No More Survey Plans! Towards Fully Digital Cadastral Survey Datasets

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SUMMARY

Land Administration agencies in Australia and New Zealand are presently undertaking major digital transformation activities that will eventually require surveyors to lodge fully digital datasets of their cadastral surveys. Currently, surveyors continue to lodge traditional survey plans while some jurisdictions also enable the exchange of matching survey data using LandXML.

The agencies are collaborating to achieve a common vision for their cadastral systems - a cyclic flow of digital data between surveying professionals and the agencies. The future lies in providing and accepting digital cadastral survey datasets, as traditional survey plans are unable to meet the changing needs of data-driven users of the cadastral system. To address these issues and to provide a sustainable future for the exchange of cadastral information, the Intergovernmental Committee on Surveying and Mapping (ICSM) commissioned the '3D Cadastral Survey Data Model and Exchange' (3D CSDM+E) programme to create a new standard for exchanging digital cadastral survey data between the survey industry and land administration agencies across Australia and New Zealand.

The first stage of the programme produced a harmonised cadastral survey data model that describes all the elements that jurisdictions require in the datasets – including 3D elements. The model is defined at the conceptual and logical levels and uses existing internationally recognised standards and ontologies wherever possible. Profiles are included in the model to meet jurisdictional-specific requirements.

The second stage is developing a 2D standard reference implementation to exercise and test the model in the recommended JSON encoding format. It will also include further development of the 3D profile specification which requires addressing some complex challenges of element representation.

This work will involve close engagement with survey software suppliers as digital lodgement will not be possible without their support.

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1. INTRODUCTION

Today's surveyors routinely collect survey data in digital format and process it using survey software. Yet the resultant cadastral survey data is not able to be readily and reliably transferred in digital format to the land administration agencies for recording in the cadastre.

The Cadastre 2034 strategy developed by the Intergovernmental Committee for Survey and Mapping (ICSM) outlines a digital future for the cadastre in Australia. New Zealand has a similar strategy. That future recognizes the role of the cadastre in enabling digital twins, smart 3D cities, integrated planning, utility management, and other forms of digital leverage. ICSM's governing body, ANZLIC has developed a Strategic Plan 2020-24 which includes initiatives on digitizing the cadastre in 3D on its road map.

To realise that future ICSM has commenced a programme of work that aims to enable surveyors and jurisdictions to exchange fully digital cadastral survey datasets. This is intended to enable surveyors to eventually transition from lodging paper or PDF files to fully digital data, including 3D.

2. BACKGROUND

ICSM represents eight Australian jurisdictions and New Zealand. The scope for the 3D Cadastral Survey Data Model and Exchange (3D CSDM+E) programme encompasses their nine similar systems which are based on similar concepts, recognising each having independent legislative and regulatory requirements.

The nine jurisdictions have committed to digital transformations of their cadastres. Some are significantly advanced with completed conversions of paper documents into digital records, and several have partial or full transactional systems in place.

A key attribute of these digital systems is the ability of the surveyor to submit their work as digital data, LandXML has been the transfer mechanism mostly used but a variety of other options have been acceptable. This variety and the limitations of LandXML have made it difficult for suppliers of survey software to meet the varying requirements. A new fully capable exchange mechanism is required that meets all the jurisdictional needs. A harmonized data model will simplify the work for survey software vendors to incorporate into their solutions and enable them to more easily support multiple jurisdictional systems.

All jurisdictions have a 3D cadastre. These are based on conventions of limited vertical extents (see later) and the representation of complex spaces through traditional plan drafting practices. To deliver on the strategic goals, jurisdictions will need to provide for digital 3D representation of the rights, responsibilities, and restrictions. Surveyors will need to be able to submit three dimensionally defined parcels which have accurate relationships to the conventional two-dimensional underlying elements.

3. GOALS

The primary objective is to enable the cyclic flow of 2D and 3D digital cadastral data to facilitate the updating of cadastres and its subsequent extraction. The concept is shown in *Figure 1*.

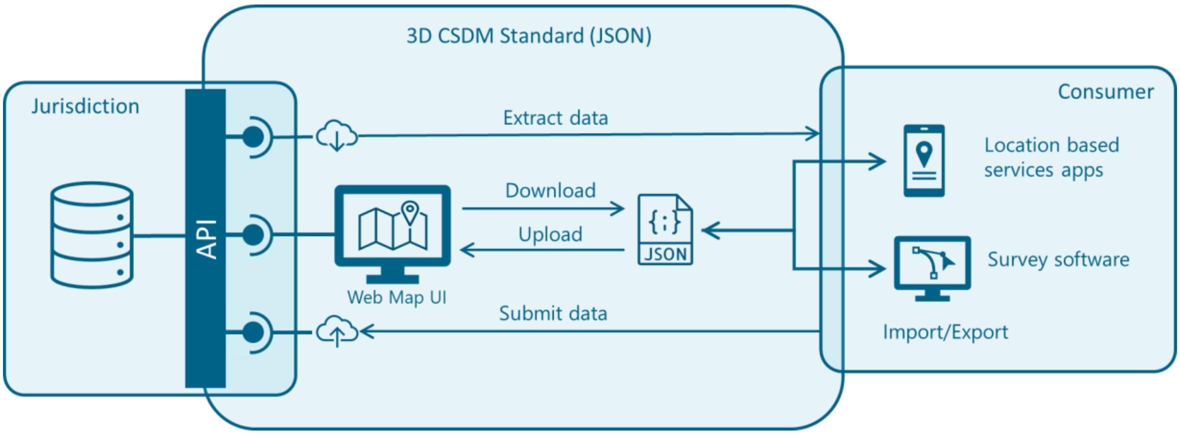

Figure 1 Cyclic flow of 2D and 3D digital cadastral data

A surveyor extracts base cadastral information from the jurisdictional cadastre, utilises software to add field observations to derive the intended changes and define new spatial extents of rights, restrictions and responsibilities. The surveyor then submits the new objects to the jurisdiction which incorporates them into the cadastre. Conceptually, this can be achieved by either exchanging digital files or machine-to-machine transfer of data.

Digital data flow provide substantial benefits including improved quality through automated validation, efficiency through data reuse, and better decision making because of improved data interpretation. A benefit of digital data is the ability to present a more intuitive and interactive user-oriented representation of the data which can become the replacement for static images.

A necessary success criterion is adoption of the proposed outcomes by software developers whose products support surveyors' workflows. A surveyor must be able to ingest authoritative cadastral data and export data sets for submission to jurisdictions.

4. METHODOLOGY

For the purpose of realising the common ICSM vision of having a standardized data model that supports the cyclic flow of digital data between surveying professionals and the agencies, the 3D CSDM+E programme is being delivered over three stages. The first stage, now complete, involved the development of a harmonised model and jurisdictional profiles that accommodate the variations in cadastral vocabulary and standards across Australia and New Zealand. This stage also produced a comprehensive options analysis of the full range of encoding options for consideration during the standardisation and implementation stages.

The second stage, commenced in early 2023, will develop a standard reference implementation specification with encoding rules for the exchange of 2D cadastral survey data according to the harmonised model produced in the first stage. This stage will also include engagement with the cadastral surveying software community to help ensure practical implementation and progress towards adoption.

The third stage will see jurisdictions and software suppliers implementing the standard in a consistent fashion, and land information agencies start transitioning towards full digital exchange of cadastral data.

4.1. STAGE 1 – Discovery, conceptual design, profiling and options analysis

Work during Stage 1 was undertaken over 2021-2022 through the services of a consortium led by SURROUND who were joined by jurisdictional experts who identified the detailed regulatory requirements. The harmonised model produced during this stage is in the form of a conceptual model and a canonical logical model that encapsulate the common data elements across all Australian and New Zealand jurisdictions. The model draws upon international standards (e.g. LADM, OGC LandInfra), ICSM's existing ePlan specification, and vocabularies (e.g. CaLAThe[i], LandVoc), and caters for 2D and 3D survey data and related features (simple and complex). Being based on international standards for feature representation, the model permits the encoding of the following cadastral information geometry types:

1. Typical '2D' footprints
2. Descriptions of extended rights in multiple (geometric) directions
3. Topographic models of the surface (e.g. a digital elevation model, or TIN)
4. Representative 3D volumes (with unbounded extensions truncated for display and calculation purposes)
5. A Discrete Global Grid Systems (DGGS) 'index' for efficient calculations

Sophisticated profiling that standardises and maps jurisdiction-specific data elements relative to the harmonised model, allowing the 9 jurisdictions to implement the model according to local legislation and policy requirements, was also developed. This profiling is a critical step towards achieving a seamless and consistent approach for software suppliers in the face of complex variations in cadastral vocabularies and standards.

Stage 1 also delivered a data exchange options analysis that tabulates the various encoding standards and formats available across the international standards landscape and comments on the respective suitability for implementing the model. The primary purpose of this analysis is to provide a sound basis for deciding which encoding standard(s) would secure widest possible adoption by the cadastral surveying software suppliers. To that end the options analysis is supplemented with recommendations on the most appropriate implementation pathway. The key conclusions that were reached from the options analysis are:

1. Most, if not all, encoding standards can support the spatial components of a cadastral dataset using existing "simple" 2D feature geometries. This means that the model can be implemented within a reasonably short time frame.
2. LandXML lacks fundamental support for 3D features, does not have a formal governance approach to ongoing development, and is not based on any open or internationally adopted standards. These limitations render LandXML unsuitable for suppliers as a viable, long-term implementation option.
3. XML-based technologies (e.g. KML, GML, CityGML, InfraGML) are intrinsically "heavy" or "verbose". Being designed for geospatial Web mapping and GIS communities of practice, GML and InfraGML are either not supported or not consistently implemented in cadastral surveying packages.
4. The prime candidate for future-ready encoding and widespread adoption that yields the longest lifespan, is JSON (including the extension JSON-LD). The line of reasoning for this recommendation is as follows:
    - JSON is an open standard file format and is used widely across the internet for exchanging information between Web services, software packages and mobile devices. JSON forms the basis of OGC's strategic roadmap and is progressively being used to implement ISO and OGC data models (e.g. it is a provisional BIM IFC format and is being used to implement CityGML).
    - JSON and JSON-LD can be used, without modification, to implement the 2D features of the 3D cadastral survey data model and jurisdictional profiling. Early benefits can be realised by creating reference implementations for parsing 2D cadastral survey datasets for each participating jurisdiction, using JSON-LD extensions to link data to jurisdiction specific requirements and thereby support jurisdiction specific validation.
    - JSON is parseable without heavyweight plug-in code or knowledge of object-oriented schemas to load data in memory. The effort to implement JSON is significantly lower than for other encodings, making it a desirable option for software suppliers.

- Development and implementation of a 3D profile specification still has some issues to address and will require additional effort. The issues are non-trivial and will involve input from experts from the international (ISO and OGC) standardisation community. It is proposed that the 3D profile requirements of the model should be submitted as an extension of the GeoSPARQL semantic standard in its planned evolution as a joint ISO/OGC/W3C standard.

4.2. STAGE 2 – Development and standardisation

Stage 2 commenced in early 2023 and aims to produce a candidate 2D encoding standard, with profile support, in JSON/JSON-LD to enable surveying software suppliers and land administration agencies to implement the model. Together with the profiling, the standard will provide unique and jurisdiction-specific vocabularies for encoding of cadastral survey data such that surveyors will be able to create and submit records of cadastral subdivisions and their accompanying surveys in a fully digital way. The standard will be furnished with a sufficient level of encoding rules such that validations can be applied to ensure the structure and integrity of the contents is both syntactically correct and logically consistent with jurisdictional regulations and policies affecting cadastral surveys. Complementary to this work will be a cyclic verification of the conceptual and logical models to ensure any shortcomings from stage 1 are addressed.

While stage 1 revealed that all cadastral surveying software suppliers were able to support JSON/JSON-LD, a deeper level of engagement with the software supplier community will be undertaken to accommodate their views and experience. This will help ensure that one of the primary objectives of the project is upheld – that data files encoded relative to the standard can be efficiently and seamlessly produced by cadastral surveyors with minimal knowledge of complex data models and standards.

Finally, this stage will propose a recommended strategy for standardising 3D cadastral data. The reason for this is that there is, currently, no “off-the-shelf” 3D encoding standard that uniquely implements 3D geometries defined by the many and varied domain models. Of the encoding standards that support 3D geometries, each expresses 3D features unique to a specific domain, making it difficult to implement a single 3D cadastral model consistently across multiple encoding standards. For example, 3D features represented by IFC do not have a consistent representation in GML. This means implementing 3D features in the conceptual cadastral data model in GML requires a different approach to implementation in IFC. For this reason, this stage of the project will propose extensions to JSON/JSON-LD for encoding or referencing cadastral geometries in 3D in a standardised way.

4.3. STAGE 3 – Implementation

In this stage, it is envisaged that land administration agencies across Australian and New Zealand jurisdictions and software suppliers will start to implement the standard. While the progress of this implementation is likely to progress at different rates, the outcome will be a consistent and harmonised approach to the exchange of cadastral surveying data. Some land information agencies will begin immediately with implementation and the consequential transition from allowing surveyors to submit PDF documents to requiring a fully digital record of cadastral data.

Long term, ICSM will continue to provide governance, leadership and responsibility for maintaining and hosting the standard and will work towards international standardisation to maximise longevity and stability.

5. 3D Digital Representation

In reality, boundaries, parcels, land tenure, rights, responsibilities, and restrictions exist in three-dimensional space. Most of these are 'unlimited' in height extending into the earth and the heavens. They are typically represented in 2D (without height) with horizontal distances at either mean height or reduced to the ellipsoid. However, others are limited in height, either above, below or both. These need to be represented with height information and are referred to as '3D'. Figure 2 illustrates the reality of the ground surface and associated 3D parcels compared to the traditional plane surface used to represent land parcels unlimited in height.

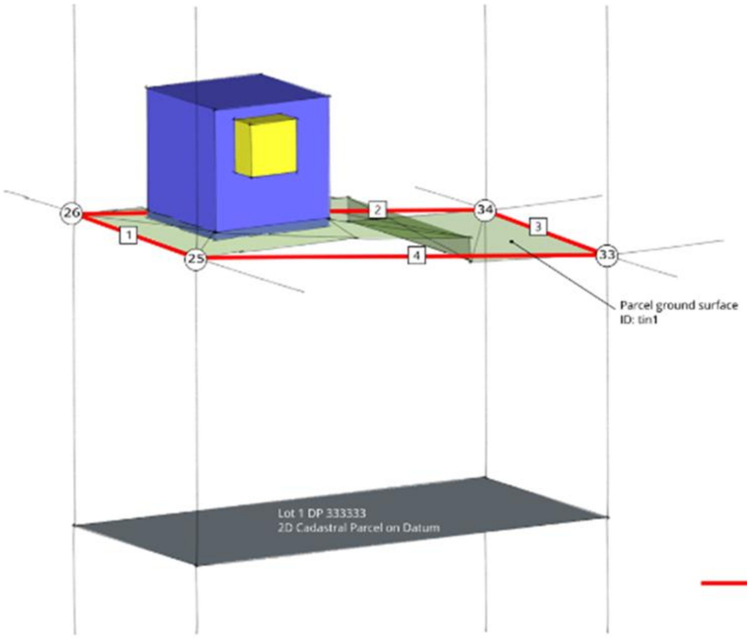

Figure 2 Typical scenario of 3D cadastral land parcels compared with 2D

When dealing with 3D, land parcels that are unlimited in height can be represented not by polygons sitting on the surface of the Earth but columns consisting of space above and/or below the surface of the Earth, as illustrated in Figure *3*.

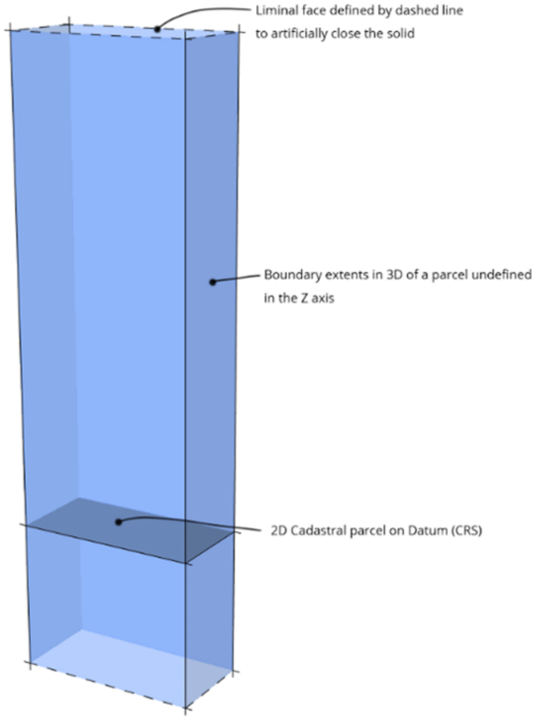

Figure 3 The true nature of 2D land parcels

Complex 3D land parcels have typically been represented on a 2D plan with height assigned to polygons or points as an attribute/annotation on the plan. Conventions such as isometric views or building sections are drafted to assist with interpretation of the extents of parcels.

Some of the key features of a 3D cadastral survey data model include the use of 3D spatial relationships to represent the physical boundaries of a property as well as any above-ground and underground features, and the ability to link cadastral information with other data sources such as building and infrastructure data. The implementation of a 3D cadastral survey data model can vary depending on the specific needs of the application or project, but it generally involves the use of sophisticated surveying tools, geospatial data management software, and data visualization tools.

The 3D Cadastral Survey Data Model (3D CSDM) allows for 3D survey observations as illustrated in Figure *4*.

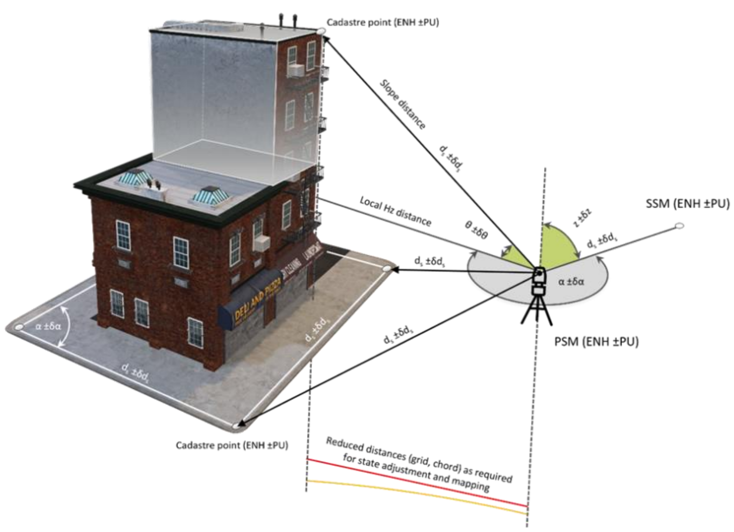

Figure 4 Typical 3D observations from cadastral reference marks to points and buildings defining cadastral parcels

The model allows for points, lines, polygons, nodes, edges, faces, solids, and cubic spaces as illustrated in Figure 5. The model also requires representation of positional information in terms of datums and projections to accurately represent both the horizontal and vertical aspects.

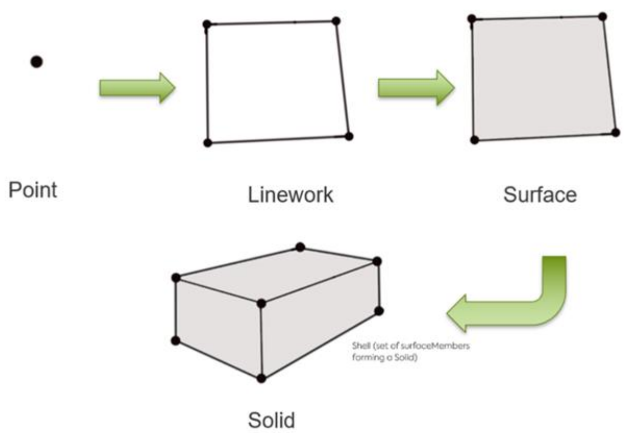

Figure 5 Relationships between point, line, surface and solid

The 3D CSDM will enable:

- survey datasets, where required or desirable in the circumstances, to include 3D observations and be connected to a geodetic datum
- represent field survey in the form of a 3D model from which the relevant cadastral data can be extracted and presented.

A key finding from the stage 1 project is that there is no existing, common expression of the basic 3D geometry and topology requirements of a range of different domain models. It concluded that a suitable profile for 3D is required, defining both the data models for 3D features with 2D and 3D geometry and topology representations (see Figure *6*). This needs to be supported by a common set of functions that can be used to transform and aggregate geometry primitives into 3D display and analysis ready objects and derive topological relationships.

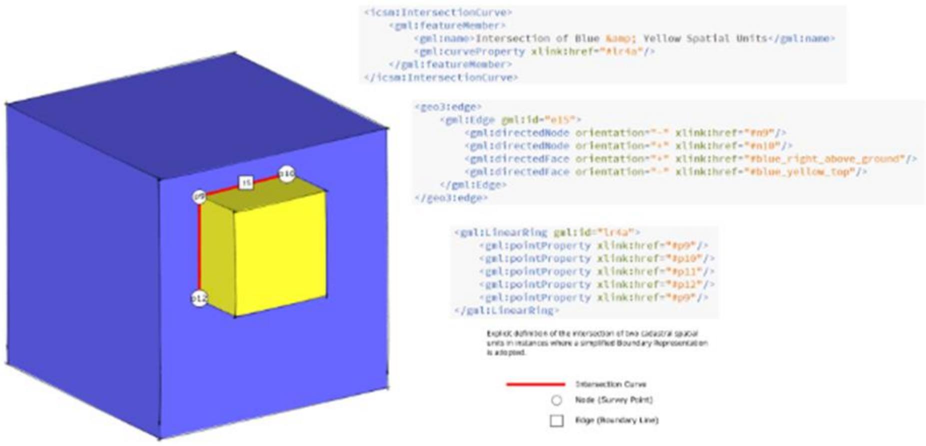

Figure 6 Aggregations and topology relationships between unique 3D geometries

The definition of such a profile would support development of tools and test suites and provide the basis for a general “uplift” in capabilities of the wider software offerings. This will help meet the requirements of both 3D Cadastral Survey Data Modelling and also related domains such as city and landscape scale models, infrastructure, local and indoor positioning and other related domains, in the same way the Simple Features Profile supports interoperability of multiple implementations of 2D GIS systems.

Consequently, the project recommended a functional profile be defined for basic 3D geometry and topology representations as exists for planar (Simple Features) geometry and encoding patterns for a 3D geometry profile be defined for multiple candidate encoding options such as GML, JSON, OWL, SQLite (Geopackage) and IFC.

6. SUMMARY

ICSM is committed to enabling fully digital 3D cadastral capability for all its participating jurisdictions. This is being facilitated by development of a harmonized data model capable of transferring 3D Digital Cadastral Data between jurisdictions and surveyors in a standardised manner.

The initial stage of this journey developed the conceptual and logical cadastral survey data models and the second stage, started in early 2023, includes the development of jurisdictional profile capability and validation through a reference implementation.

Critical to the success of this is a solution which is supported by survey software suppliers allowing for cadastral data to be ingested and exported from surveyors' environments. Active engagement has been planned to share the outputs of the first stage and enable feedback from these critical players in the system.

It is an intended focus to develop extensions for JSON and JSON-LD to allow for 3D elements following the findings that there are no suitable capable existing exchange options available.

A roadmap outlining subsequent steps will result from the work in stage 2 and will provide clarity and certainty to jurisdictions, software developers and the surveyor communities.

Successful completion of the planned reference implementation in stage 2 of this programme, including support from software suppliers, will hopefully encourage international consideration of this work as a potential pathway for wider adoption.

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BIOGRAPHICAL NOTES

Anselm Haanen has been the Surveyor-General at Toitū Te Whenua Land Information New Zealand since 2018. He was previously the Deputy Surveyor-General. He holds a Master of Surveying degree from the University of Otago and has worked in various technical capacities since joining the department in 1978. He was heavily involved in the development of Landonline, New Zealand's automated survey and title system, and helped develop New Zealand's Cadastre 2034 strategy. Anselm is the ICSM Sponsor of the 3D Cadastral Survey Data Model Programme.

Jeff Needham is Deputy Surveyor General at Toitū Te Whenua Land Information New Zealand (LINZ) and fulfils the role of SAFe Agile Business Owner in the Survey and Title Enhancement Programme (STEP) which is redeveloping the Landonline system. His background includes 25 years in private consulting focussed on Land Development, Infrastructure and digital information technologies. Jeff was the surveying profession's Stakeholder Representative involved in the original development of Landonline between 1999 and 2003. Jeff is a Fellow and past President of Surveying and Spatial NZ. Jeff is the Product Owner for ICSM on the development work underway on the 3D Cadastral Survey Data Model Programme.

Roger Fraser is Chief Geospatial Scientist at the Department of Energy, Environment and Climate Action, Victoria. Roger has been involved in several state and national geodetic and cadastral infrastructure projects including GDA94, GDA2020, Standard for the Australian Survey Control Network (SP1), AuScope GNSS, GeodesyML, DynAdjust and Victoria's digital cadastre modernisation. Roger's interests include geodesy, least squares estimation, GNSS analysis, software development, data modelling and digital cadastre automation.

Murray Dolling is currently the Principal Surveyor at Landgate which includes carrying out all statutory functions of the Inspector of Plans and Surveys. Murray has been a Licensed Surveyor in Western Australia since 1982. After spending the early part of his career in private sector employment, he joined the Western Australian state government agency DOLA (now Landgate) in 1995. His professional interests lie in improving the capabilities and efficiencies of digital plan processing and the development of the next generation spatial cadastre for Western Australia.

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[i] Cadastre and Land Administration Thesaurus. http://cadastralvocabulary.org/