Digital Lines – LandXML – A 10-year Vintage

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ABSTRACT

2025 marks 10 years since the commencement of the back capture of existing cadastral plans in NSW. A decade later, an xml file is delivered with every plan we order, but what can we do with these files and what makes them better than ordinary Computer-Aided Design (CAD) files? This paper outlines the basic components of LandXML that are important to cadastral surveyors and the advantages that having almost all plans captured in a topologically vector-based format can bring. There are currently two main ways of using LandXML data: to position it via its CgPoints, or to position it via its observations. This paper demonstrates that importation via observations is the preferred method for cadastral use, but also highlights some advantages to importation by CgPoint. It shows how back-captured LandXML files can be incorporated into cadastral workflows and outlines some of the problems that are encountered using the format. Finally, it presents some case studies of alternative uses that the release of the entire Victorian LandXML dataset has brought, such as low-accuracy bulk plan imports, monument harvesting, and cadastral database linework improvement via least-squares adjustment. LandXML as a format is here to stay, so why shouldn't we take advantage?

KEYWORDS: *LandXML, cadastral, observation, vector, back capture.*

1 INTRODUCTION

LandXML (sometimes referred to as LXML) for use in cadastral surveys has now been around for over 14 years. While there is still to be general take-up of the production of LandXML by surveyors, the back capture component (started in 2015) has been and still is the process being undertaken in numerous jurisdictions. While this data has not currently replaced the 'paper' plan, it offers an important resource to surveyors that has perhaps not yet been realised.

This paper (1) demonstrates how a LandXML file correlates information shown on a paper plan to the components of an xml file in a digital format, (2) outlines how surveyors can take advantage of that information, (3) presents a workflow where LandXML is being used for cadastral projects, (4) discusses some of the drawbacks and problems associated with back-captured LandXML data, and (5) shows alternative case studies where LandXML data has been used in unconventional ways.

2 LandXML BASICS

2.1 History

The LandXML format was created in 2000 as a way of transferring human readable information within the land development industry (LandXML.org, 2025). It contains around 240 different types of elements and was designed for all aspects of the land development process, but outside the cadastral system, in the author's experience, it is mostly used for the transfer of triangulations.

Around 2010, the Intergovernmental Committee on Surveying and Mapping (ICSM) formed a task force to come up with a national approach to digital survey plans. It published a document that outlined the elements of LandXML which should be used by jurisdictions in the creation of 'recipes' to ingest their plans into a common format that could be transferred between regions (ICSM, 2016). Shortly after, NSW Land and Property Information (LPI – now Land Registry Services, LRS) released the NSW recipe, which took the elements from the ICSM document and outlined how they would be applied to NSW plans (Deal and Choi, 2018). While the original LandXML incorporated 241 element types, this was first reduced to 50 element types in the ICSM ePlan protocol and then to 39 element types in the NSW recipe.

Did this process work as it should have? Did this process create an easily transferable digital format? Examination of one of the simplest components of a LandXML file, a boundary line, is shown below in the NSW and Victorian LandXML formats.

- NSW format: <ReducedObservation name="21" desc="Boundary" setupID="IS31" targetSetupID="IS21" azimuth="254.4010" horizDistance="15.856"/>
- VIC format: <ReducedObservation name="21" purpose="normal" setupID="IS31" targetSetupID="IS21" azimuth="254.4010" horizDistance="15.856"/ >

While these two formats look similar with the azimuth and distances being stored the same, one uses the "desc" attribute while the other uses the "purpose" attribute. One calls a boundary line a "Boundary", the other a "normal". It is evident that on one of the simplest components of a survey plan, two major Australian jurisdictions could not create a consistent format.

Around 2004, LPI put out a tender to back capture all existing plans in NSW into the LandXML format. This was completed in 2022 with over 1 million plans back-captured, and work is continuing to capture Crown plans for use by the surveying industry.

2.2 Essential LandXML Elements of a Survey Plan

2.2.1 The Line

At the base of all survey plans is the bearing and distance component. This is represented in LandXML by a ReducedObservation element with the "azimuth" and "horizDistance" attributes storing the essential information.

Examination of Figure 1 shows that while we can store the bearing and distance, there are many types of bearing and distances. There is a boundary line, a Permanent Survey Mark (PSM) connection line, a connection to the street corner line and a connection to a reference mark (which does not have a line shown). These are controlled by the "desc" attribute, which assists in generating line types and thicknesses.

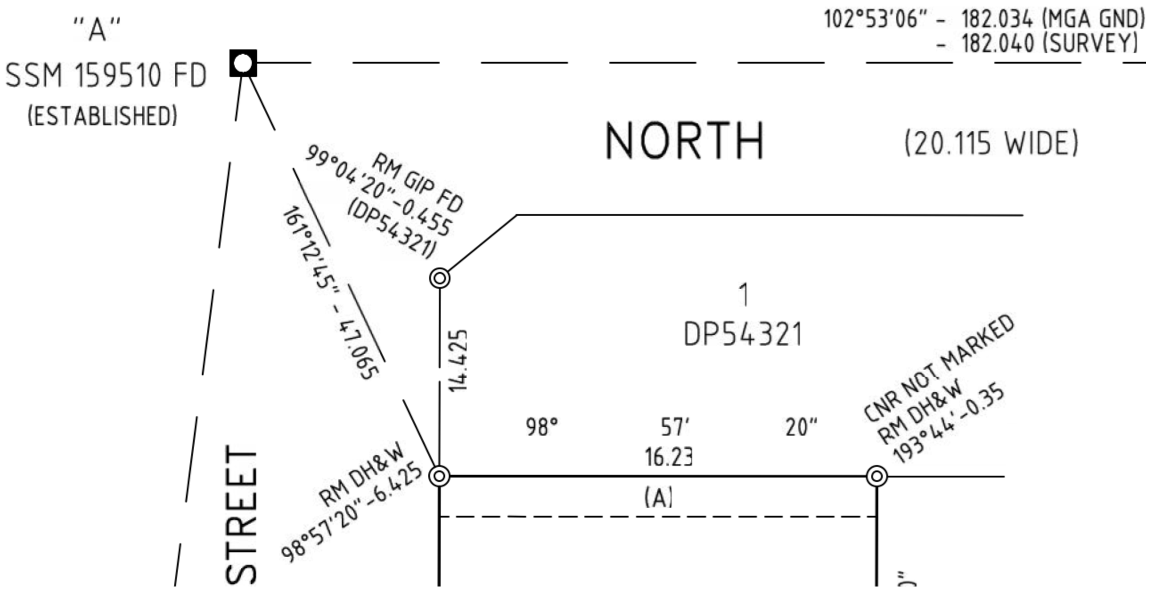

Figure 1: Survey plan extract.

However, the bearing and distance is useless without topology, i.e. the ability to connect geometric objects together. In order to do this, LandXML uses an element called CgPoint (i.e. Coordinate Geometry Point), which directs the computer where lines are drawn from and to and connects common lines together as shown in Figure 2.

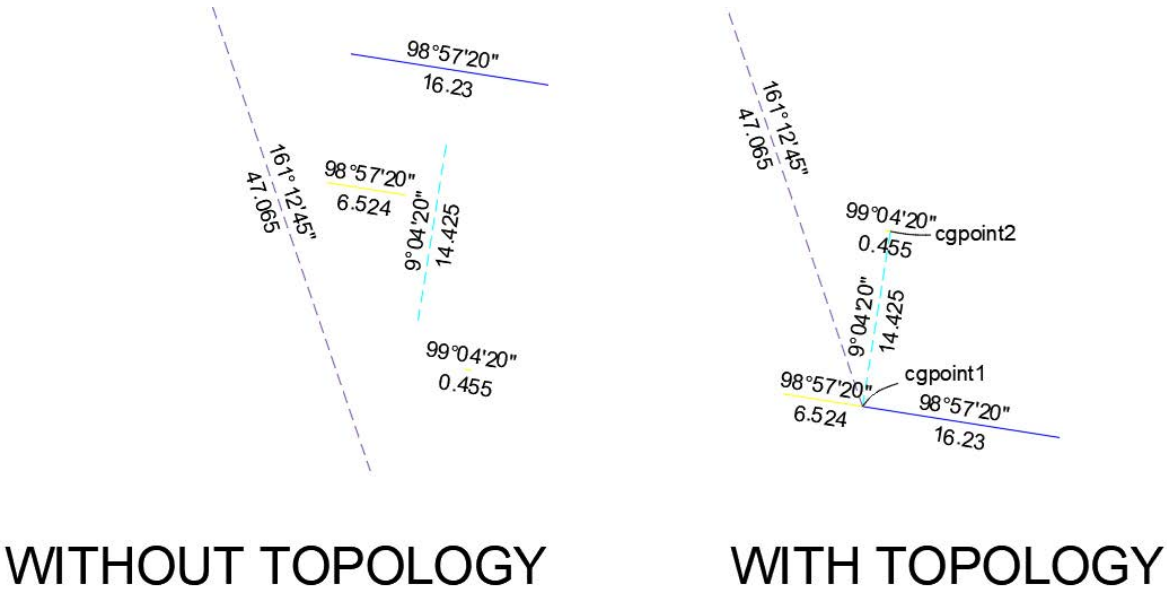

Figure 2: Using CgPoints for topology.

This is where LandXML starts to become different from normal Computer-Aided Design (CAD) drawings. The bearing and distance are stored inside the line, and the CgPoints control where it is drawn, so by manipulating the position of the CgPoint, we can create a diagrammatic version of stored information, shortening or repositioning lines without losing the bearing and distance information. For instance, Figure 3 shows manipulated CgPoints of the data presented on the right-hand side of Figure 2. Geometrically, the line between CgPoint 1 and CgPoint 2 is no longer 9°04'20" but the stored bearing and distance information has been retained inside the line object. This is one of the main fundamentals of LandXML and its advantage over simple CAD linework.

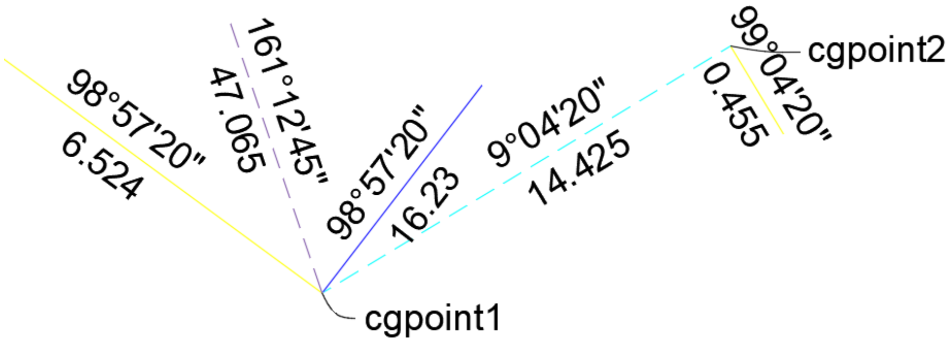

Figure 3: Manipulated topology.

2.2.2 The Lot

The second most essential part of a cadastral plan is the lot, which is stored as an element known as a parcel. Parcels are used to define new and existing lots, adjoining lots, roads and easements. They are similar to line elements, in that their position is defined by CgPoint, but the important thing is that the bearing and distance information is not stored with the parcel. This allows the same line to be used on multiple parcels, and lines can be created that do not have a bearing and distance. Parcels are not even required to be closed. For instance, in Figure 4, the green line represents a lot parcel, orange an easement parcel, red a road parcel, and blue an adjoining lot parcel.

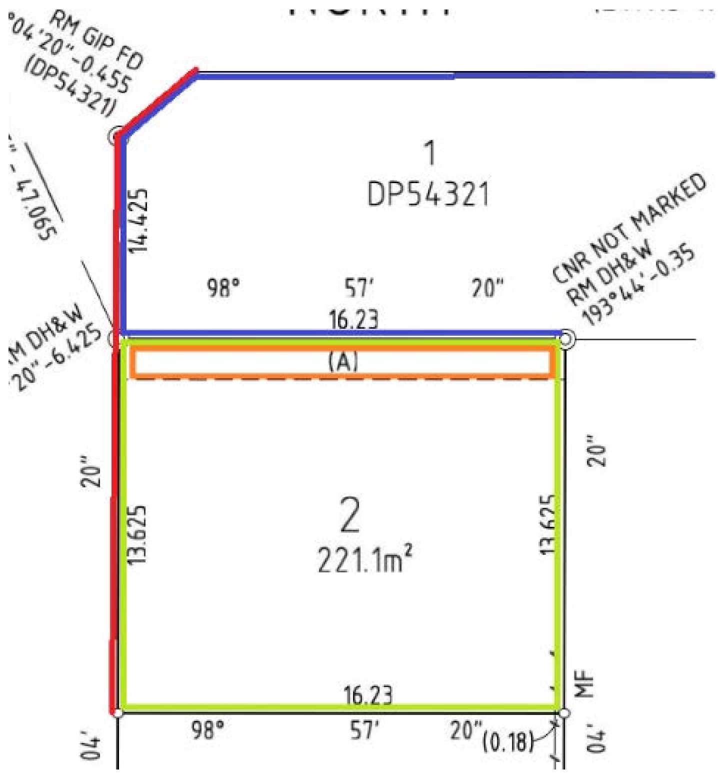

Figure 4: Parcels.

2.2.3 Other Elements

There are many other elements that turn a cadastral plan into a LandXML file (Figure 5). The basic rule is that if there is a piece of text or a line shown on the plan, it needs to the stored somehow in the LandXML file.

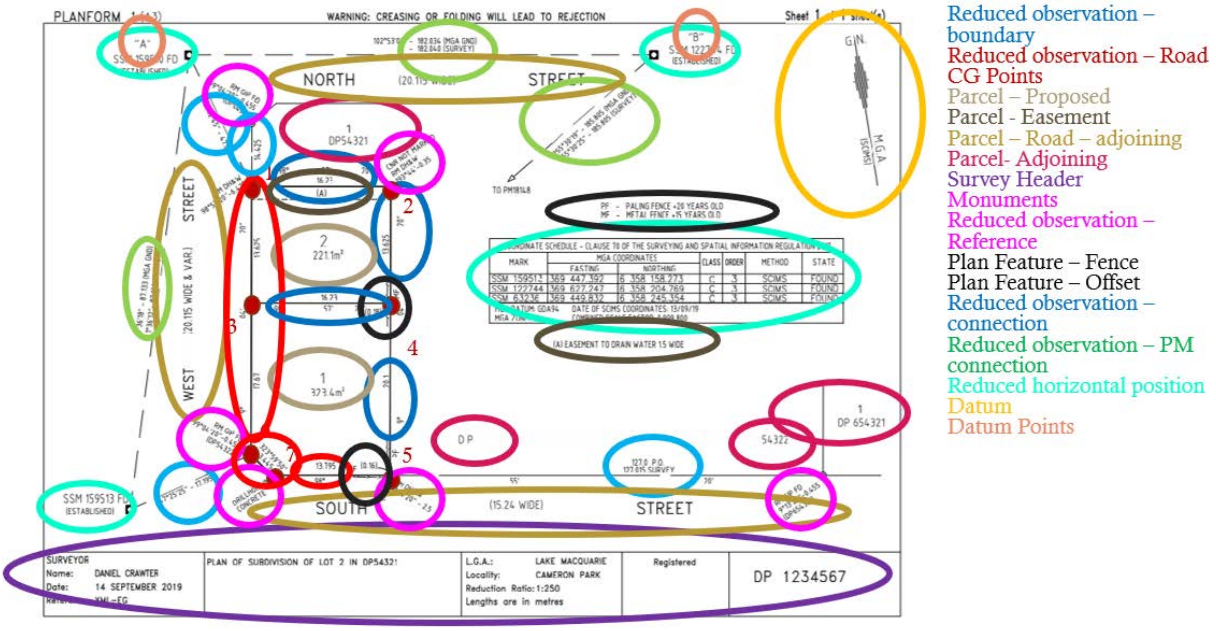

Figure 5: Common elements stored in LandXML.

3 USING LandXML FILES

One of the major drawbacks to LandXML files is that there is limited mechanism for their use in existing surveying software. Where there is LandXML support, there is generally a lack of understanding of the fundamental advantages of LandXML, i.e. the use of topology.

There are two main ways to import a LandXML file: by CgPoint and by observation. The author released a free lisp plugin for AutoCAD in 2015 for creation and importation of LandXML files and continues to support this program, which is available at https://tinyurl.com/mt4aausu. This section mentions tools in this program.

3.1 Importation by CgPoints

Importation by CgPoints utilises the coordinates stored in the file as they were created by the data entry person. This can be done using the XIN function in the lisp plugin. In NSW, CgPoints can be local (1000, 5000) for LandXML files without Map Grid of Australia (MGA) connections or in MGA for files with a connection. The problem with CgPoints is that they may not have prioritised certain lines in a particular way, e.g. the user may wish to hold the alignment of a road straight and the data entry person may not have done this. It is also impossible to know where any misclose might have been placed and what the extent of any error is in the plan.

However, CgPoints are a great way to diagrammatically position LandXML files. For example, occupation, which is quite often exaggerated on Deposited Plans (DPs), can be placed in an exaggerated position while keeping the LandXML offset value true, or PSM connections can be kept out of scale to fit on a plan while also being recorded via their plan dimensions as shown in Figure 6.

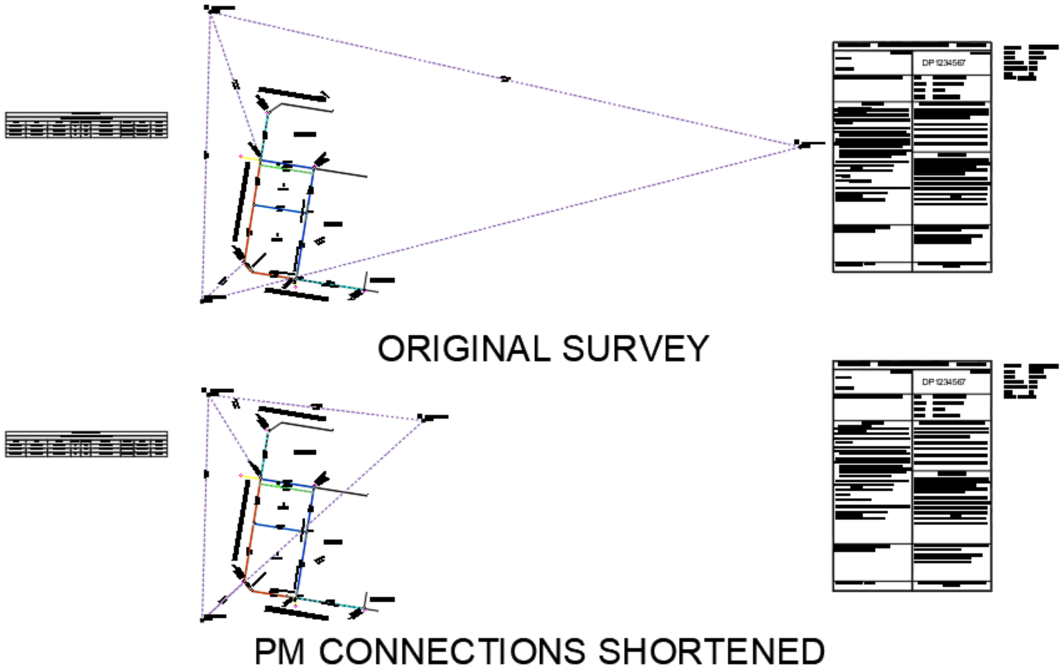

Figure 6: Manipulated CgPoints.

In Victoria, the CgPoints of all back-captured LandXML files are snapped to the Digital Cadastral Database (DCDB) as it was in 2020, which means that most of the geometry of the lines does not match their bearing and distance data. The reason for this was to enable the creation of massive network adjustments, so having data roughly in the right position and abutting with neighbouring plans was more important than having the lines match recorded bearing and distance.

3.2 Importation by Observation

The alternative way to import LandXML data is using the observation information. Using the bearing and distance information and a random start point, the data can be imported and drawn. The drawback to importation by observation is the problem with non-orthogonal geometry, and where to put miscloses.

Any survey plan that uses non-orthogonal vector geometry (i.e. lines that are not parallel or at 90° to each other) will have a slight closing error. For example, in Figure 7, the parcel on the left closes perfectly, but the parcel on the right has a 0.3 mm misclose.

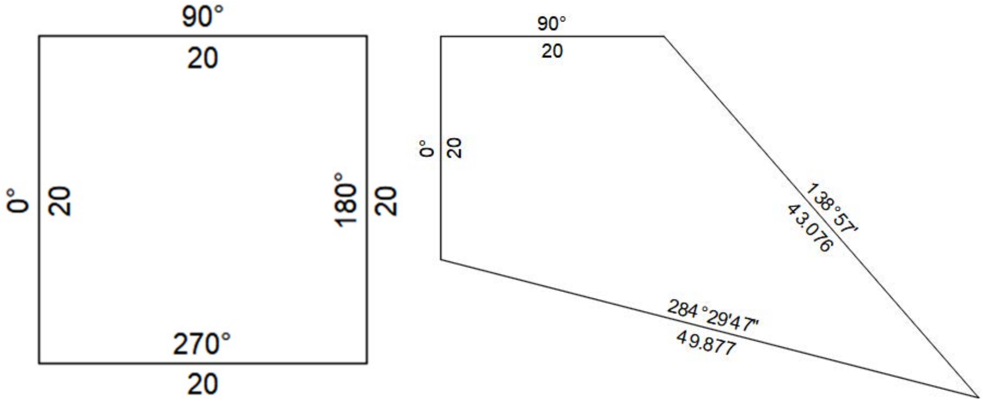

Figure 7: Orthogonal and non-orthogonal vector-based geometry.

The placement or distribution of this misclose is usually at the discretion of the surveyor, but in the case of LandXML importation this choice is required to be automated and marked. It would be an easy choice to just distribute the error through the plan using Bowditch or least-squares, but this would most likely create non-intentional errors, e.g. a road that is no longer straight.

The lisp plugin created by the author for the importation of LandXML by observation takes the approach a surveyor might take when entering the plan, importing the road alignments first, then the side boundaries, then other connections. This maintains the road alignments and pushes most miscloses into the side and back of parcels. This priority system is demonstrated in Figure 8, where the first number is the order in which the reduced observations are recorded in the LandXML file and the bracketed number is the order in which the program plots the observations (or lines). The green circles are where a misclose will be calculated and placed.

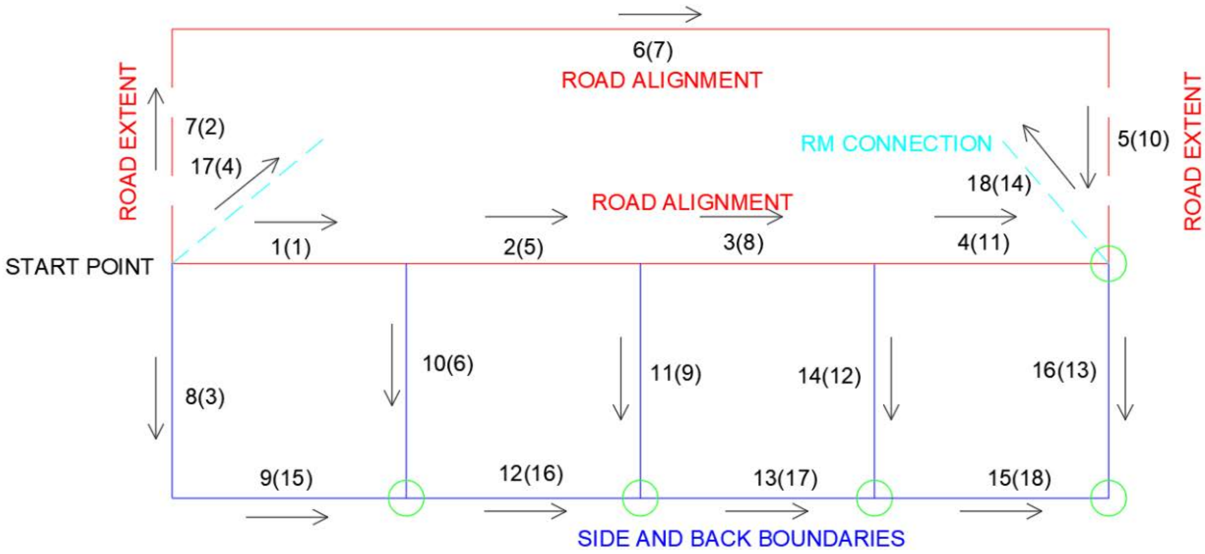

Figure 8: Importation by observation order.

In this method, no adjustment is made to the misclose. The closing line is simply snapped back to the first line. In Figure 8, the misclose in the road parcel line 4(11) would snap to the position generated by 5(10), and the misclose marked so that the user knows one of the lines from that point is not as per the plan (Figure 9).

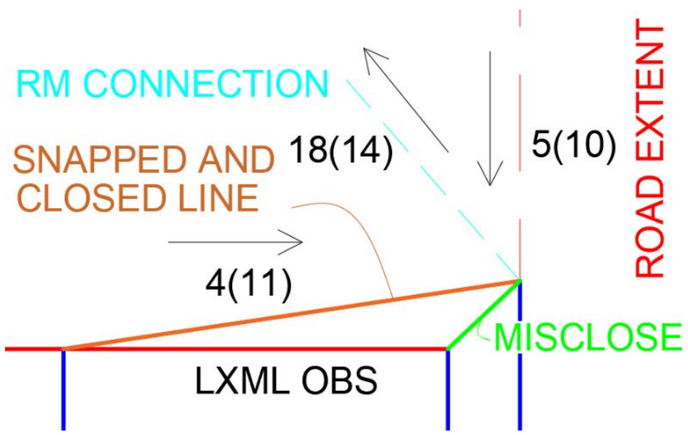

Figure 9: Miscloses.

Another important point of the importation by observation method is that loop closures are calculated, so if there is an error or a compiled residual parcel with a large misclose, this is calculated and reported, highlighting potential problems that might not be realised with an importation by CgPoints.

3.3 Using LandXML in Cadastral Compilations

The primary use of LandXML data is to speed up the compilation of data. As an entire plan can be imported in seconds, a compiled cadastre can be built very quickly, and plans that might have normally been passed over as not being of use due to the onerous need to manually type them in can easily be added. A typical workflow is to import the plans via observation, compile common plans together to create a segregated master, then put all the segregated masters together and position them in a coordinated position (Figure 10). In AutoCAD, this is enabled by using the group tool to connect the imported LandXML files and moving the plans like a jigsaw piece.

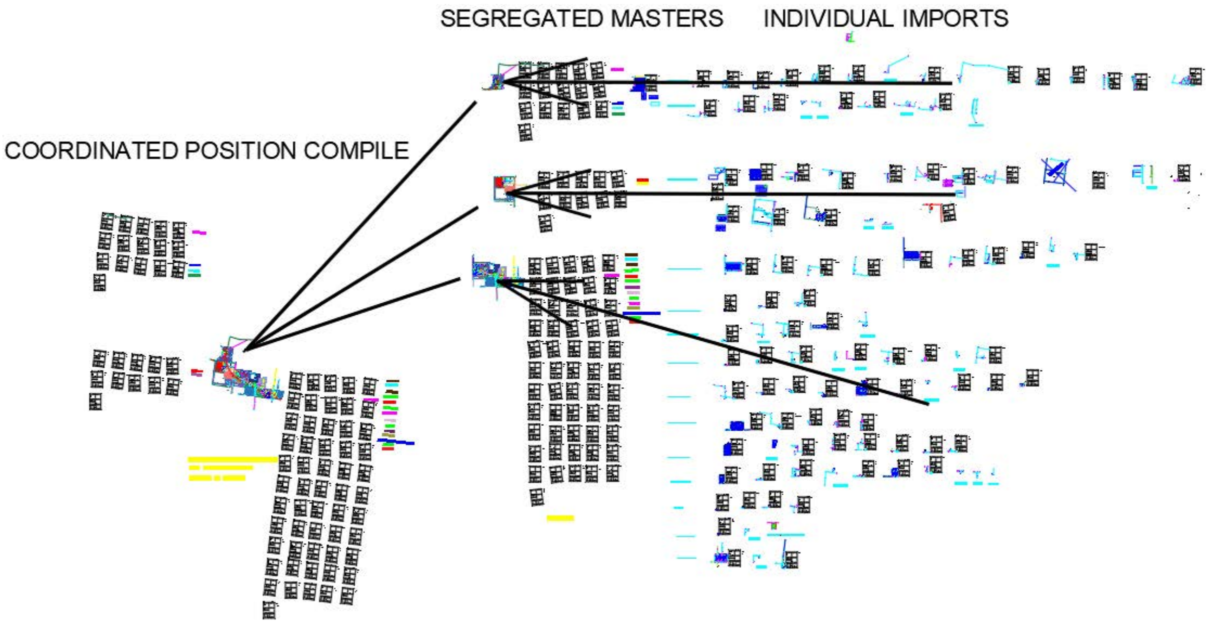

Figure 10: Compiled LandXML files for 1.5 km of urban redefinition.

While the pieces are being put together, the user can examine the fitness for purpose of plans and identify possible problem areas. Once compiled and placed in a coordinated position, the monument information from the plan can be exported to a text file and used to assist in monument location in the field.

Once the field survey is complete, compiled data is put to one side, the field survey data is imported, and the plans can be placed on the field surveyed positions. If everything fits together within tolerance, the redefined boundaries can then be taken from the LandXML and used in the new survey plan. If things do not fit or there are problems with the LandXML, the user may have to resort to manual entry or more traditional methods of boundary definition.

It is important to note that this is not meant to be a replacement for proper survey investigation. The technique is meant to be a tool to assist a cadastral surveyor by reducing the amount of time spent typing in plan information and giving them quick access to more data when the search area in the field needs to be expanded.

3.3.1 Example

A boundary overlay is needed for DP735556. The plan was completed in 1985 and is on a true north azimuth, with no connection to marks on public record in the Survey Control Information Management System (SCIMS). DP11957273 to the north does have a SCIMS connection to coordinated marks as well as marks from DP735556 (Figure 11). Both plans are imported into AutoCAD using the XINO function (import by observation) of the lisp plugin (Figure 12).

Figure 11: DP735556.

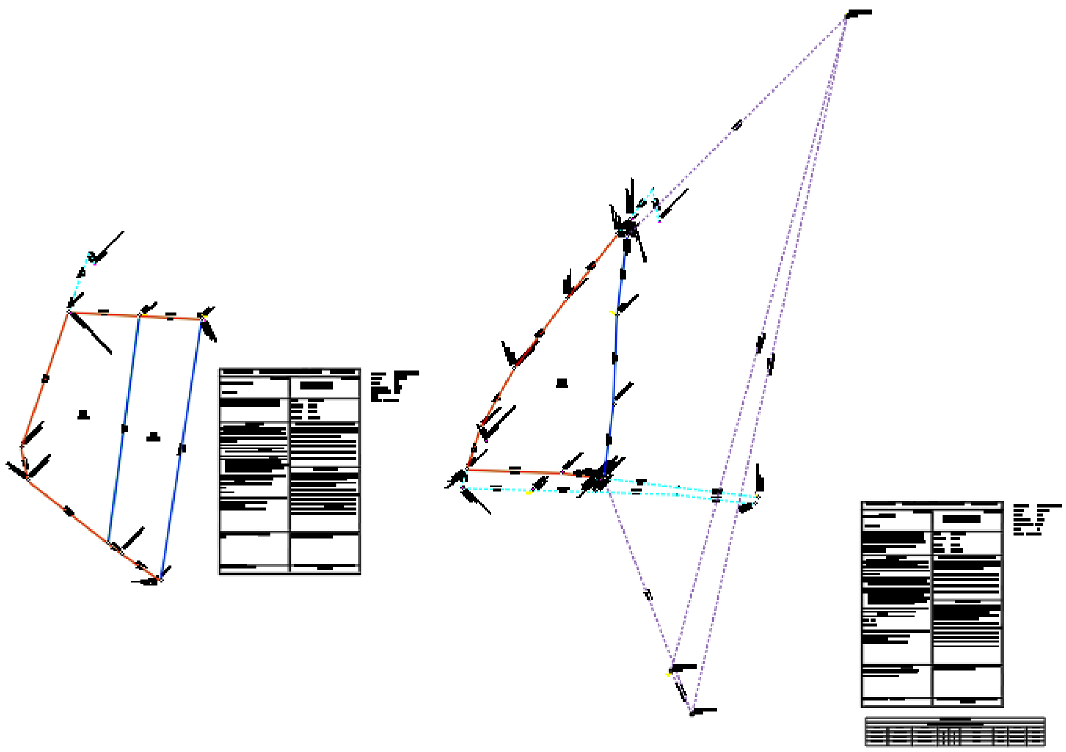

Figure 12: Plans imported by observation.

The plans are then grouped and coloured, and DP735556 (green) is aligned to DP11957273 (red) based on common points (Figure 13).

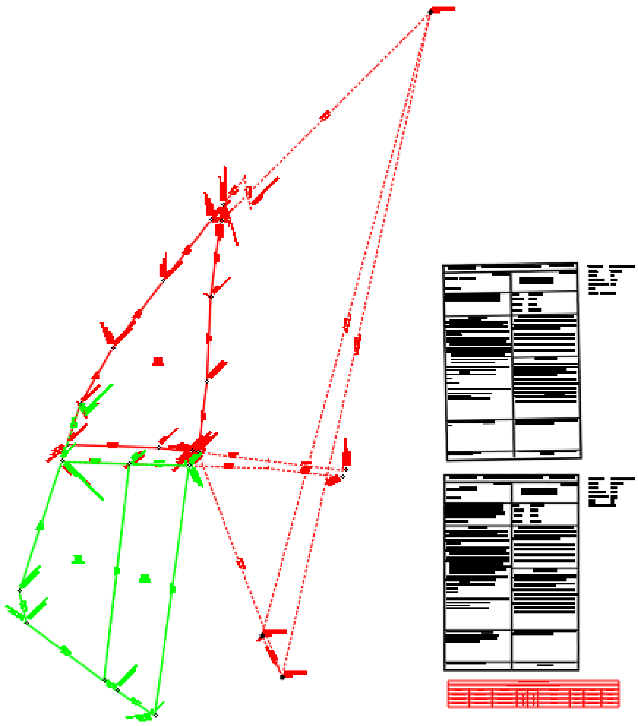

Figure 13: Combined files joined by common points.

The combined plans are placed in the correct coordinated position based on the SCIMS marks, then the XMO (export monuments) function is used to export a csv output of marks ready to find in the field (Figure 14).

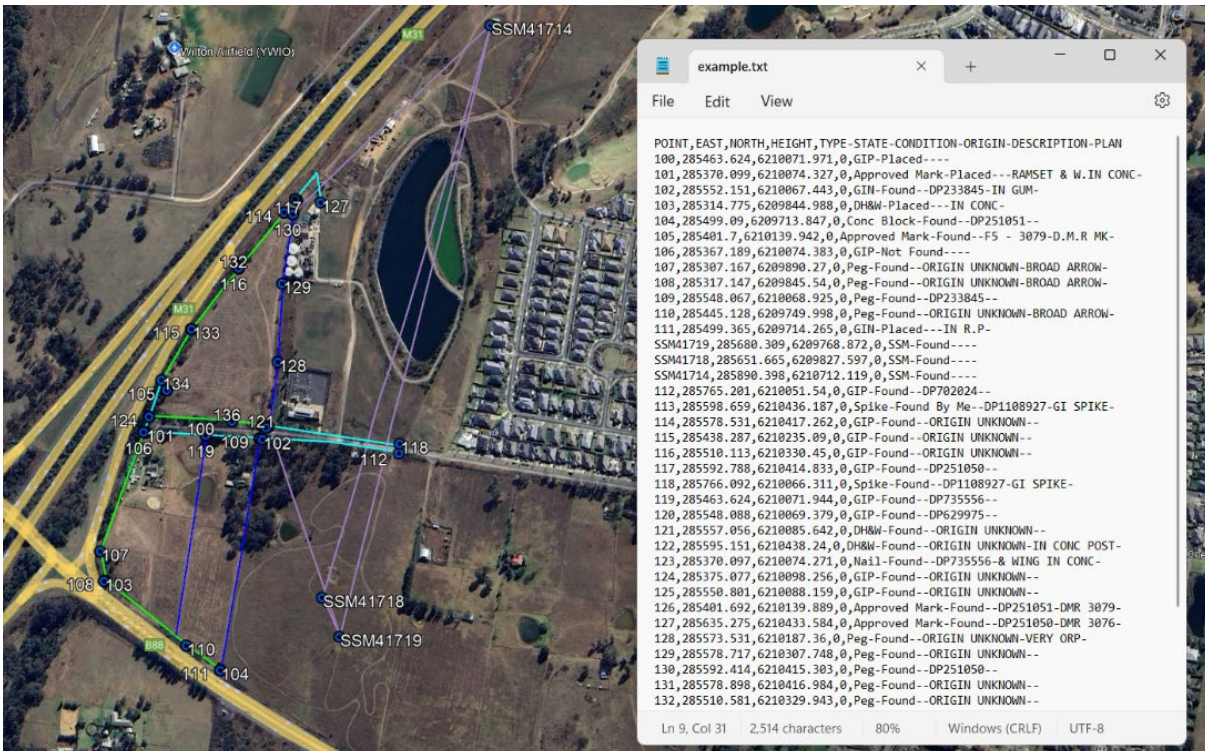

Figure 14: Marks exported ready for use in the field.

When the field work is completed, the marks surveyed in the field are imported back into CAD. The grouped LandXML files can then be positioned on these surveyed points and the boundary overlay extracted (Figure 15). Comparison can also be made to the original plan through the first imports for reporting purposes.

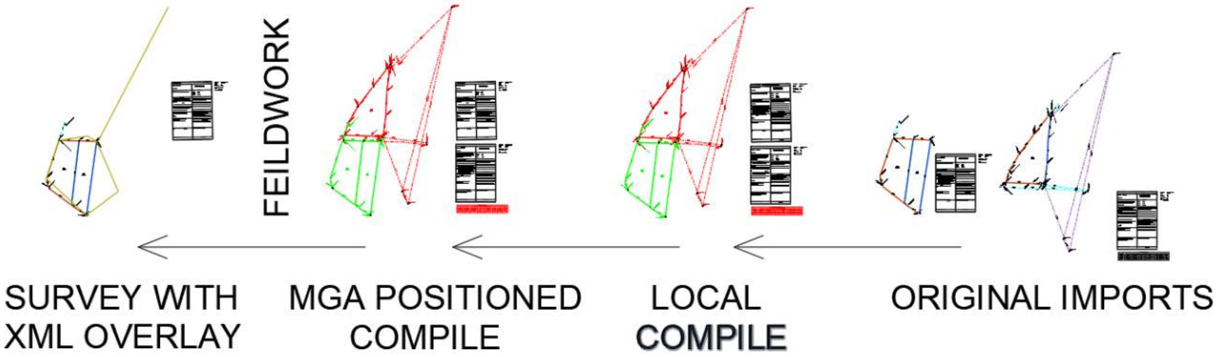

Figure 15: LandXML workflow.

4 COMMON PROBLEMS WITH BACK-CAPTURED LandXML FILES

4.1 Errors

One of the biggest problems with the back-captured LandXML data is the number of errors from the back capture provider. In the Victorian back-captured data we estimate that about 1 in 10 plans contains an error, mostly in non-boundary related observations (of which there are more in Victoria). It is harder to determine an estimate for NSW as there was no release of all LandXML files like in Victoria, but the numbers are likely to be similar.

The sheer volume of information recorded means that even at low transcription error percentages there is still a massive potential for error. Unfortunately, while both NSW and Victoria profess to have performed quality assurance on their data (DCS Spatial Services, 2025a; VIC Department of Transport and Planning, 2024a), a simple loop closure compared to distance covered does not seem to be part of the checking process.

4.2 Gross Errors

4.2.1 Incorrect Data Entered

An example of incorrect data entered for DP803167 is shown in Figure 16. This error was alerted by a 4 metre misclose (the bearing of the 4-metre line to the bank should be 86°22'), the 107.1 m line is a through distance, and the LandXML file has an additional line (the 4 m should have been bracketed).

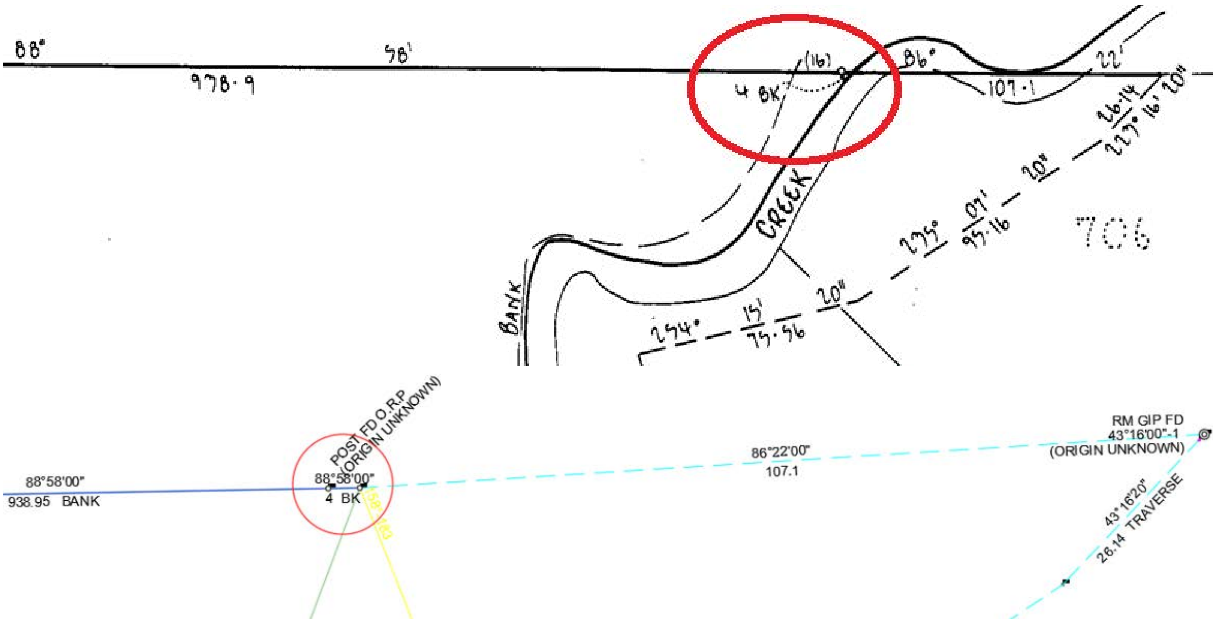

Figure 16: DP803167.

4.2.2 Data Missed

An example of data missed for DP1282949 is shown in Figure 17, alerted by a 300 m misclose. In this case, an entire 300 m line has been missed.

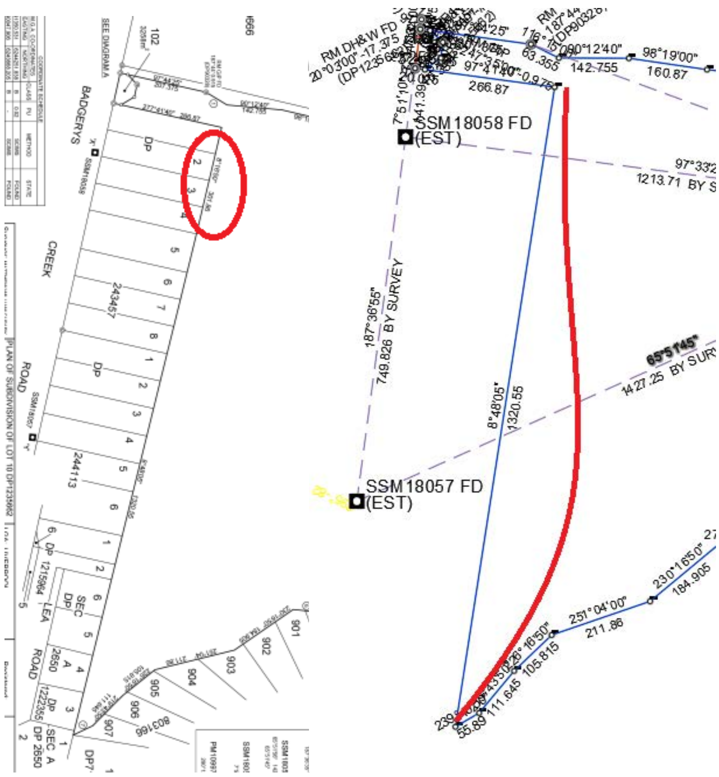

Figure 17: DP1282949.

Another problem are plans of poor quality. In DP248047, the number on the plan does actually look like a “3”, but there is a 1.2 m misclose in the LandXML file, pointing to a potential error. Upon investigation, it was finally isolated to this particular line. A quick check of the table of conversions was very helpful in this case (Figure 18). This is a classic example where the experience of the surveyor comes into play. A surveyor entering this plan might get a 1.2 m error on a compiled residual parcel and accept it as reasonable but would not accept a 1.2 m error in a road parcel from 1974. A minimally trained data entry person got this 1.2 m error but continued without further action.

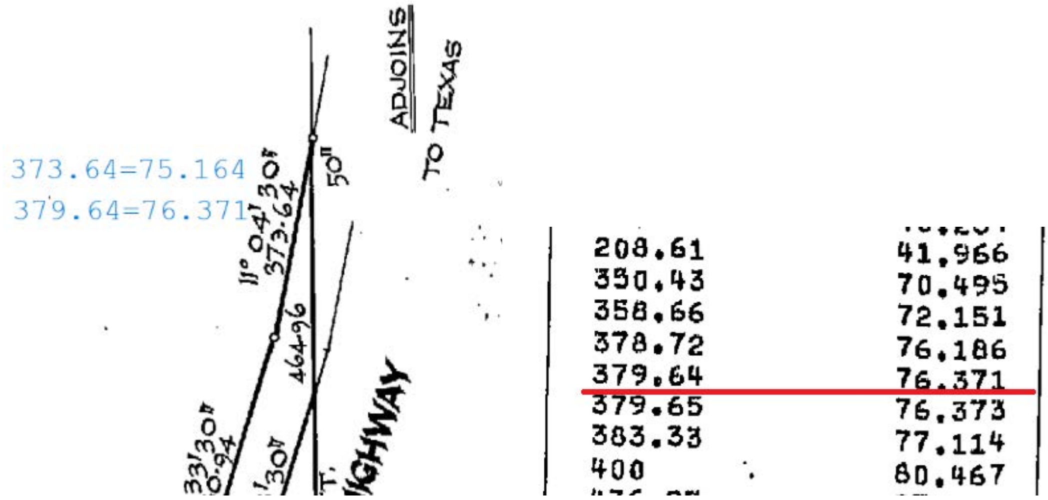

Figure 18: DP248047.

4.2.3 Lack of Understanding Error

Sometimes there is simply a lack of understanding of what is shown on the plan. Just about every surveyor would look at the plan and understand that there was a stringybark reference tree at this corner (Figure 19). The LandXML file for this corner has the tree directly on the corner (and every other corner) with the reference bearing as a description and no reference to the distance.

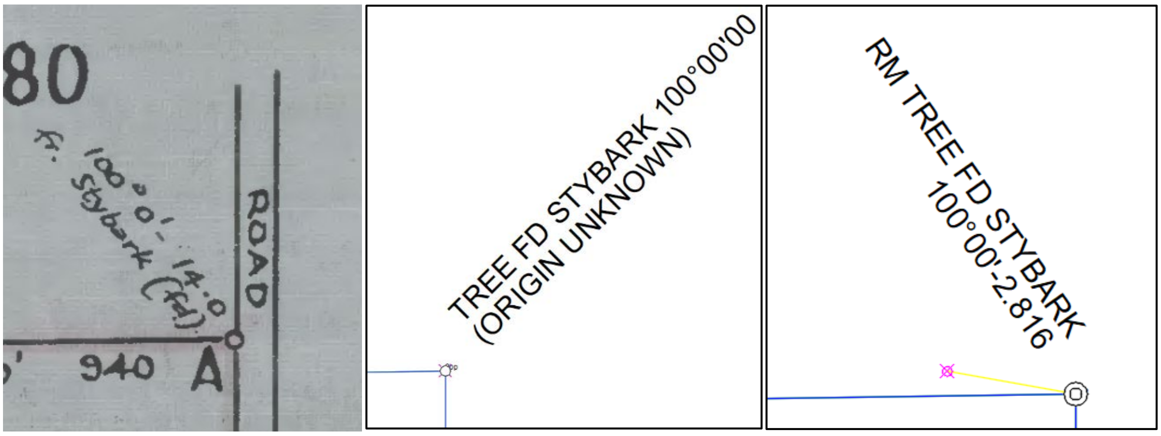

Figure 19: Plan on the left, initial LandXML in the centre and correct LandXML on the right.

4.2.4 Other Common Errors

Quite often a line has been placed from the wrong point, e.g. a Reference Mark (RM) comes from the wrong boundary corner. In Victoria, chainages (which are popular on Victorian field notes) are often started from the wrong point or a restarted chainage is missing. NSW plans also contain quite a few 'guessed' dimensions where the data might have been illegible on the plan, but the guessed value could have been easily verified using surrounding information. Often small lines in diagrams are missed.

However, not all errors originate from the data entry. Some survey errors also slip through the cracks. For example, in DP803167 the arc distance should probably be 115.80 m (Figure 20).

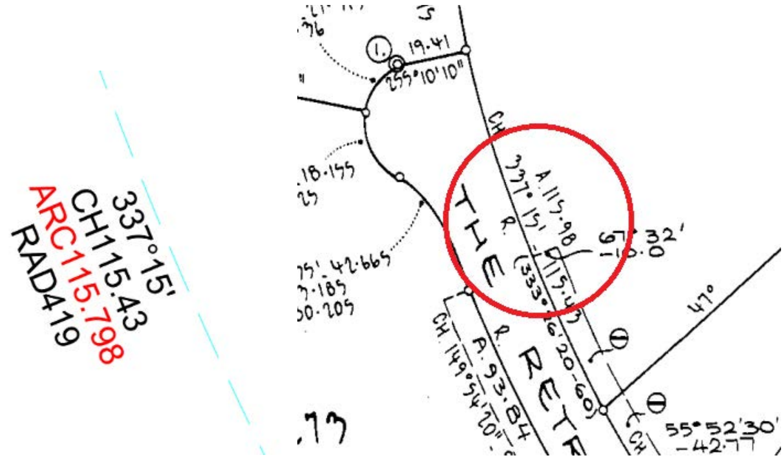

Figure 20: DP803167.

4.3 Compound and Rounding Errors

Because of how LandXML works, sometimes small errors creep in that a surveyor might have entered differently. Regarding cutoff corners, normally a surveyor would enter the data and run the 10’ cutoffs to the intersection. However, as the diagonal component has a higher class (being a road boundary line), and the cutoff extensions are in the connection layer, the diagonal line takes priority and creates a 5 mm error in the corner as shown in Figure 21.

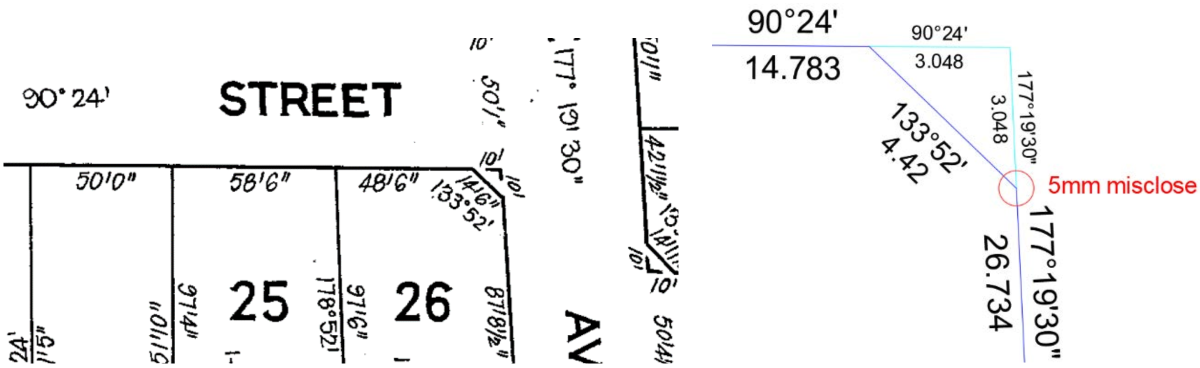

Figure 21: Cutoff corner error.

In another example, a series of parcels might have a 66’ frontage, which when rounded to the nearest millimetre during conversion, would be 20.117 m. If there were 20 of these parcels, this would equate to a 4 mm error. While a surveyor might use the correct conversion to 20.1168 m due to the rounding to the nearest millimetre, the LandXML will be 4 mm shorter. Depending on the rounding shown on the plan, this error can become quite large.

4.4 Intention Lost

LandXML files by nature import based on the information shown on a plan, but sometimes the intention of a plan is lost through the use of those dimensions. For example, in Figure 22 the intention is to have Penleigh Court parallel to and at 140’ from the western boundary. If the LandXML importer draws the line between lots 8 and 9 before the Penleigh Court frontages or the rear and side boundaries of lot 11 and 9, there will be an 8 mm error introduced into one of those lines (due to the plan rounding to the nearest ½ inch). Penleigh Court is also intended to be 50’ wide while this may not be the case after the curved boundaries have been drawn. On plans with a large number of parcels, we find that, while the LandXML is suitable for compiling for the purpose of finding marks in the field, the plans are required to be redrawn manually for the final boundary overlay.

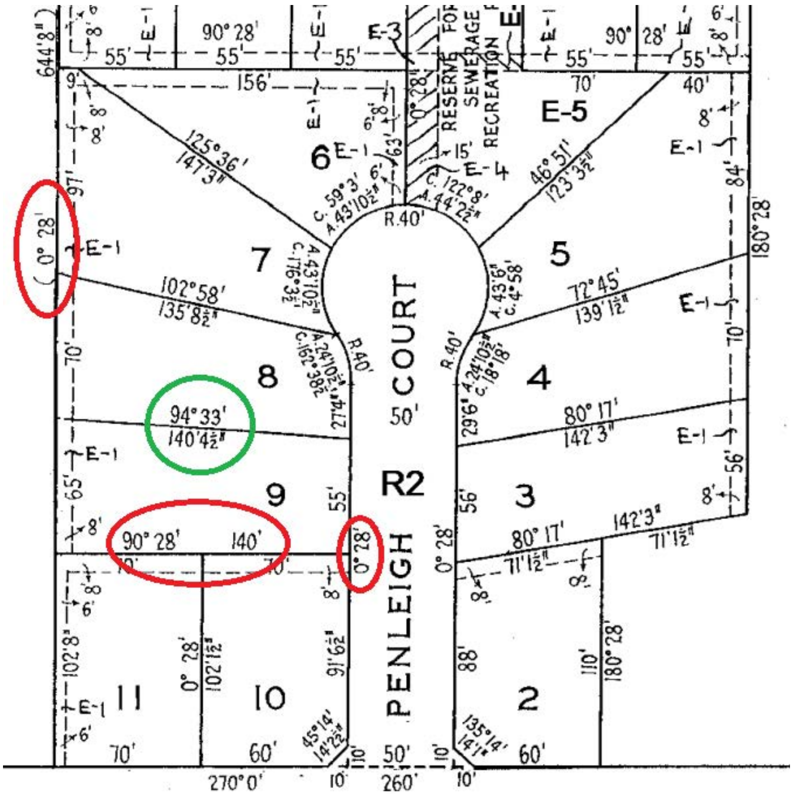

Figure 22: Intention of the plan.

5 WHAT ELSE CAN LandXML DO?

5.1 Least-Squares Adjustments

As mentioned earlier, a least-squares adjustment may not be a suitable for cadastral purposes. A least-squares adjustment takes any error you have and distributes it into the surrounding lines, where perhaps in a cadastral situation it would be best left in a particular line. However, there are advantages to using a least-squares network with LandXML data. Each point and subsequently each line will have a calculated positional accuracy based on the estimated accuracy of the plan and the results of the adjustment. We like to think of this accuracy as a line thickness.

Victoria has completed a least-squares adjustment on about half of the state and for these areas there is now a downloadable DCDB with this positional accuracy as an attribute. With a little bit of coding, this attribute can be used to show how good or bad the DCDB in a certain area is. That is what we did. Figure 23 shows an extract of the DCDB with the positional accuracy applied to the thickness of the line. It can be noticed that if we were working on block number

1, we might have more trouble with our definition than we would for block number 2. This is possibly because block 1 has no MGA connections, or it could relate to very old surveys or there is an error somewhere in this block. This is a handy tool. For example, if we wanted to design a sewer through this area, we could make the designers aware of areas where the DCDB might be unreliable and will need field verification.

Figure 23: DCDB with least-sqaures positional accuracy as thickness.

Jacobs did some pilots for this work, although it was not awarded the project in this case. However, some of the tools we developed to allow us to interface LandXML with the HAVOC (DCS Spatial Services, 2025b) and DynAdjust (Fraser et al., 2025) least-squares adjustment tools have been useful on other projects.

Before the release of this attributed DCDB, Jacobs was asked to see if something similar could be done in a large rail infrastructure project. The client wanted confidence in the DCDB position but did not want to pay for a full re-establishment of the rail corridor at the concept design stage. We took the LandXML files for the area, added a standard deviation based on the date the plan was surveyed, snapped them all to the existing DCDB and tied common points together, then exported this to a least-squares adjustment package. The problem with the differing datums was overcome by not using the bearings of the lines and instead using the angles between boundaries from the same plan in the adjustment software.

As mentioned earlier, 10% of plans contain an error and a large proportion of the time was spent identifying and correcting these errors. However, considering it was not until halfway through the project that we received the LandXML files over our area of interest (until that time we had been manually entering plans), significant time savings were realised by using the back-captured LandXML data.

The project resulted in fixing some large discrepancies in the DCDB, the discovery of some hiatus and overlaps in the subject area and identifying areas where the cadastral fabric was of a lesser accuracy (see Figure 23). Figure 24 shows on the left exaggerated error ellipses, indicating the accuracy of the adjustment, and on the right the amount the DCDB was corrected by (the red arrows indicating the magnitude of the correction).

Figure 24: Error ellipses of cadastral boundaries (left) and shifts to the DCDB (right).

5.2 Information Harvesting

In Victoria, a large proportion of the LandXML files was released to the public as large zip files, unlike in NSW where payment is required for a plan to receive the associated LandXML file. The information stored in these files can be used and harvested for unique purposes.

5.2.1 PCMs

In Victoria, an RM placed for a boundary survey quite often is given what is called a Primary Cadastral Mark (PCM) number, which is a combination of the registration number of the surveyor placing the mark and an incrementing counter. For example, the author's PCM number is 12058#####, the 1 at the start identifying a PCM, 2058 being the registration number and the #s representing the counter number. From the introduction of the PCM system to the removal of coordinates from survey plans (a period from about 1995 to 2013) the PCMs were being included in the Survey Marks Enquiry Service (SMES – see VIC Department of Transport and Planning, 2024b). However, since 2014 this has ceased to continue (Boyle, 2013), which has resulted in many cases of the same mark being given multiple PCM numbers (sometimes even by the same surveyor).

In order to try and prevent Jacobs from perpetuating this problem, we developed some code and read all 1,000,000 LandXML files, harvested all the PCMs, then compared this to the SMES database to figure out which marks were not currently in the database. We then created a kml file for Google Earth where all missing PCMs for a Local Government Area (LGA) could be loaded. As an example, Figure 25 shows the extent of PCMs not added to SMES in the LGA of Port Phillip from 2013 to 2021.

Figure 25: Missing PCMs in the LGA Port Phillip.

5.2.2 Missing PSMs

The PCM harvesting technique was modified to instead harvest all PSMs from the LandXML files for the purposes of finding PSMs that had not been added to SMES. For a period of about 30 years in Victoria, it was not compulsory, nor was there a mechanism, to add a plan showing PSMs placed in large subdivisions, and the placed PSM sketch plans were often not supplied to the geodetic department. This has resulted in many undocumented PSMs that surveyors would stumble across in subsequent surveys. By harvesting all the PSMs from the LandXML files, then filtering out all those with an existing number or within 30 m of an existing mark, some of the missing PSMs were able to be identified, checked and added to the SMES network.

5.3 Bulk Loading

As all the Victorian LandXML files are located based on the DCDB position, this can be used to a surveyor's advantage, giving them the ability to see the cadastral fabric of an area. While the accuracy of the position of these LandXML files is poor (DCDB level), an entire area can be loaded and connecting information, not realised by rifling through plans, might be discovered. Bulk loading LandXML files (via the XBLIN function of the lisp plugin) has now become a common tool used by Jacobs surveyors as a supplement to the cadastral survey process. LandXML files are automatically loaded into AutoCAD based on a list of plans, grouped and coloured in order to examine the cadastral fabric of an area. A plan can be picked up and identified and connections to common marks identified, as shown in Figure 26. This is particularly useful if a mark is gone. There is the possibility of indirect re-establishment through a possibly unrelated plan.

Figure 26: XBLIN imported network (left) and typical corner with multiple plan connections to marks (right).

6 CONCLUDING REMARKS

This paper has outlined some of the key components of LandXML for use by surveyors, demonstrated how LandXML could be incorporated into cadastral workflows, highlighted some common errors that LandXML users should be aware of, and demonstrated some alternative uses for LandXML data that may not have been envisaged at the commencement of the back capture process.

LandXML as a format for storing cadastral information is here to stay. The mass of information that has been converted from the paper (raster) based format into vector-based data in this format means that even if a new format is developed, it will require conversion from these LandXML files. For all potential uses of this back-captured LandXML data, the biggest benefit to cadastral surveyors is the use of the individual xml files, taking advantage of the observation data for various uses.

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