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The LandXML to SCIMS (LX2S) Pilot Project

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ABSTRACT

LandXML is an international data standard for exchanging geospatial information. Since 2015, DCS Spatial Services has captured and stored registered Deposited Plans (DPs) in the LandXML format. To date, this has resulted in the capture of more than 1 million DPs including over 4.4 million land parcels. The DP LandXML files are stored in Cadastre NSW, a system to centrally store, index and track the lifecycle of cadastre-specific data assets (including LandXML files). Constituting the NSW State Control Survey, the Survey Control Information Management System (SCIMS) is the state's database containing more than 250,000 survey marks on public record, including coordinates, heights, accuracy classifications and other metadata. This paper outlines the innovative LandXML to SCIMS (LX2S) pilot project, which was initiated by DCS Spatial Services to automate the harvesting of State Control Survey observations from registered DPs, adjust the 'islands' of harvested observations, and publish the adjusted GDA2020 coordinates and their quality in SCIMS. The automated harvesting and adjustment for the LX2S pilot project was executed using Python code developed in-house to retrieve, test and process DP LandXML files from Cadastre NSW. This initiative supports industry and community growth by extending the state's fundamental positioning framework, the State Control Survey, with a greater density of survey marks with GDA2020 coordinates of known quality. It also demonstrates to industry customers the clear benefit and outcomes of the regulatory requirement for survey plans to connect to the State Control Survey. In recognition of its innovative design and the enormous benefits it provides, the LX2S pilot project was awarded joint winner of the 'Extra Dimension & Innovation' category at the 2023 Excellence in Surveying and Spatial Information (EISSI) awards.

KEYWORDS: *Innovation, LandXML, SCIMS, densification, harvesting, adjustment.*

1 INTRODUCTION

The NSW regulatory requirement for survey plans to connect to Permanent Survey Marks (PSMs) has the long-recognised potential to assist in the densification of the State Control Survey. On behalf of the Surveyor-General, DCS Spatial Services, a unit of the NSW Department of Customer Service (DCS), is responsible for the establishment, maintenance and improvement of the State Control Survey, which is made available to users via the Survey Control Information Management System (SCIMS). SCIMS is the state's database containing more than 250,000 survey marks on public record, including coordinates, heights, accuracy classifications and other metadata, provided in the Geocentric Datum of Australia 2020 (GDA2020 – see Harrison et al., 2023), its predecessor GDA94 (ICSM, 2024) and the Australian Height Datum (AHD – see Roelse et al., 1971; Janssen and McElroy, 2021). The basic concept of the SCIMS database is illustrated in Figure 1.

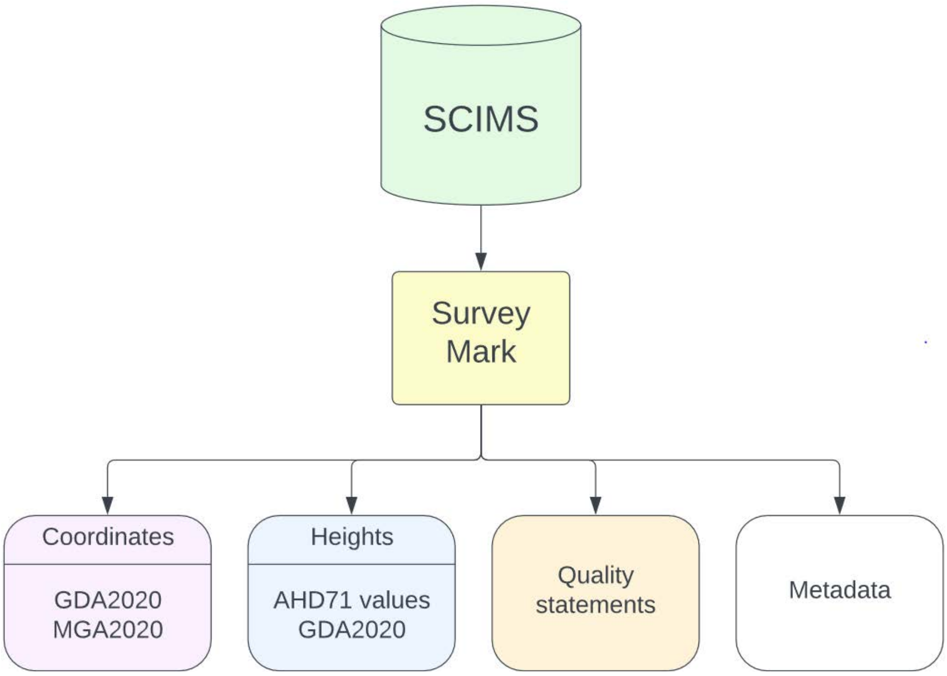

Figure 1: Simplified SCIMS database concept.

LandXML is an international data standard for exchanging geospatial information. The Intergovernmental Committee on Surveying and Mapping (ICSM) has developed a national LandXML schema from which NSW has developed a subset NSW LandXML recipe. Over recent years, LandXML has become increasingly popular as a format to store survey plans in the digital age. In 2015, DCS Spatial Services initiated a project to capture and store registered Deposited Plans (DPs) in the LandXML format, which has to date captured over 1 million DPs including over 4.4 million land parcels. DPs are captured using the NSW LandXML recipe and stored in Cadastre NSW, a system to centrally store, index and track the lifecycle of cadastre-specific data assets (including LandXML files) (Figure 2).

This paper outlines, in general terms, the innovative LandXML to SCIMS (LX2S) pilot project, which was initiated by DCS Spatial Services to automate the harvesting of State Control Survey observations from registered DPs, adjust the 'islands' of harvested observations, and record the adjusted GDA2020 coordinates and their qualities (i.e. Horizontal Class and Horizontal Positional Uncertainty, HPU) in SCIMS. Automated harvesting and adjustment for the pilot project was executed using sophisticated Python code developed in-house that retrieved registered DP LandXML files conforming to the NSW LandXML recipe from Cadastre NSW (Figure 3).

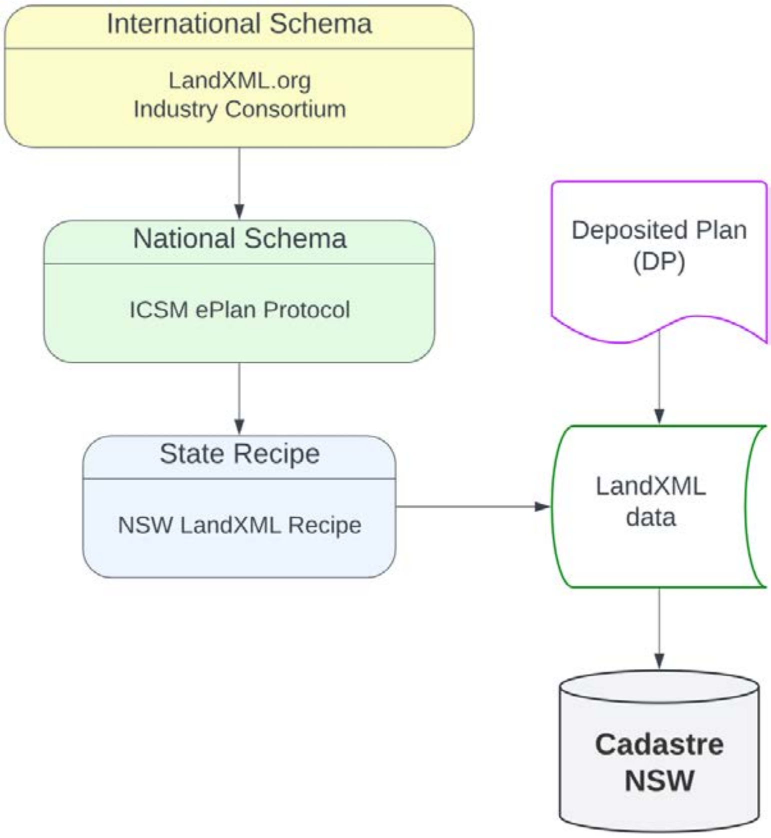

Figure 2: Structural concept of LandXML, Deposited Plans and Cadastre NSW.

Figure 3: Concept of harvesting LandXML control data to update SCIMS.

2 NEW SPATIAL APPLICATIONS REQUIRED

The LX2S pilot project required several new spatial applications to be generated in order to support the automated workflow design. This was critical to enable the desired automated harvesting, Quality Assurance (QA), adjustment and SCIMS update for vast amounts of data.

2.1 Python Code Base

DCS Spatial Services has been developing in-house utilities to automate and streamline its unique workflows for more than 50 years. The in-house utilities support the maintenance and extension of the State Control Survey and the cadastre, both being legislative requirements of the Surveyor-General under the Surveying and Spatial Information Act 2002. The development of in-house utilities also directly supports the digital business initiatives of Digital.NSW (e.g. the harvesting of DP LandXML data) to support our industry customers and stakeholders. To this end, a closed-source code repository called SurvPy (within a 'Git' distributed version control system) has been developed to facilitate fulfilment of the Surveyor-General's legislative requirements using the interpreted, dynamically typed programming language Python.

The LX2S pilot project utilises innovative data structures and algorithms. As no off-the-shelf software existed for the project requirements, the small project team had to develop a custom-built code base to further extend the SurvPy library (calling many of the unique functions within SurvPy). Python was chosen to develop the LX2S code base in the current digital framework, as the existing SurvPy library could be directly used with no translation required. Python is also compatible with major platforms and systems, has a large standard library and is cost-effective to use and maintain. Python is considered one of the most globally popular programming languages and used by organisations such as Geoscience Australia and ICSM.

A commercial Integrated Development Environment (IDE) was used to develop the LX2S Python code base. An IDE is software that facilitates code development and provides a code editing interface with productivity tools that substantially increase the efficiency, standardisation and integration of code development. LX2S adopted an Object-Oriented Programming (OOP) model, as this was considered the only viable option for a project of this size. The LX2S code base greatly increases the scope of the existing SurvPy library, with additions for the LX2S pilot project totalling approximately 25,000 lines of Python code. This number continually increases as processes are refined, expanded and optimised into the future.

2.2 SQLite Database

In order to store, perform QA, query and output the relevant State Control Survey observations from registered DPs, a customised SQLite relational database was built to fulfil the project requirements. SQLite was chosen as the database format for its ease of use, lightweight structure, read-write performance and reliability. Customised LX2S database tables were configured for the storing of observations and metadata pertinent to each observation, including its parent DP, observation weightings, QA assessments and overrides (both automatic and manual). For example, the extract of the LX2S database shown in Figure 4 includes columns detailing the survey mark name/number as harvested from the DP, its verification, override option and relevant comments. The customised LX2S database is the project-critical data structure in the transition from DP LandXML files to the production of least squares adjustment input files.

id	plan_id	pntref	name	name_verified	name_manual	name_comment
Filter	Filter	Filter	Filter	Filter	Filter	Filter
113	27	3	SS185957	SS185957	NULL	Coordinates match SCIMS
114	28	860	PM50232	PM50232	NULL	Near stations check, exact match - 1.544 m
115	28	861	SS17266	SS17266	NULL	Near stations check, exact match - 1.438 m
116	28	862	SS144731	SS144731	NULL	Near stations check, exact match - 1.492 m
117	28	863	SS208127	SS208127	NULL	Coordinates match SCIMS

Figure 4: Extract of a customised LX2S database table.

2.3 Adjustment Software

The open-source DynAdjust least squares network adjustment software distributed by ICSM (Fraser et al., 2023, 2024) was used to adjust the LX2S output data. DynAdjust was chosen due to the high performance of both its simultaneous and phased adjustment modes and for consistency and compatibility with the GDA2020 state and national adjustments, which also use DynAdjust. It should also be noted that LX2S team members have made contributions to improve the DynAdjust GitHub code repository. Customised LX2S Python modules allow the automated sequential execution of each auto-generated DynAdjust input file comprising the LX2S adjustment islands. Figure 5 shows a DynAdjust input file extract, detailing the ellipsoidal distance measurement and its standard deviation between SS69512 and SS69517, harvested from DP1254738 dated 30 October 2019.

```
<!-- Type E Ellipsoidal Distance -->
<!-- StdDev from: Constant=0.010, PPM=50, C.L.=95% -->
<!-- Source legislation: Surveying and Spatial Information Regulation, 2017 -->
<DnaMeasurement>
  <Type>E</Type>
  <Source>CadNSW_dp1254738.xml_LANDXML_SUPP_v9_2020-12-23T22:44:49</Source>
  <Epoch>30.10.2019</Epoch>
  <Ignore/>
  <First>SS69512</First>
  <Second>SS69517</Second>
  <Value>79.9131</Value>
  <StdDev>0.0071</StdDev>
  <MeasurementID>103000025</MeasurementID>
</DnaMeasurement>
```

Figure 5: Extract of a DynAdjust input file.

2.4 Mathematical Integrity Report

The Mathematical Integrity Report (MIR) was developed to speed up the examination of individual DP LandXML files when testing code development and manually assessing individual LX2S island adjustments. The report has large spin-off benefits to DCS Spatial Services as it reduces manual close-checking time from hours/days to minutes and empowers the NSW Surveyor-General with better tools to uphold legislative responsibilities. The MIR also has potential to be of significant benefit to industry stakeholders external to DCS Spatial Services.

The MIR is an attention-focuser that highlights mathematical integrity problems within a DP LandXML file via the use of juxtaposed textual and graphical reports. The MIR converts a DP LandXML file from data to meaningful diagrams and analytical reports of the many survey closures within the LandXML file in a manner fit for human interpretation. At a fundamental level, it checks the closes in a plan in the same manner that a professional surveyor would manually check them with a hand-held calculator, whilst also detecting and highlighting potential problem observations.

The report is delivered as a colour pdf with navigational bookmarks for ease of use. Summary tables (Figure 6) and graphics (Figures 7 & 8) explicitly show those closes which exhibit a misclose outside the relevant legislative tolerances. Details of each close are reported (Figures 9 & 10).

Possible error edges (measured edges - edge dimensions as quoted in XML)

(from, to)	Bearing	Chord	Arc	Radius	Rot.	Meas.	Type
(86, 87)	32° 03' 45"	16.9				True	Connection
(324, 87)	343° 38' 38"	13.777				True	Reference

Cycles with Misclose Weight Ratio < 1 (non-compliant)

Cycle	Misclose Weight Ratio	Misclose	Nom. tolerance
PSM_cad_cycle_8	0.08	0.401	0.031
PSM_cad_cycle_19	0.08	0.403	0.034
PSM_cad_cycle_13	0.09	0.399	0.034

Figure 6: MIR summary extract, detailing possible error edges and cycles with misclose problems.

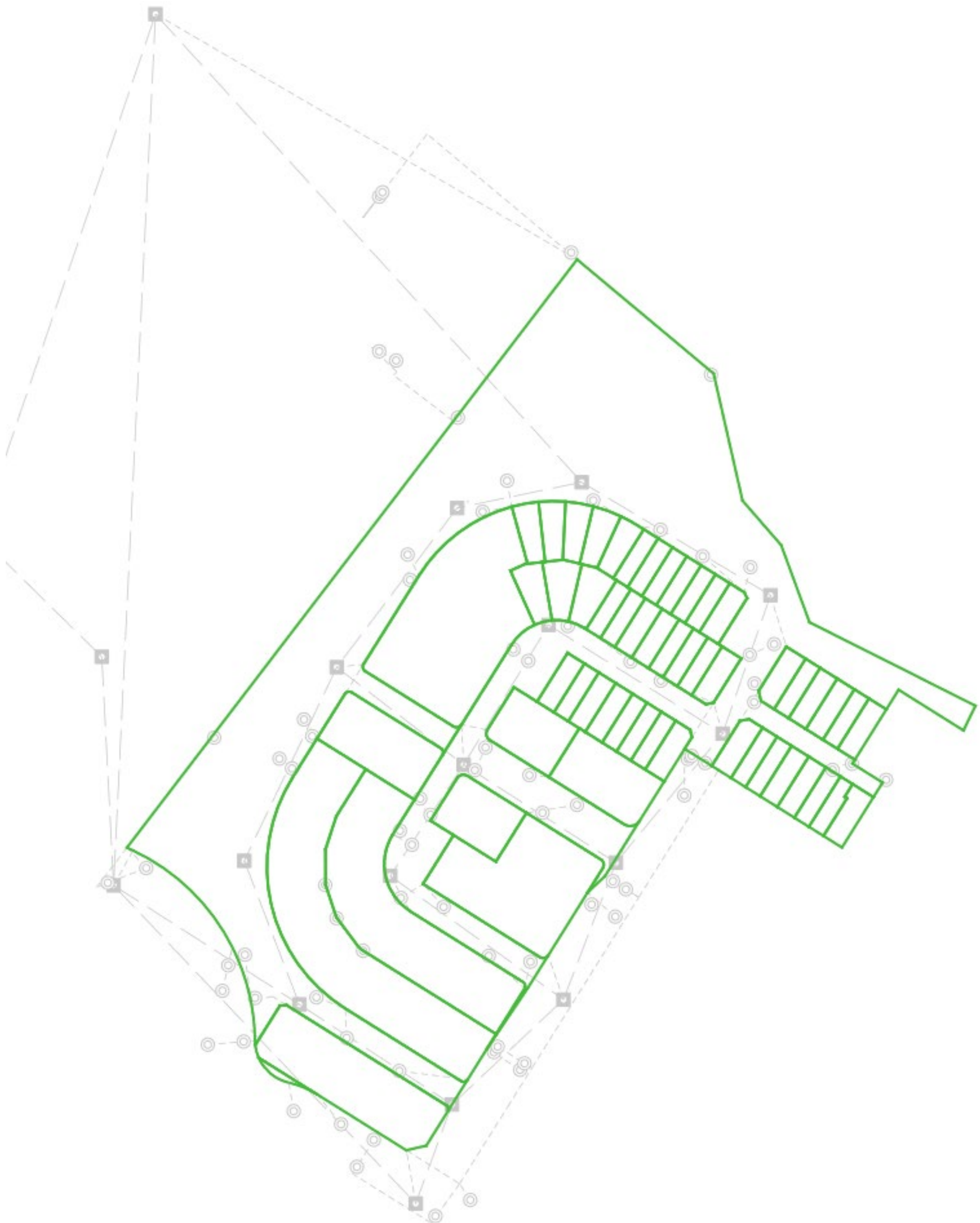

Figure 7: MIR parcels health diagram example, indicating no misclose problems (green = good).

Figure 8: MIR extracted cycles health diagram example, indicating problematic cycles (orange = suspect, red = possible error).

Misclose

M/C dist.	M/C bearing	MWR	Prop (1:)	PPM	Nom. tolerance
0.004	76° 42' 57"	19.2	158943	6.3	0.086

Cycle vectors

(from, to)	Bearing	Chord	Arc	Radius	Rot.	Meas.	Type
(212, 213)	268° 08'	27.415				True	Boundary
(213, 215)	6° 37' 40"	7.581	7.585	67.7	CCW	True	Road
(215, 216)	88° 08'	27.41				True	Boundary

Figure 9: MIR parcel report extract, detailing the misclose and cycle vectors.

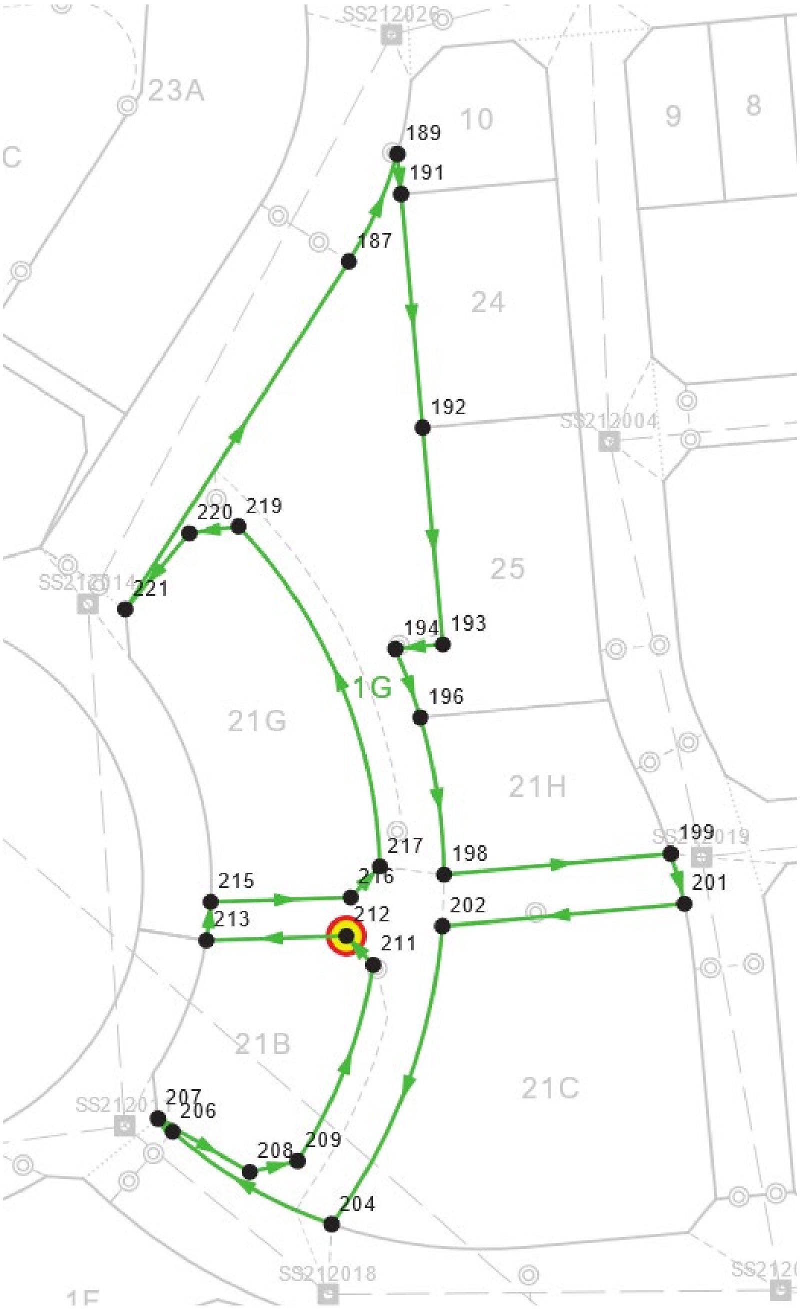

Figure 10: MIR parcel diagram example, indicating 212 as the start/end point of the cycle for manual examination purposes.

3 INNOVATIVE METHOLOGY

The scale of the LX2S project vision required innovative approaches to each stage of the project workflow. The project workflow can be broken into four broad categories (Figure 11). The following sections briefly discuss each part of this workflow.

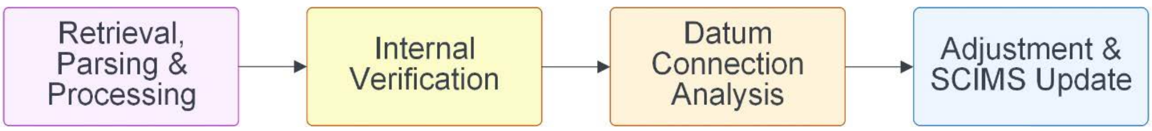

Figure 11: Workflow overview.

3.1 Retrieval, Parsing and Processing

The LX2S methodology for retrieving bulk quantities of DP LandXML files from Cadastre NSW requires a focused balance between retrieval speed and hardware capacity limitations. To achieve the desired balance, a strategy of chunked asynchronous retrieval using 'Elasticsearch' queries was adopted (Figure 12), where the overall query is, if required, broken into smaller chunks so that hardware capacity limits are not breached in downstream processing. Each chunk is then submitted asynchronously to maximise the speed of retrieval of each Cadastre NSW DP bundle. Bundles are assessed to determine the best available LandXML file for each DP.

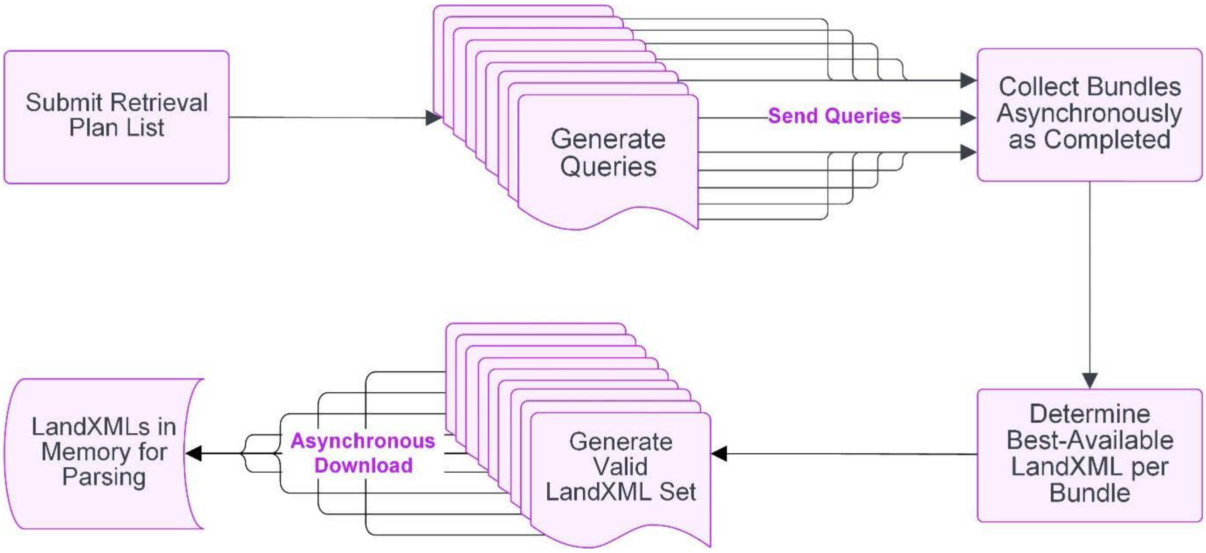

Figure 12: Retrieval overview.

The process of parsing (breaking up the LandXML file into its components) and storing required the LX2S team to custom-build a complete object-oriented data structure to fulfil current and future processing requirements of DP data from LandXML sources, other existing sources as well as sources and formats yet to be defined. LX2S parses retrieved LandXML data and places the parsed data into 'DepositedPlan' Python objects (Figure 13). The DepositedPlan Python object contains attributes, some of which themselves can be objects with attributes (think of a set of drawers where a drawer can itself be broken into a set of drawers). It is into these compartments and sub-compartments that the parsed data is stored.

```
class DepositedPlan:
    """
    Contains attributes & methods pertinent to a range of applications requiring analysis of a registered
    Deposited Plan as captured into an appropriate data format.

    :cvar scims_marktypes: Set containing all valid SCIMS mark types
    :type scims_marktypes: set
    """

    scims_marktypes = {'PM', 'SS', 'TS', 'CR', 'CP', 'GB', 'MM'}
```

Figure 13: Code extract of the DepositedPlan object.

LX2S processing passes the DepositedPlan object to custom-built Python processing objects. The processing objects populate the component objects and attributes within the DepositedPlan object and calculate any attributes required in the downstream load flow. One of the main priorities in processing is assessment of the mathematical integrity of the DepositedPlan object, as this comprises the critical pre-QA assessment. This is essentially a misclose check of the LandXML data for the subject DP and leverages sophisticated applications of mathematical graph theory. Simply put, graph theory examines the relationships of graphs, which are mathematical objects consisting of vertices (or nodes) connected pairwise by edges (or lines). It is a branch of mathematics used to represent relations and networks and is widely used in network analysis.

As a result of the mathematical integrity assessment, each observation is given a weighting, the Misclose Weight Ratio (MWR) (Equation 1), which is applied downstream in adjustment weighting. Observations involved in closes outside legislative tolerances are down-weighted unless the MWR value is below a floor value, at which point they are discarded. Observations only involved in closes that meet legislative tolerances are given a ceiling MWR value.

$$MWR_n = \frac{legislative\ misclose\ tolerance_n}{misclose_n} \tag{1}$$

Once processing is complete, the relevant data is extracted from the processed DepositedPlan objects and written to the custom-built LX2S SQLite database.

3.2 Internal Verification

Sophisticated, highly detailed internal verification objects form the bulk of the automated LX2S QA processes, whose broad categories can be summarised as follows:

1) A-priori coordinate generation: The LandXML CgPoint attributes stored in the DepositedPlan object are transformed to the best approximation of datum via sequential transformation method attempts, including a Euclidian least squares transform method.
2) Permanent Survey Mark (PSM) label verification: The PSM labels are verified using a range of techniques, including string matching (exact and combination matching), progressive radial searching for near stations, mark type switching, mark number integer substitution and Trigonometrical Station (TS) name matching.
3) Measurement QA: The validity of each PSM-to-PSM observation is assessed against multiple criteria, including MWR threshold testing, self-looping observations, compiled status and mark status.
4) PSM heights: It is ensured that all PSMs have a valid ellipsoidal or orthometric height for reduction of ground distances to the ellipsoid. PSMs without a height are given an orthometric (AHD71) height interpolated from the NSW Digital Elevation Model (DEM) (Smith and Janssen, 2022).
5) Measurement reduction: All observations are rigorously reduced to the ellipsoid surface in preparation for the adjustment step.
6) Measurement outlier detection: Outliers are detected and removed using a range of detection techniques, including modified z-score distribution analysis and comparison with SCIMS values (Figure 14).

primary_edge	qa_status	qa_comment	adj_island	adj_status
Filter	Filter	Filter	Filter	Filter
True	active	MWR passed|||SINGLE MSR - no internal distribution test performed|||...	1	active
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	2	active
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	2	active
True	active	MWR passed|||SMALL DATASET - passes internal edge distribution test|||...	3	active
True	active	MWR passed|||SMALL DATASET - passes internal edge distribution test|||...	3	active
True	inactive	MWR rejection	NULL	inactive
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	1	active
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	1	active
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	1	active
True	active	MWR passed|||LARGE DATASET - passes internal edge distribution test|||...	1	active
True	inactive	MWR rejection	NULL	inactive
True	inactive	MWR rejection	NULL	inactive

Figure 14: Automated QA results in the LX2S database.

3.3 Datum Connection Analysis

Datum connection paths are regressively determined for all PSMs and adjustment islands generated (where datum connection is available) using mathematical graph theory. To be classified as ‘connected to datum’, an island must be connected to two or more established PSMs with HPU in SCIMS.

3.4 Adjustment and SCIMS Update

The adjustment files are written from the LX2S database to the DynAdjust input files using the LX2S PlanAdjustmentWriter object. The input observations are collated into the islands formed in the datum connection step (see section 3.3) and written to separate adjustment input files. The PSMs with HPU in SCIMS (as determined during the datum connection analysis) are used as the constraints for each island adjustment. Observations that retain an active status in the LX2S database are sent to the input files with a-priori weightings calculated from a combination of legislative tolerances and the MWR.

Once the automated adjustment process and a report of the adjustment outcomes (including convergence status, number of outliers, etc.) is complete, the outcomes are examined for any adjustments requiring manual intervention (Figure 15). Where manual intervention is required, staff assessment is carried out and the required data fields in the LX2S database are manually edited (e.g. mark name changed or observation de-activated) (Figure 16) and the adjustment files re-generated.

```
may_2023_pilot_island_18.simult.adj     : CONVERGED   - NO OUTLIERS

may_2023_pilot_island_19.simult.adj     : OUTLIER COUNT > 0
                                          Outlier Count = 1
                                          Outliers within accepted tolerance (N -stat < 3.0) --> ACCEPTED
```

Figure 15: Extract of adjustment processing log.

manual_status ▲1	comments
Filter	Filter
use	MIR analysis indicates OK
use	MIR analysis indicates OK
use	MIR analysis indicates OK
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Adjustment outlier
ignore	Gross error in bearing
ignore	Gross error in ground distance

Figure 16: Example of manual overrides in the LX2S database.

The results of all successful island adjustments are collated into a single SCIMS bulk update file. The strategy for the SCIMS update required detailed attention from the LX2S team so that survey mark coordinates of superior quality were not accidentally overwritten (Figure 17).

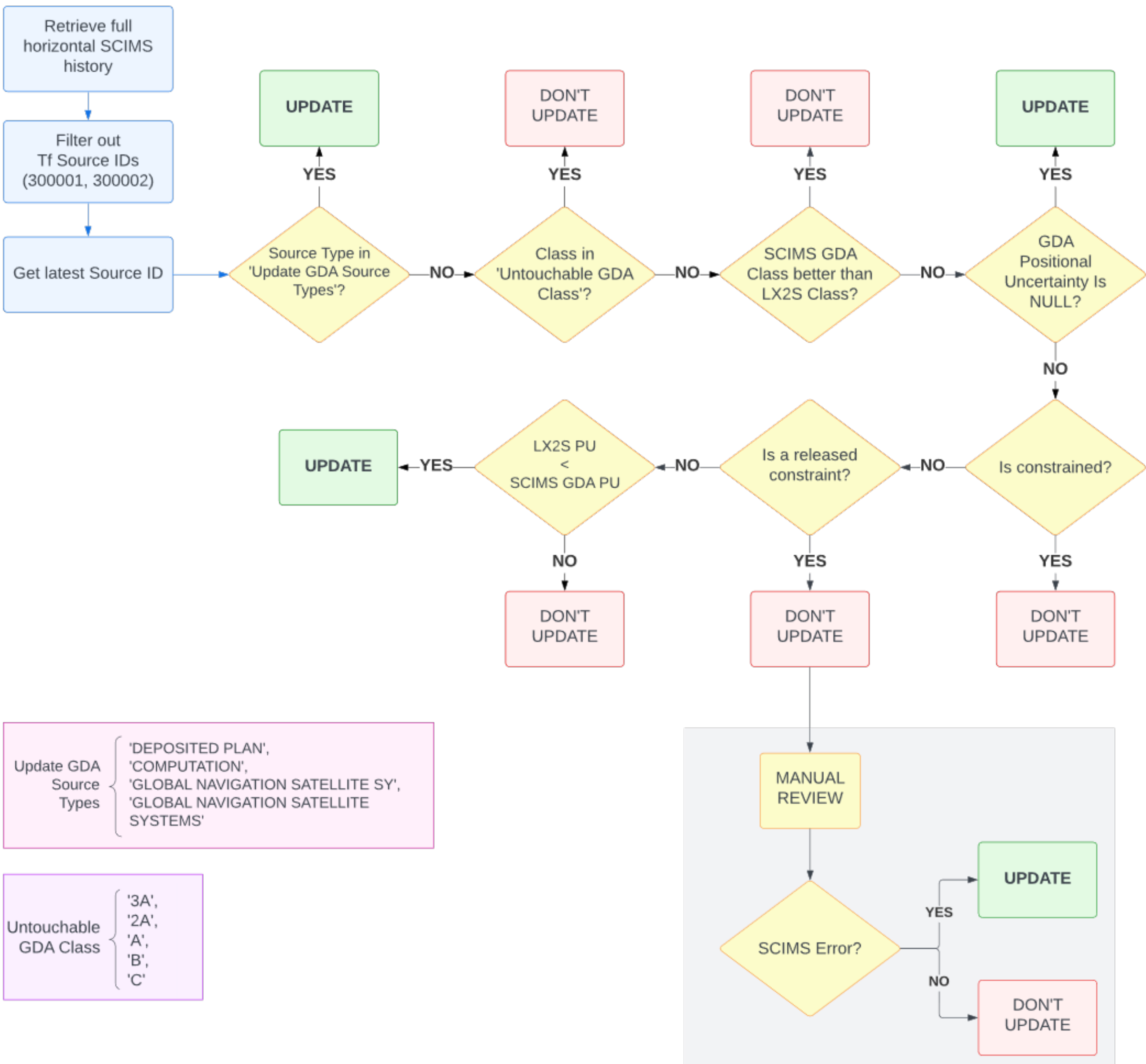

Figure 17: SCIMS update strategy.

A major strategic decision made was not to update hanging communities of survey marks. Extensive analysis of the pilot project areas showed that the veracity of the observations downstream from the articulation point (pivot) could not be ascertained (Figure 18). For all other survey marks, SCIMS is updated with GDA2020 coordinates, HPU and Horizontal Class according to the strategy shown in Figure 17. The minimum HPU that can be attained by a mark being updated is that of the smallest constraint HPU in the subject adjustment island. Horizontal Class is rigorously assessed using horizontal relative uncertainties, and the best Horizontal Class that can be obtained is Class D.

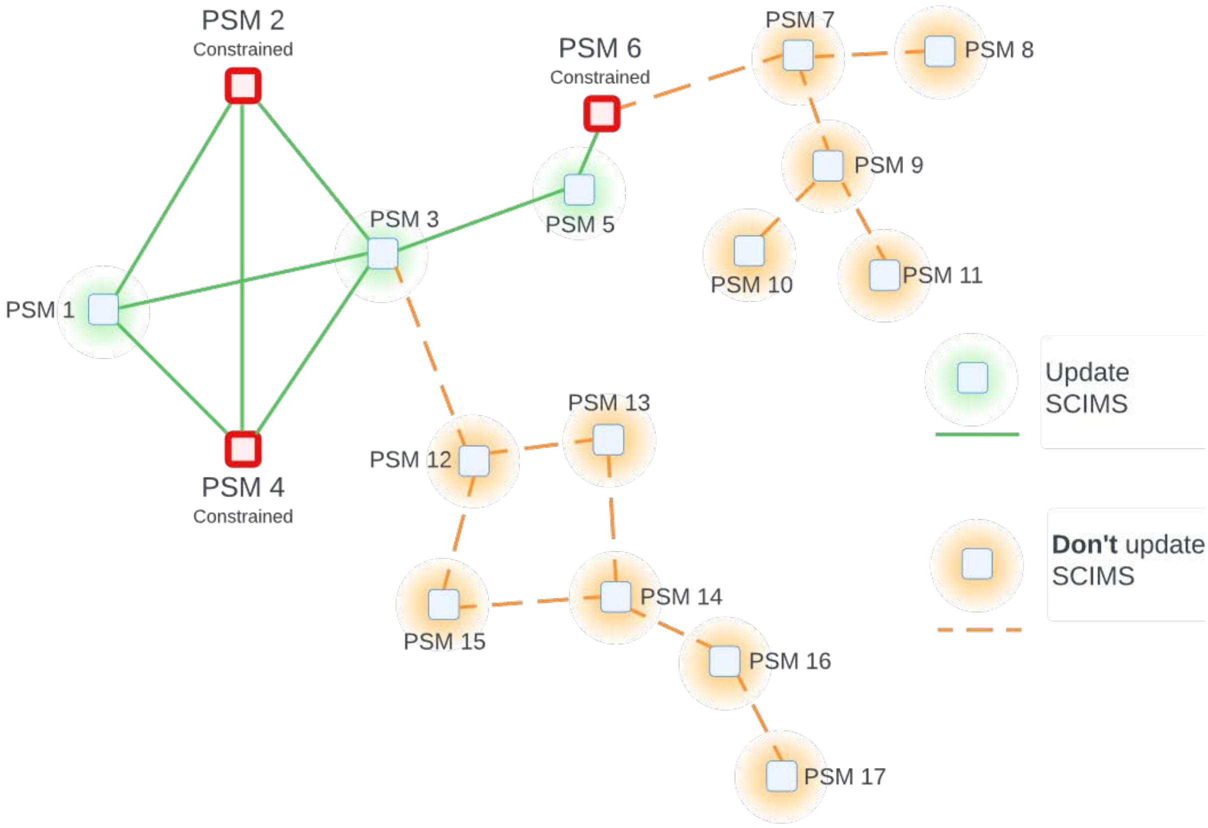

Figure 18: Hanging community strategy.

4 PILOT PROJECT AREAS AND RESULTS

Eleven major pilot areas were chosen, covering a diverse range of geographical areas in NSW with the intention of including areas in proximity of each Survey Operations office (Figure 19). Overall, across the 11 test areas (and the suburbs within these), the LX2S pilot project retrieved 7,099 DPs, extracted and analysed 33,981 measurements from these DPs, and updated 4,188 survey marks in SCIMS. Of these, 2,059 survey marks (49%) were newly established with Horizontal Class D:

- 1,367 survey marks were upgraded from Horizontal Class U.
- 692 survey marks were upgraded from Horizontal Class E.

A breakdown of the pilot area results is given in Table 1, listing the total number of survey marks updated and how many of those were established or newly established by the LX2S pilot. The distribution of HPU for the upgraded survey marks is impressive, with a median value of 0.035 m and a standard deviation of 0.024 m (Figure 20).

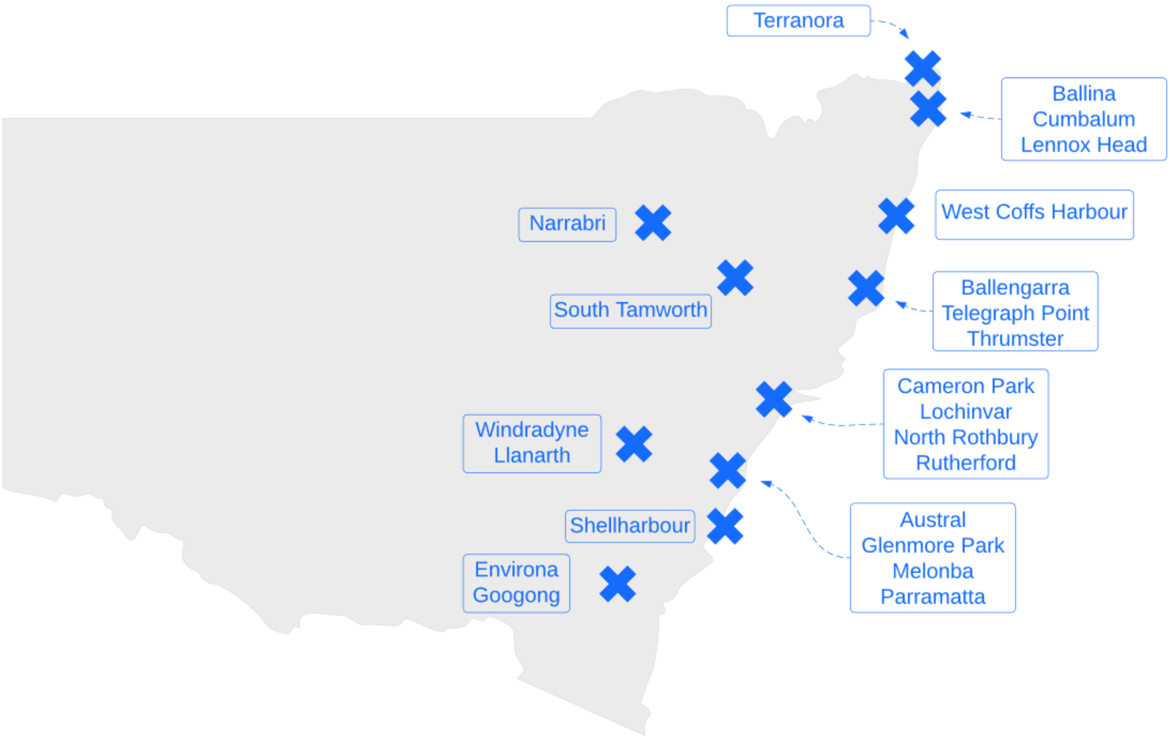

Figure 19: Location of the LX2S pilot areas and their suburbs.

Table 1: Breakdown of pilot area results according to Survey Operations office location and suburb.

Survey Operations Office	Total	Established	Newly Established
Bathurst	803	793	349
Windradyne / Llanarth	148	148	44
Googong	264	264	95
Environa	61	61	61
Narrabri	73	71	51
South Tamworth	257	249	98
Sydney Metro	1482	1470	823
Glenmore Park	461	455	38
Austral	359	355	326
Melonba	479	479	307
Parramatta	183	181	152
Newcastle / Hunter	967	963	525
Cameron Park / Edgeworth	382	380	218
North Rothbury / Greta	156	156	146
Lochinvar	78	78	69
Rutherford	351	349	92
Coffs Harbour	281	281	116
West Coffs Harbour	67	67	23
Telegraph Point / Ballengarra	10	10	8
Thrumster	204	204	85
Lismore	289	289	135
Ballina	60	60	25
Cumbalum	76	76	34
Lennox Head / Skennars Head	80	80	49
Terranora	73	73	27
Nowra	366	361	111
Shellharbour	366	361	111
Total	4188	4157	2059

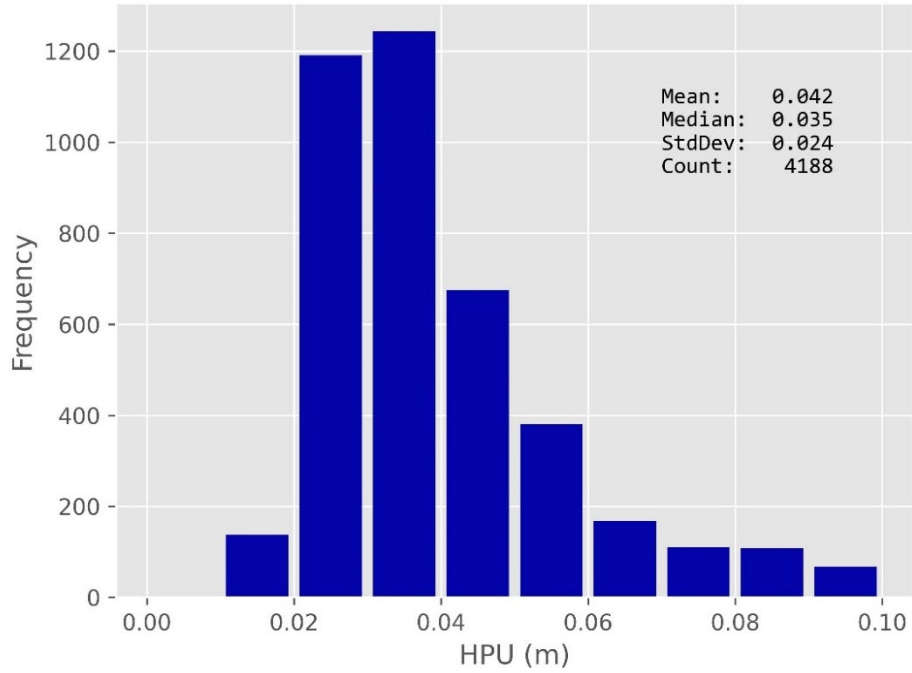

Figure 20: Distribution of Horizontal Positional Uncertainty (HPU) across the LX2S pilot areas.

As an example, Figures 21-23 illustrate the results for three pilot areas (Cameron Park / Edgeworth, Googong and Shellharbour), showing the horizontal constraints, the measurements between marks and the resulting Horizontal Class after the SCIMS update. The vastly increased density of established survey marks in each area is clearly evident, indicating the immense improvement made to the NSW State Control Survey through the LX2S pilot project.

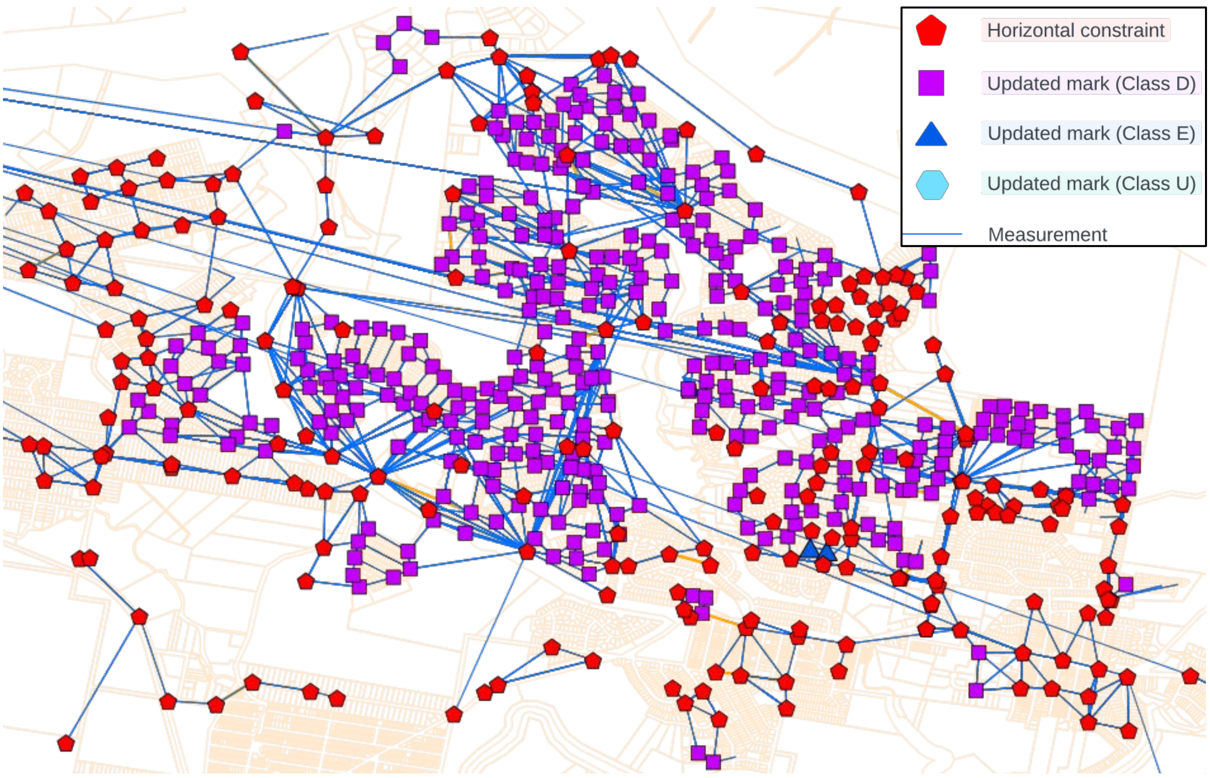

Figure 21: Resulting survey mark updates in the Cameron Park / Edgeworth pilot area – 380 marks established, of which 218 were newly established.

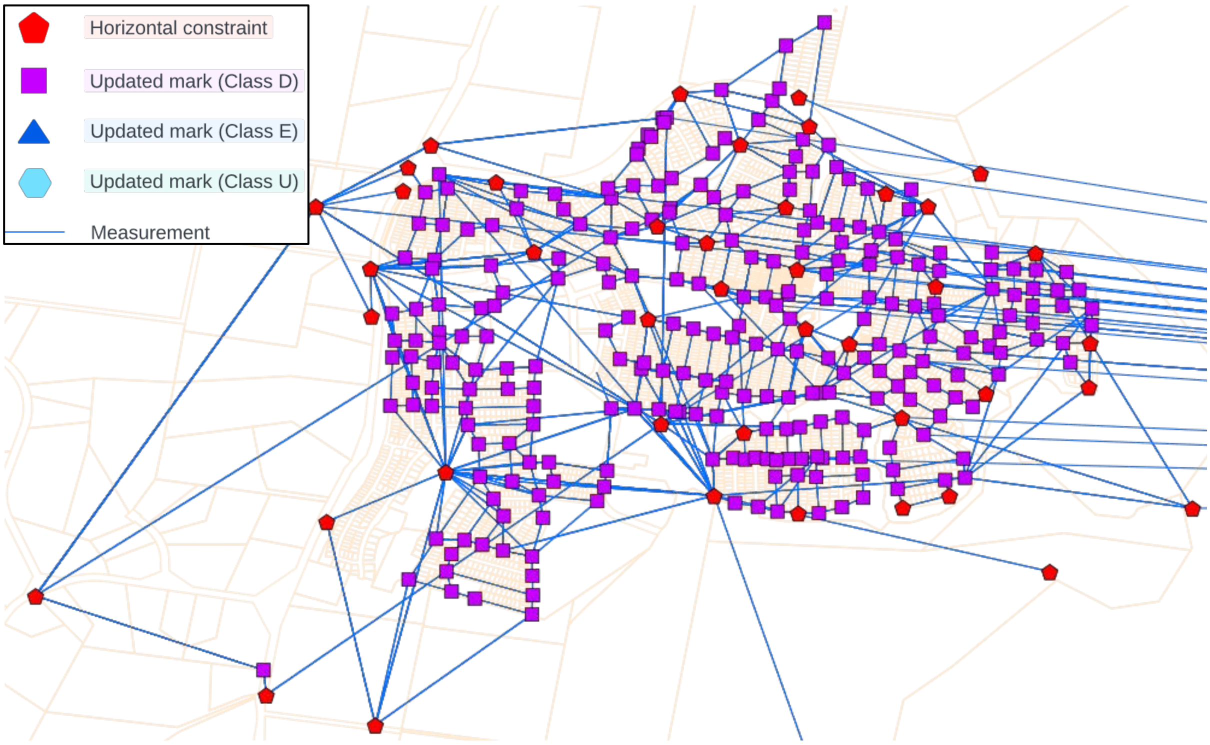

Figure 22: Resulting survey mark updates in the Googong pilot area – 264 marks established, of which 95 were newly established.

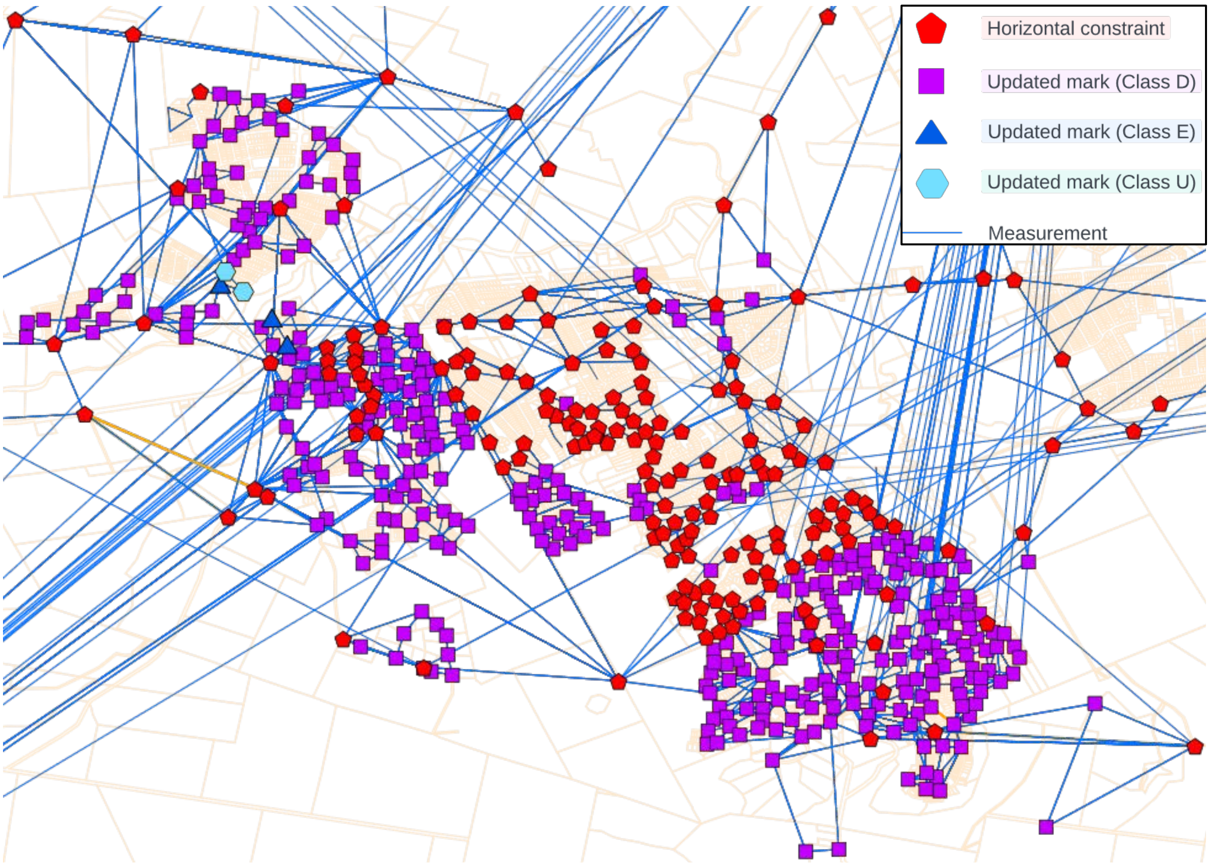

Figure 23: Resulting survey mark updates in the Shellharbour pilot area – 361 marks established, of which 111 were newly established.

5 FUTURE DIRECTION

The vision for the future of the LX2S initiative is a fully automated incremental feed of registered DPs updating the State Control Survey on a regular basis, with only minor manual intervention when required. The intent of the LX2S pilot project was to develop the base code structures and workflows necessary to realise this vision for the future, demonstrate the very substantial productivity gains for DCS Spatial Services as well as for internal and external stakeholders and to determine areas of refinement required for the production environment.

The pilot project has identified the next steps required to realise the LX2S vision (Figure 24):

- Realise an area-based (e.g. town or suburb) harvesting model prior to an incremental-feed workflow.
- Refine the automatic QA process.
- Augment reporting to focus the targeting of future field work by DCS Spatial Services surveyors.
- Investigate the potential for access to tools:
  - Mathematical Integrity Report.
  - Visualisation of LX2S networks.
  - Provision of metadata.
  - Awareness, training and education of DCS Spatial Services staff and customers.

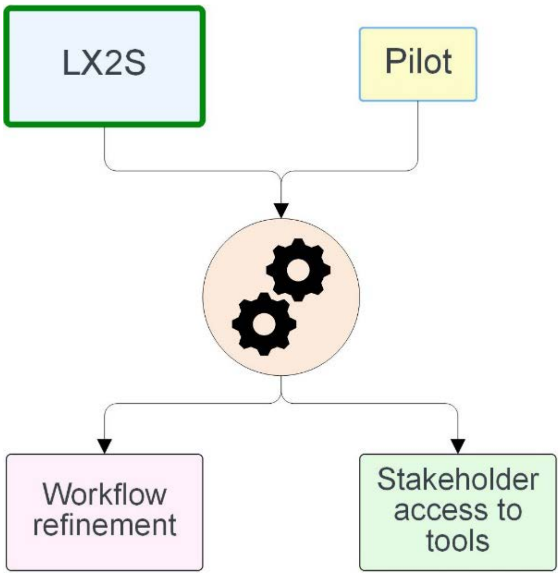

Figure 24: LX2S future direction.

6 ECONOMIC AND COMMUNITY BENEFITS

The LX2S pilot project provides substantial benefits to the surveying profession in particular and the people of NSW in general, including industry and community growth, economic benefits, regulatory benefits and increased community awareness. Based on the pilot project, it is anticipated that LX2S will have the greatest benefit in urban areas, as the active nature of development in those areas engenders a higher density of PSMs with viable paths to datum.

It supports industry and community growth by extending the state's fundamental positioning framework, the State Control Survey, with a greater density of survey marks with GDA2020 coordinates of known quality. Such densification of survey marks with GDA2020 coordinates generates several industry and community benefits:

- Improved positional accuracy of the NSW cadastre, hence improved positional accuracy of the Foundation Spatial Data Framework (FSDF) and the Digital Cadastral Database (DCDB).
- Enablement of infrastructure development (large and small).
- Improved positioning of utilities and underground services.
- Enablement of emerging technologies reliant on positioning.
- Contribution to ICSM's Cadastre 2034 vision.

Densification of geodetic networks, being the fundamental outcome of the LX2S pilot project, has long-recognised economic benefits to a nation and state (United Nations, 2015), including:

- Interoperability and standardisation of disparate spatial datasets across a wide range of applications.
- Improved integration of digital mapping, planning and infrastructure management.
- Improved natural hazard and disaster management.
- Sea level and climate change monitoring.
- Further enablement of digital government outcomes.

In addition, the LX2S pilot project realises specific economic gains for NSW, including:

- Enablement of easier compliance with the Surveying and Spatial Information Regulation 2017, thus reducing time and cost of acquiring datum for preparation of DPs, in turn reducing cost to the general community.
- Enablement of faster turn-around-time harvesting DPs to densify the State Control Survey.
- Faster ingestion of DPs into the DCDB, enabling faster state and local government outcomes.
- Associated tools for efficiency gains in spatial processing:
  - Mathematical Integrity Report – reducing plan checking from hours/days to minutes.
  - Targeting activities of DCS Spatial Services field teams to realise the best gains for government, industry and the general community.
- Greater integrity of the State Control Survey densification from DPs (larger redundancy), reducing time loss due to outlier resolution reported by industry customers.

The LX2S pilot project uses the State Control Survey information required to be shown on DPs by the Surveying and Spatial Information Regulation 2017 and does so in a timely manner. This demonstrates to industry customers the clear benefit and outcomes of the regulatory requirement for DPs to connect to the State Control Survey (Figure 25).

The economic and time-saving benefits stemming from the LX2S pilot project provide real-world gains in deliverables to the community from the surveying industry and all levels of government. This will foster an increased awareness and appreciation of the innovative, practically focused nature of the surveying profession.

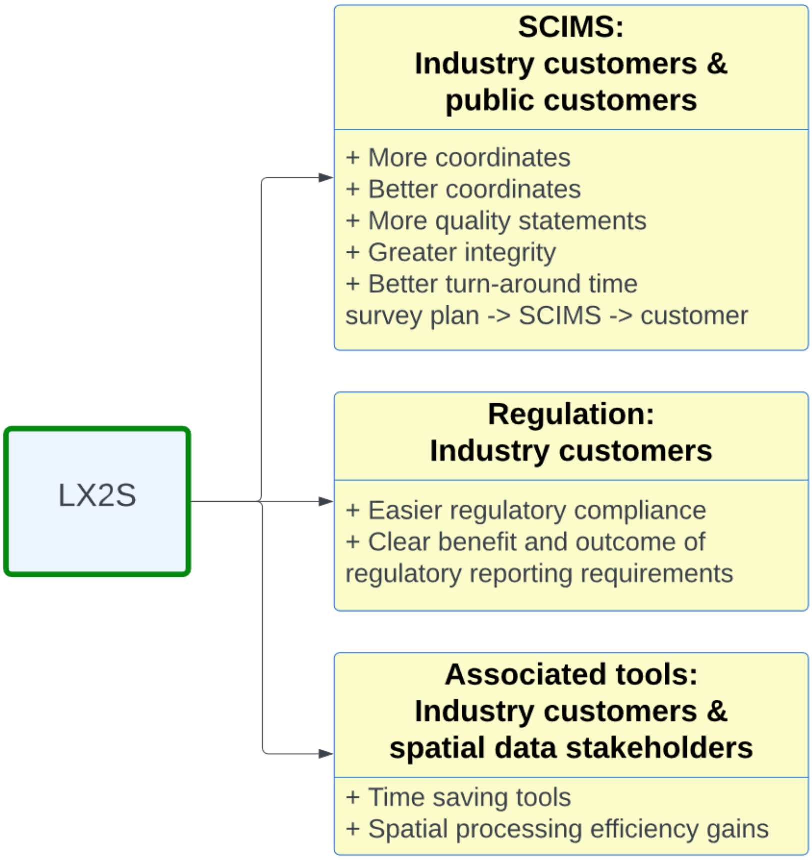

Figure 25: LX2S benefits.

7 CONCLUDING REMARKS

On behalf of the Surveyor-General, DCS Spatial Services is responsible for the establishment, maintenance and improvement of the NSW State Control Survey, which is made available to users via SCIMS. To this end, this paper has presented, in general terms, the innovative LandXML to SCIMS (LX2S) pilot project, which was initiated by DCS Spatial Services to automate the harvesting of State Control Survey observations from registered DPs, adjust the ‘islands’ of harvested observations, and publish the adjusted GDA2020 coordinates and their quality in SCIMS. The automated harvesting and adjustment was executed using sophisticated Python code and innovative workflows developed in-house to retrieve, test and process DP LandXML files from Cadastre NSW.

Across 11 pilot areas incorporating several suburbs distributed across eastern NSW, the LX2S pilot project successfully retrieved 7,099 DPs, extracted and analysed 33,981 measurements from these DPs, and updated 4,188 survey marks in SCIMS, resulting in 49% of these being newly established with Horizontal Class D. The distribution of HPU for the upgraded survey marks is impressive, with a median value of 0.035 m and a standard deviation of 0.024 m.

The LX2S pilot project has successfully developed the base code structures and workflows necessary (and identified the required refinements for the production environment) to realise the vision of a fully automated incremental feed of registered DPs updating the State Control Survey on a regular basis, with only minor manual intervention when required. It has also demonstrated the substantial productivity gains for DCS Spatial Services, its stakeholders and customers once this vision is realised. This includes the clear benefit and outcomes of the regulatory requirement for survey plans to connect to the State Control Survey. It is anticipated that LX2S will realise the greatest benefit in urban areas, due to the higher density of PSMs with viable paths to datum. In recognition of its innovative design and the enormous benefits it provides, the LX2S pilot project was awarded joint winner of the 'Extra Dimension & Innovation' category at the 2023 Excellence in Surveying and Spatial Information (EISSI) awards.

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