direct method of data collection and computation. Parcels in the urban areas of the region make up most of the percentage with the area designated B&D Plot 0.1m totalling 67% of the total parcel count. When looking at the region from an area perspective the numbers show that there is a greater amount of land area that is yet to be updated. This area is what was assessed to see whether the applied techniques and positional accuracies assigned are within their defined range. This study has shown that while the data collection technique of direct field measurements for updating a digital cadastre can be costly and not time efficient, due to using only a part of the data set, spread out over its area, we were able to gain an understanding of the accuracy of each of the categories of the DCDB. This study suggests a way for local governments and other utility organisations to assess areas of interest in a way that reduces risk and cost of doubling up on work that has already been achieved by the Department of Resources, but still can give a good understanding of how their region as a whole is performing and where to focus efforts. The original research questions were:

6.1. How reliable is the DCDB in the Mackay Region?

The results indicate that the DCDB in the Mackay region is more reliable that is indicated by the assigned accuracies. Out of the nine (9) areas assessed which haven't been directly updated previously six (6) are achieving greater accuracies. It can be expected that there are possible discrepancies in the data outside of the parcels assessed, but that is to be expected.

6.2. What areas can be prioritised and what areas left as they are?

This study was able to prove areas were much more reliable and accurate then otherwise stated in their PU, and for future development and asset management these areas for those purposes are suitable. Any attempt at improving the positional accuracy of those areas would not be a worthwhile venture as the increase would be minimal compared to what is existing. The areas designated Upgrade Adjustment 0.25m – 2m, Upgrade Photogrammetry 2m & Upgrade Rectification 2m are areas where improvements aren't necessary. The other areas which were updated by map or imagery should be prioritised for updating.
A future aim for this project would be to see whether the reference marks already measured as part of the assessment could be used in a computational method like the least squares adjustment to assist in the updating of that area. More reference marks may be required to achieve this outcome and a focus on smaller sections of a chosen area for a more accurate outcome.

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Appendix A

Standard 1:10000 Cadastral Map 6m			
n=18	Easting	Northing	Hz Difference
RMSE	1.851	2.039	2.754
Mean	-0.479	0.372	2.400
Standard Dev	1.840	2.063	1.390
Margin of Error	0.850	0.953	0.642
CI 95%(lower)	-1.329	-0.581	1.758
CI 95%(higher)	0.371	1.325	3.042

Parish Map 1:100000 Control 57m			
n=14	Easting	Northing	Hz Difference
RMSE	2.998	8.463	8.978
Mean	-0.503	2.135	4.381
Standard Dev	3.067	8.498	8.133
Margin of Error	1.607	4.452	4.260
CI 95%(lower)	-2.110	-2.317	0.121
CI 95%(higher)	1.103	6.586	8.641

Upgrade Adjustment 0.25m			
n=3	Easting	Northing	Hz Difference
RMSE	0.034	0.070	0.078
Mean	-0.014	-0.042	0.075
Std Dev	0.038	0.069	0.025
Margin of Error	0.043	0.078	0.028
CI 95%(lower)	-0.056	-0.119	0.046
CI 95%(higher)	0.029	0.036	0.103

Upgrade Adjustment 0.5m			
n=4	Easting	Northing	Hz Difference
RMSE	0.053	0.212	0.219
Mean	0.020	-0.197	0.205
Std Dev	0.057	0.093	0.089
Margin of Error	0.055	0.091	0.087
CI 95%(lower)	-0.035	-0.288	0.118
CI 95%(higher)	0.076	-0.105	0.292

Upgrade Adjustment 1m			
n=26	Easting	Northing	Hz Difference
RMSE	0.222	0.135	0.260
Mean	0.007	-0.049	0.203
Standard Dev	0.226	0.128	0.165
Margin of Error	0.087	0.049	0.063
CI 95%(lower)	-0.080	-0.099	0.140
CI 95%(higher)	0.094	0.000	0.267

Upgrade Adjustment 2m			
n=33	Easting	Northing	Hz Difference
RMSE	0.376	0.317	0.491
Mean	0.134	-0.039	0.339
Standard Dev	0.280	0.260	0.217
Margin of Error	0.096	0.089	0.074
CI 95%(lower)	0.038	-0.127	0.265
CI 95%(higher)	0.229	0.050	0.413

Upgrade Imagery 25m			
n=26	Easting	Northing	Hz Difference
RMSE	3.398	4.168	5.378
Mean	-0.034	1.139	4.361
Standard Dev	3.466	4.089	3.210
Margin of Error	1.332	1.572	1.234
CI 95%(lower)	-1.366	-0.433	3.127
CI 95%(higher)	1.298	2.711	5.595

Upgrade Photogrammetry 2m			
n=12	Easting	Northing	Hz Difference
RMSE	0.145	0.139	0.201
Mean	-0.029	-0.037	0.155
Standard Dev	0.149	0.140	0.134
Margin of Error	0.084	0.079	0.076
CI 95%(lower)	-0.113	-0.117	0.079
CI 95%(higher)	0.056	0.042	0.231

Upgrade Rectification 2m			
n=16	Easting	Northing	Hz Difference
RMSE	0.209	0.147	0.256
Mean	-0.046	0.020	0.178
Standard Dev	0.211	0.150	0.189
Margin of Error	0.103	0.074	0.093
CI 95%(lower)	-0.149	-0.053	0.085
CI 95%(higher)	0.058	0.094	0.271

The data in the tables above are representative of the areas chosen to assess the DCDB. These show how the areas in the regions DCDB compare against their assigned accuracies with comparison in the coordinates and a direct distance measurement.

BIOGRAPHICAL NOTES

Luke Cimpa started surveying in 2012 and completed Certificate IV of Surveying while working in private practice. In 2015 joined the Mackay Regional Council as the Survey Officer specialising in ADAC and As Constructed surveys. In 2018 promoted to the Assistant Survey Coordinator helping to manage a team of 8 surveyors to deliver the survey needs of the Mackay Regional Council. Started to study the Bachelor of Surveying at UniSQ in 2016 with final research paper submission completed in November 2024.

CONTACTS

Title Mr Luke Cimpa
Mackay Regional Council
73 Gordon St
Mackay
AUSTRALIA
Tel. +61 437017691
Email: luke_105@hotmail.com