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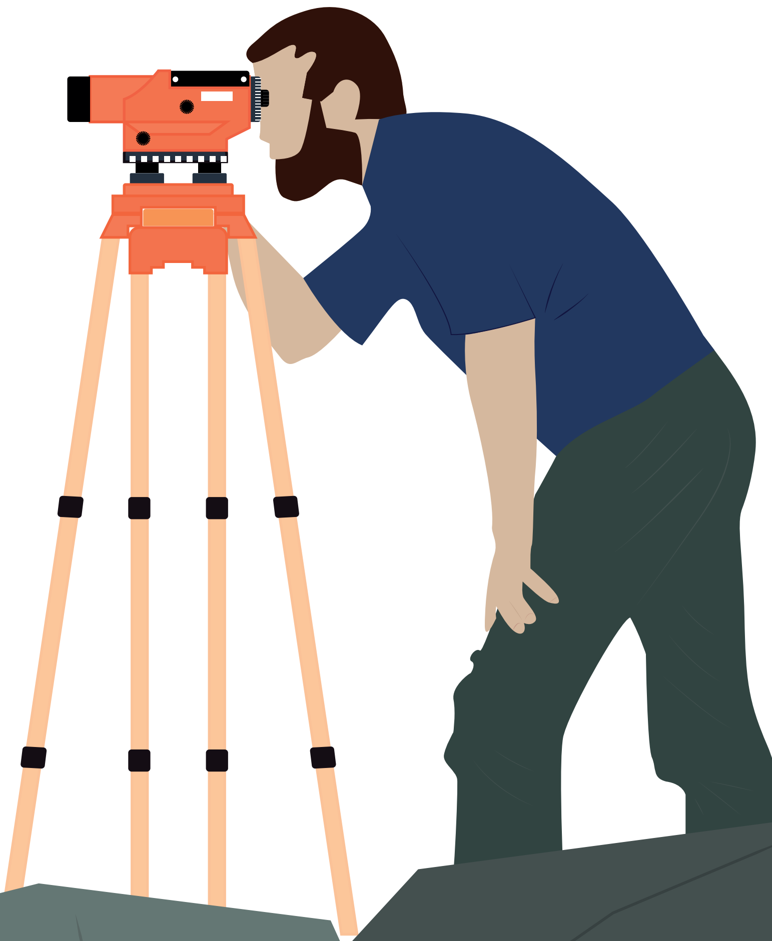

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Table of Contents

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Editorial

These proceedings contain the papers presented at the APAS Webinar Series 2020 (AWS2020), held 5 May – 30 June 2020. Unfortunately, the Association of Public Authority Surveyors Conference (APAS2020) had to be cancelled at the last minute due to social distancing measures introduced to combat the coronavirus/COVID-19 pandemic. In order to allow APAS to still provide a professional development event for all those that had registered for the APAS2020 conference, it was decided to organise the APAS Webinar Series 2020.

Papers were not peer-reviewed but have been subject to changes made by the Editor. The Editor would like to thank all authors for their contributions covering a wide range of topics relevant to the surveying and spatial information community, thus ensuring an exciting and informative online event. The University of Southern Queensland (USQ) is thanked for hosting the APAS Webinar Series 2020 at short notice, with special thanks to Jessica Smith, Lecturer in the School of Civil Engineering and Surveying.

Authors are welcome to make their paper, as it appears in these proceedings, available online on their personal and/or their institution's website, provided it is clearly stated that the paper was originally published in these proceedings. Papers should be referenced according to the following template:

Janssen V. and McElroy S. (2020) Evaluating the performance of AUSPOS solutions in NSW, *Proceedings of APAS Webinar Series 2020 (AWS2020)*, 5 May – 30 June, 3-19.

APAS is not responsible for any statements made or opinions expressed in the papers included in these proceedings.

Spatial Services, a unit of the NSW Department of Customer Service (DCS) is gratefully acknowledged for providing the front cover artwork and producing these proceedings. The APAS committee is thanked for their hard work in organising this event.

Dr Volker Janssen
APAS Publications Officer, Program Chair and Editor
Spatial Services
NSW Department of Customer Service
Publications@apas.org.au

Evaluating the Performance of AUSPOS Solutions in NSW

Volker Janssen
Spatial Services
NSW Department of Customer Service
Volker.Janssen@customerservice.nsw.gov.au

Simon McElroy
Spatial Services
NSW Department of Customer Service
Simon.McElroy@customerservice.nsw.gov.au

ABSTRACT

AUSPOS is Geoscience Australia's free online Global Positioning System (GPS) processing service. It takes advantage of the International GNSS Service (IGS) network station data and products to compute precise coordinates, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours duration). This paper outlines how AUSPOS and CORSnet-NSW are used to support datum modernisation and to maintain and extend the Survey Control Network on behalf of the NSW Surveyor General. The quality of AUSPOS solutions is investigated using more than 2,400 successful datasets incorporating observation sessions ranging from 2 hours to 48 hours in length. It is shown that AUSPOS routinely delivers Positional Uncertainty (PU) values at the 0.02-0.03 m level for the horizontal component and about 0.05-0.06 m for the vertical (ellipsoidal) component. As expected, it is evident that a longer observation span improves PU, particularly in regards to the vertical component. The results illustrate why Geoscience Australia stipulates, and NSW supports, a minimum observation span of 6 hours for inclusion into the national GDA2020 adjustment to propagate the Survey Control Network. However, they also show that shorter observation sessions are of sufficient quality to strengthen and improve the State's survey infrastructure, justifying the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods to maintain and extend the State's Survey Control Network.

KEYWORDS: *AUSPOS, Positional Uncertainty, CORSnet-NSW, datum modernisation, GDA2020, survey infrastructure*.

1 INTRODUCTION

Geoscience Australia's free online Global Positioning System (GPS) processing service, AUSPOS, was developed to provide an online positioning service primarily for Australian users (Jia et al., 2014; GA, 2020a). Since its initial release in 2000, it was frequently upgraded in order to incorporate improvements. For example, this included switching to the Bernese Global Navigation Satellite System (GNSS) software processing engine in 2010, introducing a more realistic assessment method of coordinate uncertainty in 2013 and upgrading to the latest Bernese software version 5.2 (Dach et al., 2015) in 2015 (Jia et al., 2016). In order to support national datum modernisation efforts, AUSPOS started delivering results in both GDA94 and GDA2020 (ICSM, 2020a), as well as ITRF2014 (Altamimi et al., 2016), with version 2.3 in November 2017. However, it remains GPS-only. AUSPOS was ranked highest in a comparison of free online services for GPS post-processing (Gakstatter and Silver, 2013) and has successfully processed more than 1 million jobs worldwide over the last 10 years (M. Jia, pers. comm.).

AUSPOS takes advantage of the International GNSS Service (IGS) network station data and products (e.g. final, rapid or ultra-rapid orbits depending on availability – see IGS, 2020) to compute precise coordinates, using static dual-frequency GPS carrier phase and code data of at least 1 hour duration (recommended minimum of 2 hours, maximum of 7 consecutive days). When submitting 30-second Receiver Independent Exchange (RINEX) data, users are required to specify the antenna type (using the IGS naming convention) and the antenna height to the Antenna Reference Point (ARP). Following processing, an AUSPOS report (pdf) is emailed to the user (generally within a few minutes), which includes the computed coordinates and their uncertainties, ambiguity resolution statistics, and an overview of the GPS processing strategy applied. For advanced users, Solution Independent Exchange (SINEX) files containing more detailed information are also available for download.

CORSnet-NSW is Australia’s largest state-owned and operated Continuously Operating Reference Station (CORS) network (e.g. Janssen et al., 2016; NSW Spatial Services, 2020a). It is built, owned and operated by Spatial Services, a unit of the NSW Department of Customer Service. CORSnet-NSW currently consists of 203 stations, providing fundamental positioning infrastructure that is authoritative, accurate, reliable and easy-to-use for a wide range of applications. CORSnet-NSW sites comprise a fundamental, high-density and long-term component of AUSPOS infrastructure within the State. In February 2019, CORSnet-NSW started delivering services in both GDA94 and GDA2020. Since May 2019, it provides all-in-view, all-signals, multi-constellation GNSS data (i.e. GPS, GLONASS, BeiDou, QZSS and Galileo), making it the nation’s first CORS network to reach this milestone. At any given time, CORSnet-NSW stations typically deliver at least 40 satellites in view.

All CORSnet-NSW stations are part of the Asia-Pacific Reference Frame (APREF – see GA, 2020b), including 13 concrete-pillared NSW sites incorporated in the IGS network. AUSPOS uses up to 15 surrounding CORS as the reference stations, generally the 7 closest IGS sites and the 8 closest APREF sites (Jia et al., 2014). This approach provides a relatively dense network for generating a reliable regional ionospheric delay model and tropospheric delay corrections to support ambiguity resolution. Based on these reference stations, a precise solution for the user data is then computed using double-differencing techniques. The coordinates of the IGS stations are constrained with uncertainties of 1 mm for horizontal position and 2 mm for the vertical, while lower-tier CORS coordinates are constrained with uncertainties of 3 mm for horizontal position and 6 mm for the vertical (due to the shorter CORS operation time span, lower data quality and/or lower-grade monumentation).

The GPS data is processed in the IGS realisation of the ITRF2014 reference frame and then transformed to GDA2020 via the Australian Plate Motion Model. Derived Australian Height Datum (AHD – see Roelse et al., 1971) heights are computed by applying a gravimetric-geometric quasigeoid model (AUSGeoid2020 – see Brown et al., 2018; Janssen and Watson, 2018; Featherstone et al., 2019) to the GDA2020 ellipsoidal heights. Legacy GDA94 coordinates are obtained from GDA2020 by coordinate transformation. More information about GDA94 and GDA2020, along with their technical manuals, can be found on the Intergovernmental Committee on Surveying and Mapping (ICSM) website (ICSM, 2020a).

Positional Uncertainty (PU) is calculated based on the East, North and ellipsoidal height coordinate uncertainties according to the Guideline for Adjustment and Evaluation of Survey

Control, which is part of ICSM's Standard for the Australian Survey Control Network (SP1), version 2.1 (ICSM, 2014). The coordinate uncertainties of the East, North and ellipsoidal height components are scaled using an empirically derived model, which is a function of duration, data quality and geographical location (latitude and CORS density), and expressed at the 95% confidence level (Jia et al., 2016).

This paper outlines how AUSPOS and CORSnet-NSW are used to support datum modernisation and improve state survey infrastructure across NSW. The quality of AUSPOS solutions is investigated using more than 2,400 successful datasets, incorporating observation sessions ranging from 2 hours to 48 hours in length.

2 USING AUSPOS TO SUPORT DATUM MODERNISATION AND IMPROVE SURVEY INFRASTRUCTURE IN NSW

Datum modernisation and further improvement of survey infrastructure is required in order to accommodate the increasing accuracy and improved spatial and temporal resolution available from modern positioning technologies to an ever-broadening user base concerned with surveying, mapping, navigation, engineering, machine guidance and precision agriculture, to name but a few.

All CORSnet-NSW stations contribute to the AUSPOS service, i.e. most NSW users are close to a dense network of surrounding CORS. As demonstrated in the next section, this results in strong AUSPOS processing results even for shorter observation sessions of at least 2 hours, provided sky view conditions are reasonable. Consequently, the use of AUSPOS campaigns has developed into a very capable and reliable alternative to conducting traditional static GNSS baseline surveys (e.g. Gowans et al., 2015; Janssen and Watson, 2018), simplifying logistics by removing the requirement of field crews having to occupy particular survey marks at a set time. As a consequence, processing, adjustment and report writing efforts have been significantly reduced or removed, and office time is typically cut to 1 hour per day per survey crew in the field. AUSPOS also forms a new and fundamental component of vertical datum modernisation and the propagation of the Australian Vertical Working Surface (AVWS – see ICSM, 2020b) in the State.

NSW Spatial Services will therefore continue to apply, expand and accelerate this proven approach to improve the State's Survey Control Network, with appropriate Class being assigned in accordance with ICSM (2007) and Surveyor General's Direction No. 12 (Control Surveys and SCIMS) (NSW Spatial Services, 2019), and uncertainty as described in Janssen et al. (2019). To this end, AUSPOS data of at least 6 hours duration is used to propagate the datum in NSW, while AUSPOS data of less than 6 hours duration strengthens the datum. The profession is encouraged to contribute to these efforts by submitting suitable AUSPOS data and related metadata (NSW Spatial Services, 2020b) in order to facilitate the update of survey information on public record in the Survey Control Information Management System (SCIMS). SCIMS is the State's database containing about 250,000 survey marks across NSW, including coordinates, heights, accuracy classifications and other metadata, provided in GDA94, GDA2020 and AHD (Janssen et al., 2019).

At present, the GDA2020 state adjustment incorporates approximately 30,000 survey control marks across NSW, i.e. 12% of all marks in SCIMS. Consequently, 88% of the marks in SCIMS are currently transformed from GDA94 to GDA2020. Uncertainties of these transformed

GDA2020 coordinates are given null values until these are calculated via inclusion in the state adjustment. As shown in this paper, AUSPOS is a suitable method to accelerate the process of including additional survey marks into the state adjustment in order to improve user access to GDA2020 coordinates and uncertainties across the State.

In support of these datum modernisation efforts, NSW Spatial Services is currently building an updated 'passive' Survey Control Network (in the Eastern and Central Divisions) with a minimum of one fundamental survey mark observed by 6+ hour AUSPOS every 10 km. Its vision is to ensure that any future user is no further than 5 km (and often much less) from such a fundamental mark providing direct connection to datum. Similarly, levelled AHD marks are observed by 6+ hour AUSPOS every 10 km, often at a far greater density. This will allow users to achieve NSW Spatial Services' vision of a Positional Uncertainty (PU) of 20 mm in the horizontal and 50 mm in the vertical (ellipsoidal height) component anywhere in the State and easily apply transformation tools to move between current, future and various historical datums and local working surfaces (e.g. railway datum or standard datum).

Following successful AUSPOS processing (GPS-only, using final IGS products) by NSW Spatial Services, GNSS data of more than 6 hours duration (with a maximum observation length of 48 hours) is submitted to Geoscience Australia toward the National GNSS Campaign Archive (NGCA) database of 6+ hour AUSPOS datasets. Currently, this data is grouped into simultaneously observed sessions and processed through an *offline* AUSPOS engine with the results expressed as baselines to nearby CORS, rather than absolute measurements of position. This avoids introducing additional adjustment constraints outside of APREF.

GNSS data of 2-6 hour duration is handled according to a similar principle but brought about by slightly different means. Again following successful AUSPOS processing by NSW Spatial Services to verify the required data quality, the *online* AUSPOS results are converted to be expressed as baselines to nearby CORS.

3 QUALITY OF AUSPOS SOLUTIONS ACROSS NSW

3.1 Data and Testing Methodology

The quality of AUSPOS solutions was investigated using 2,618 GNSS datasets observed by NSW Spatial Services over the last 5 years, between November 2014 and August 2019, under typical conditions generally encountered in the field and incorporating observation sessions ranging from 2 hours to 48 hours in length. These datasets were processed individually with *online* AUSPOS version 2.3 (GA, 2020a), using final IGS products.

A small number of AUSPOS solutions was rejected for this analysis due to warnings in the AUSPOS report, referring to poor ambiguity resolution and/or large uncertainties. Overall, 154 sessions (5.9%) were rejected, including 121 (10.1%) of the 2-6 hour sessions and 33 (2.3%) of the 6-48 hour sessions. Upon investigation of site photos and other metadata, this was generally attributed to ambitious attempts to observe survey marks in locations with substantial tree cover, resulting in poor sky view conditions. As expected, shorter observation sessions were more prone to be negatively affected by these unfavourable conditions.

For all 2,464 successful AUSPOS solutions (with almost 44% of these being 2-6 hour sessions), descriptive statistics were then used to evaluate the uncertainties of the resulting GDA2020 coordinates. Positional Uncertainty (PU) is defined as the uncertainty of the horizontal and/or vertical coordinates of a point, at the 95% confidence level, with respect to the defined reference frame (datum) (ICSM, 2014). A description of the practical implementation of PU in NSW (particularly SCIMS) can be found in Janssen et al. (2019).

Three tests were performed to investigate the quality of AUSPOS solutions in NSW:
1) Analysing Horizontal PU (HPU) and Vertical PU (VPU) of the AUSPOS solutions for GDA2020 horizontal coordinates and GDA2020 ellipsoidal heights, respectively.
2) Analysing the repeatability of AUSPOS solutions for reoccupations on the same mark.
3) Analysing AHD results by comparing the AUSPOS-derived AHD heights (using AUSGeoid2020) to levelled AHD heights of sufficient quality on public record and investigating the AHD-PU reported by AUSPOS.

The results of these three tests are presented and discussed in the following sections. Figure 1 shows the location of the 2,464 successful AUSPOS solutions analysed in this study, colour-coded to indicate observation length.

Two further tests were conducted, the results of which can be immediately summarised:
- Whilst AUSPOS uncertainty is known to be affected (scaled) by latitude, the variation is negligible for user results within the bounds of NSW.
- Whilst IGS products have continuously improved and CORS density has increased, AUSPOS version 2.3 performance has remained stable, predictable, repeatable and of high quality within NSW in the recent past.

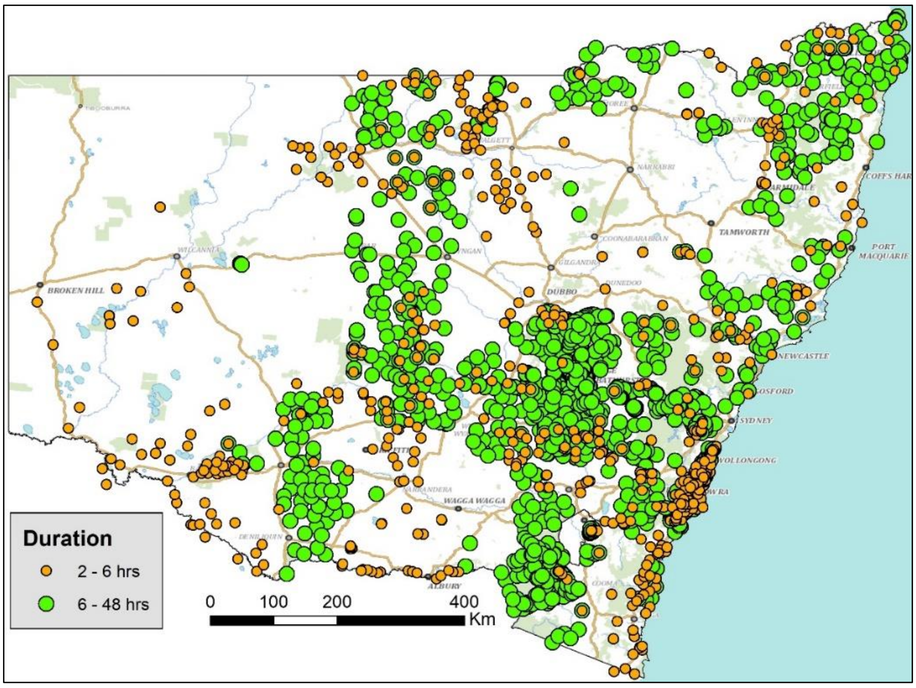


Figure 1: Location of the 2,464 successful AUSPOS solutions analysed across NSW, colour-coded to indicate observation length.

3.2 PU of AUSPOS Solutions

Horizontal PU (HPU) and Vertical PU (VPU) of the AUSPOS-derived GDA2020 horizontal coordinates and GDA2020 ellipsoidal heights were obtained from the SINEX file associated with each AUSPOS solution (these values are also stated in the AUSPOS report). Table 1 summarises descriptive statistics regarding HPU and VPU for the entire dataset of 2,464 successful AUSPOS solutions (2-48 hour duration), also providing this information for the 2-6 hour and 6-24 hour subsets, respectively, to allow examination of the effect the observation session length has on the resulting uncertainties. Figure 2 provides a graphical visualisation of the results, showing PU as a function of observation session length.

Table 1 and Figure 2 show that the majority of solutions meet or are better than the 20 mm HPU and 50 mm VPU thresholds targeted by NSW Spatial Services. The benefit of longer observation sessions is demonstrated by mean values of 0.023 m ± 0.006 m (1 sigma) for HPU and 0.069 m ± 0.022 m (1 sigma) for VPU when using 2-6 hour data, compared to values of 0.015 m ± 0.003 m (1 sigma) for HPU and 0.033 m ± 0.016 m (1 sigma) for VPU when using 6-24 hour data. This supports the notion that AUSPOS data of 6+ hour duration is used to propagate the datum, while AUSPOS data of less than 6 hours duration supplements the datum. The median values indicate that no significant offsets caused by possible outliers are present.

Table 1: Descriptive statistics for the HPU and VPU analysis (all values in metres).

Dataset	Statistic	HPU	VPU
Entire dataset: 2,464 solutions	**Min.**	0.011	0.015
	Max.	0.074	0.161
	Range	0.063	0.146
	Median	0.017	0.042
	Mean	0.018	0.048
	STD	0.006	0.026
2-6 hour data: 1,076 solutions	**Min.**	0.014	0.029
	Max.	0.074	0.141
	Range	0.060	0.111
	Median	0.022	0.065
	Mean	0.023	0.069
	STD	0.006	0.022
6-24 hour data: 1,280 solutions	**Min.**	0.011	0.018
	Max.	0.042	0.161
	Range	0.031	0.143
	Median	0.014	0.027
	Mean	0.015	0.033
	STD	0.003	0.016

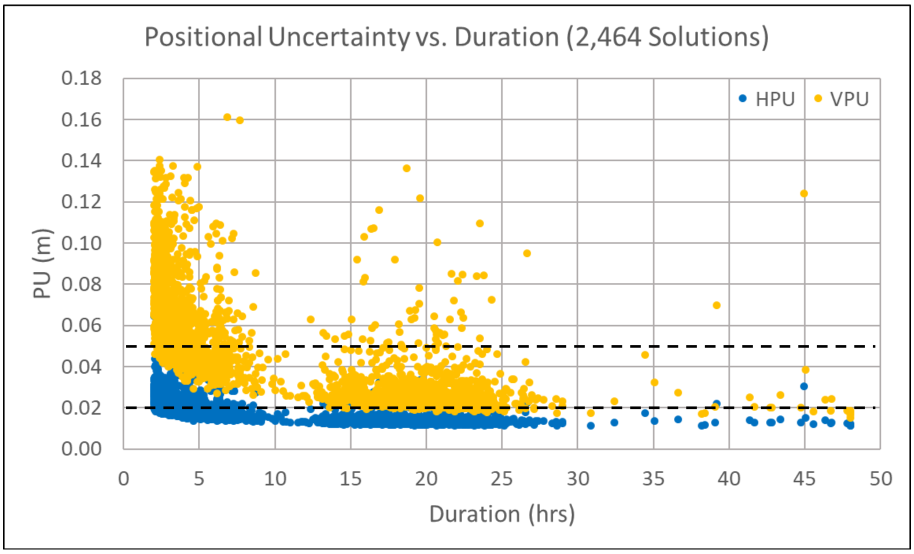


Figure 2: Positional Uncertainty (PU) vs. duration for the entire dataset.

Figure 3 investigates the data shown in Figure 2 in more detail. As expected, a longer observation span generally improves PU. Most of the improvement is gained by increasing the observation length from 2 hours to about 4-5 hours (Figure 3a), with minor but not insignificant improvement when the observation span is increased to 24 hours (Figure 3b). Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component.

An investigation of site photos and other metadata attributed the larger VPU values evident for solutions greater than 15 hours duration to poor sky view conditions caused by substantial tree cover. As an example, Figure 4 illustrates the conditions encountered at the sites producing the largest three VPU values in Figure 3b. In spite of these poor sky view conditions, AUSPOS solutions generally achieve acceptable HPU and heights with a VPU of better than 0.1 m.

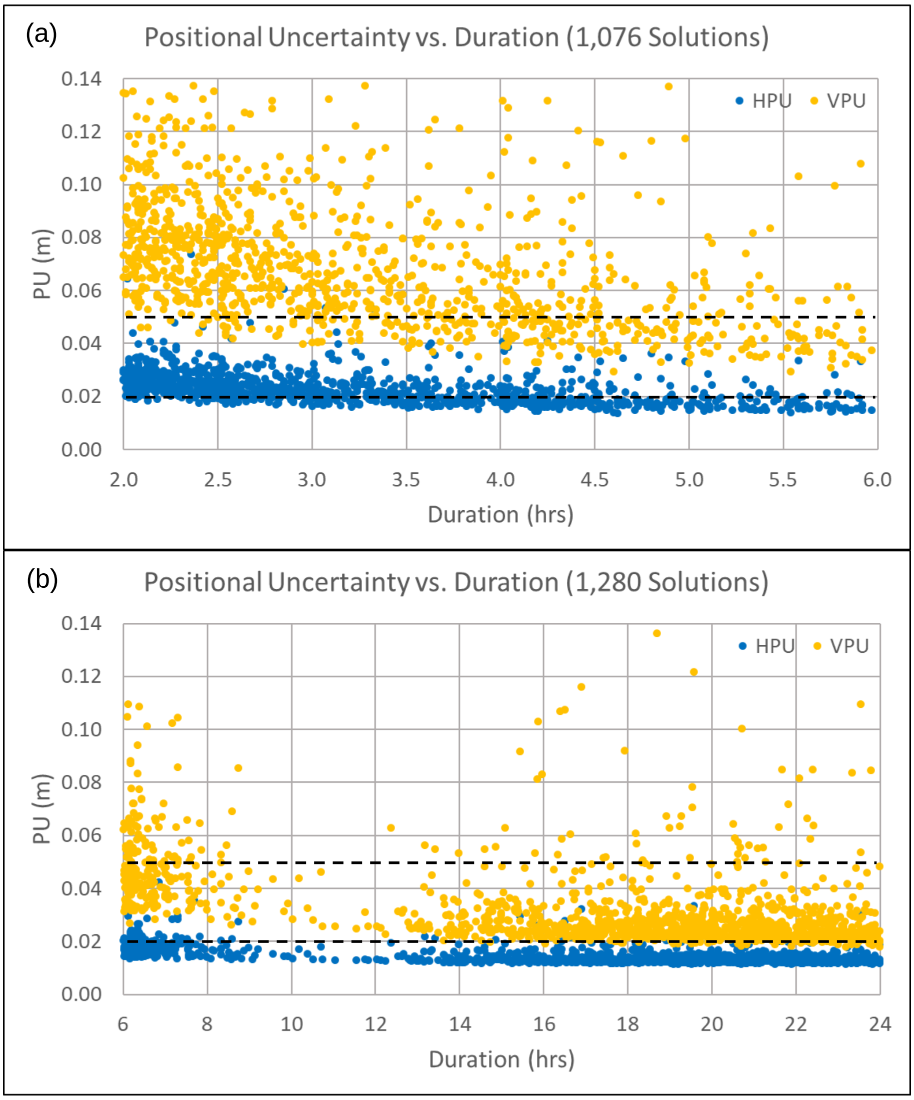


Figure 3: Positional Uncertainty (PU) vs. duration for (a) 2-6 hour data, and (b) 6-24 hour data.

Figure 4: Pushing the boundaries of reasonable sky view conditions in the field: TS486, SS4115, MM3634.

The cumulative distribution allows us to quantify the percentage of AUSPOS solutions meeting a particular PU threshold. Figure 5 visualises the cumulative distribution in regards to HPU and VPU for the 2-6 hour and 6-24 hour subsets. These graphs can be used as a simple 'look-up' tool to estimate the likelihood of achieving any specified HPU or VPU threshold with 2-6 hour and 6+ hour observation sessions.

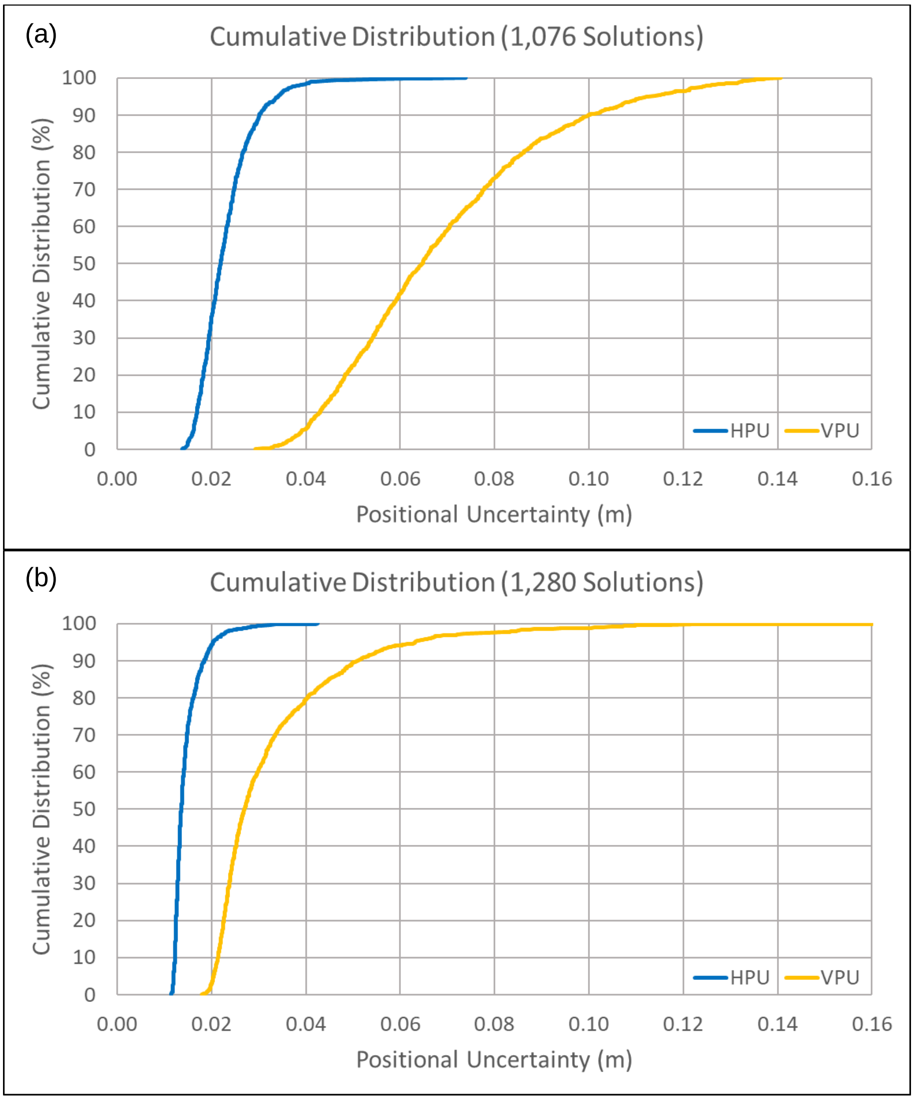


Figure 5: Cumulative distribution of PU for (a) the 2-6 hour data, and (b) 6-24 hour data.

Across the entire dataset, 70.6% of the AUSPOS solutions have HPU values of 0.02 m or better, i.e. these survey marks have an absolute horizontal accuracy slightly larger than the size of a 50c piece (radius of 16 mm) with respect to the national datum. This includes 38.6% of the 2-6 hour AUSPOS solutions and 95.2% of the 6-24 hour solutions with HPU values at this level. Similarly, 95.7% of all solutions have HPU values of 0.03 m or better, including 90.8% of the 2-6 hour solutions and 99.5% of the 6-24 hour solutions.

In regards to the vertical component (ellipsoidal height), 61.0% of the AUSPOS solutions have VPU values of 0.05 m or better across the entire dataset in absolute terms. This includes 23.3% of the 2-6 hour AUSPOS solutions and 89.7% of the 6-24 hour solutions with VPU values at this level. These results are impressive, remembering that the uncertainties are stated at the 95% confidence level. Again, as expected, it is evident that a longer observation span improves PU, particularly in regards to the vertical component. Similarly, 71.8% of all solutions have VPU values of 0.06 m or better, including 42.7% of the 2-6 hour solutions and 94.3% of the 6-24 hour solutions.

These results clearly show the important role of AUSPOS in propagating and strengthening the Survey Control Network in NSW. This investigation confirms and expands on earlier findings by Jia et al. (2014), illustrating why Geoscience Australia stipulates (and NSW supports) a minimum observation span of 6 hours for direct inclusion into the national GDA2020 adjustment via the NGCA. It also shows that shorter observation sessions are of sufficient quality to improve the State’s survey infrastructure, justifying the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods that can be used for this purpose (see section 2).

3.3 Repeatability

This section investigates the repeatability of AUSPOS solutions for independent reoccupations on the same mark. Where possible from the dataset discussed in section 3.2, independent pairs of sessions on the same mark were selected for three scenarios: two short sessions (2-6 hrs), one short (2-6 hrs) and one long session (6+ hrs), and two long sessions (6+ hrs). In each case, each session was only paired once. Since it is necessary to consider coordinate differences of opposite signs, the Root Mean Square (RMS) is deemed appropriate to quantify the average agreement in the vertical component.

Table 2 summarises descriptive statistics referring to the horizontal distance between the two AUSPOS solutions, as well as the difference in ellipsoidal height (shorter session minus longer session). Figure 6 visualises these results graphically. Again, it is evident that AUSPOS produces high-quality positioning results. While longer observation sessions improve the precision (repeatability) and reduce the risk of outliers (range), shorter sessions provide results suitable for improving state survey infrastructure. The median values indicate that no significant offsets caused by possible outliers are present.

It should be noted that the AUSPOS results are not compared to the marks’ GDA2020 coordinates on public record in SCIMS because such an investigation of accuracy would only be possible for shorter sessions on established marks that are part of the NSW state adjustment. An independent appraisal of accuracy for shorter AUSPOS sessions may be undertaken at a later stage, once more SCIMS marks are included in the state adjustment.

Table 2: Descriptive statistics for reoccupied pairs (all values in metres).

Dataset	Statistic	Diff in Hz	Diff in EHGT
Short sessions: 145 pairs	**Min.**	0.001	-0.079
	Max.	0.083	0.119
	Range	0.082	0.199
	Median	0.010	0.000
	Mean	0.013	0.000
	STD	0.009	0.026
	RMS	0.016	0.026
Short-long sessions: 75 pairs	**Min.**	0.003	-0.044
	Max.	0.043	0.050
	Range	0.041	0.094
	Median	0.010	0.003
	Mean	0.011	0.000
	STD	0.008	0.021
	RMS	0.015	0.021
Long sessions: 94 pairs	**Min.**	0.001	-0.064
	Max.	0.029	0.072
	Range	0.028	0.137
	Median	0.006	-0.002
	Mean	0.008	-0.002
	STD	0.006	0.019
	RMS	0.010	0.019

In July/August 2019, TS3663 PANORAMA (located in Bathurst, close to NSW Spatial Services) was occupied 38(!) times, providing an opportunity to investigate the repeatability of AUSPOS solutions on this high-quality, concrete-pillared mark with excellent sky view (Figure 7). The longest observation session (48 hours) was assumed ground truth, with the AUSPOS results of the shorter sessions being compared against it (Figure 8). The average agreement is found to be 0.006 m ± 0.003 m (1 sigma) in the horizontal component, and the RMS in the vertical component (ellipsoidal height) is 0.010 m (1 sigma), showing that observation sessions of less than 6 hours in length have high reliability and repeatability. A bullseye plot of the difference in horizontal position from the 48-hour solution is shown in Figure 9, providing a spatial perspective and illustrating the high precision of these results.

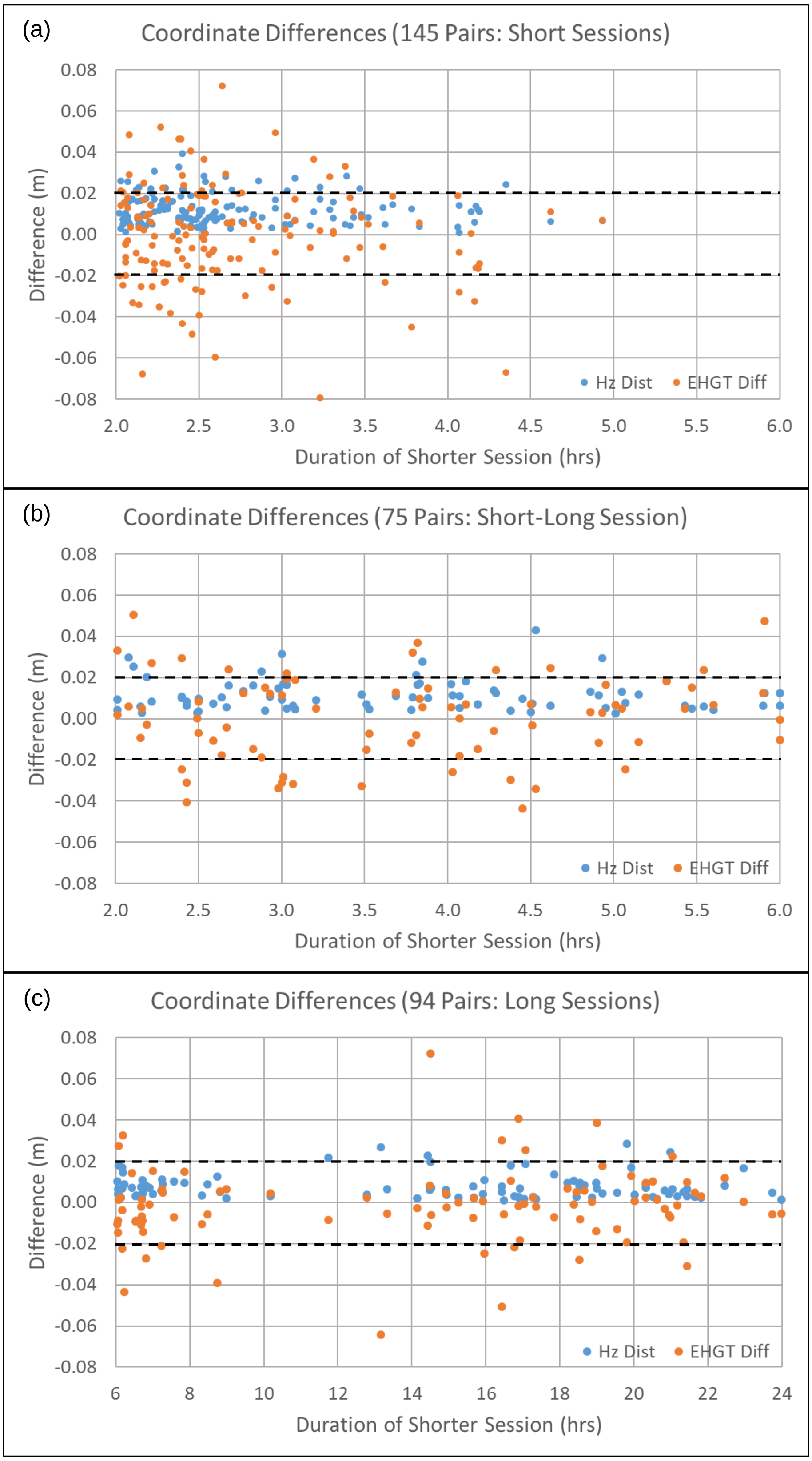


Figure 6: Difference in horizontal and vertical coordinates vs. duration for (a) 145 short-session pairs, (b) 75 short-long-session pairs, and (c) 94 long-session pairs.

Figure 7: TS3663 PANORAMA.

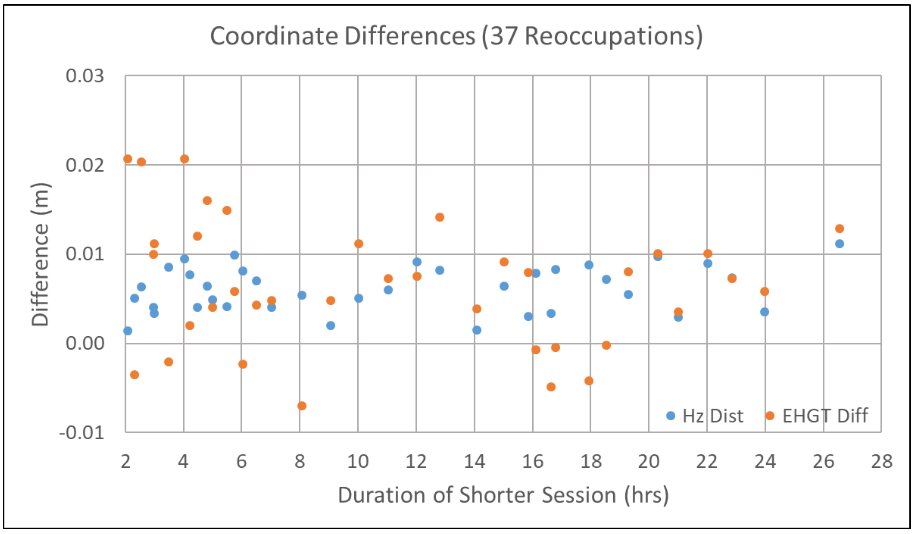


Figure 8: Difference in horizontal and vertical coordinates vs. duration for TS3663 PANORAMA.

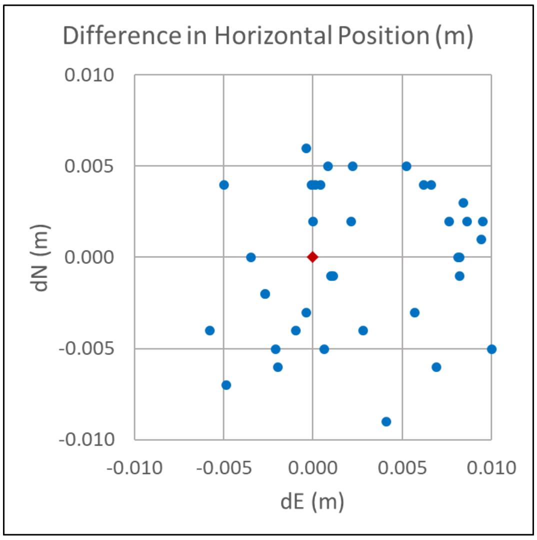


Figure 9: Difference in horizontal position from 48-hour solution for TS3663 PANORAMA (37 reoccupations).

Figure 10 depicts the AUSPOS-reported PU values corresponding to these AUSPOS solutions, again illustrating the benefit of longer observation sessions. The 'smoothness' of the PU curves also confirms that the PU values provided by AUSPOS are calculated (scaled) with significant influence and predictability of the observation session length.

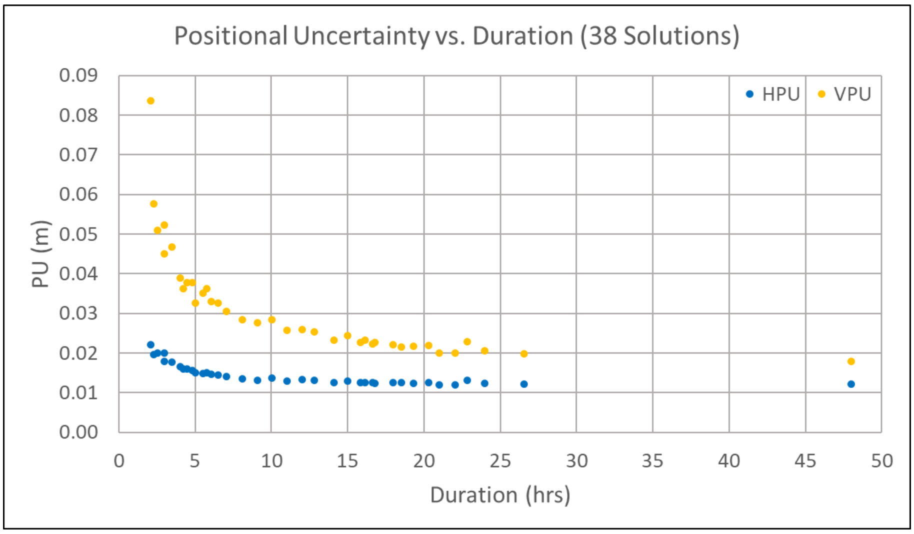


Figure 10: Positional Uncertainty (PU) vs. duration for TS3663 PANORAMA.

3.4 Connecting to AHD via AUSPOS

The quality of AUSPOS solutions with regards to providing a connection to AHD was investigated by comparing the AUSPOS-derived AHD height (using AUSGeoid2020) to levelled AHD heights of sufficient quality on public record in SCIMS.

The data investigated is a subset of the AUSPOS solutions analysed in section 3.2 and independent of the data used to produce the current version of AUSGeoid2020 (version 01/02/2018). This subset comprises marks that have AHD heights of class LC or better in SCIMS. To ensure full independence, observation sessions exceeding 6 hours duration are only considered for data collected after 1 February 2018, i.e. the date the current version of AUSGeoid2020 was computed. Again, since it is necessary to consider coordinate differences of opposite signs, the RMS is used to quantify the average agreement to AHD.

Table 3 summarises descriptive statistics referring to the difference between the AUSPOS-derived AHD height (using AUSGeoid2020) and the levelled AHD height on public record in SCIMS, as well as the derived AHD-PU provided by AUSPOS. These statistics are provided separately for the entire subset, the 2-6 hour data and the 6-24 hour data, respectively. Figure 11 visualises these results graphically.

It can be seen that the AUSPOS solutions are consistent across all marks and observation durations, delivering AHD heights with an RMS of about 0.040 m (1 sigma) or 0.078 m (95% confidence level) and a range of about 0.35 m (-0.20 m to +0.15 m). It is also evident that the derived AHD-PU reported by AUSPOS appears to be overly conservative for the data investigated, providing a mean AHD-PU of 0.182 m, which is more than double the RMS value for the difference to the levelled AHD height at the 95% confidence level (i.e. about 0.078 m). This can be explained by the conservative AUSGeoid2020 uncertainty grid values applied (the best-case official AUSGeoid2020 uncertainty in NSW is about 0.14 m at the 95% confidence level). The interested reader is referred to Brown et al. (2018), Janssen and Watson (2018) and

Featherstone et al. (2019) for more information and discussion on this topic. It is pleasing to see that AUSPOS provides a much better connection to AHD across NSW than reported.

Table 3: Descriptive statistics for AHD analysis, considering levelled marks only (all values in metres).

Dataset	Statistic	Diff to AHD	Derived AHD-PU
Entire subset: 810 solutions	**Min.**	-0.206	0.147
	Max.	0.148	0.251
	Range	0.354	0.104
	Median	-0.012	0.179
	Mean	-0.012	0.182
	STD	0.038	0.016
	RMS	0.040	0.183
2-6 hour data: 394 solutions	**Min.**	-0.201	0.160
	Max.	0.148	0.233
	Range	0.349	0.073
	Median	-0.011	0.180
	Mean	-0.013	0.183
	STD	0.036	0.012
	RMS	0.039	0.183
6-24 hour data: 383 solutions	**Min.**	-0.206	0.147
	Max.	0.104	0.251
	Range	0.310	0.104
	Median	-0.011	0.175
	Mean	-0.010	0.181
	STD	0.040	0.019
	RMS	0.041	0.182

4 CONCLUDING REMARKS

Spatial Services, on behalf of the NSW Surveyor General, has a legislative, regulative responsibility to maintain and extend the Survey Control Network in NSW. This paper has outlined how AUSPOS and CORSnet-NSW are used together to support datum modernisation and improve state survey infrastructure across NSW. Using more than 2,400 successful AUSPOS datasets, incorporating observation session lengths between 2 hours and 48 hours, the quality of AUSPOS solutions was investigated.

It was shown that AUSPOS routinely delivers Positional Uncertainty values at the 0.02-0.03 m level for the horizontal component and about 0.05-0.06 m for the vertical component. As expected, a longer observation span improves PU. Most of the improvement is gained by increasing the observation length from 2 hours to about 4-5 hours. Observation sessions exceeding 12 hours provide AUSPOS solutions of substantially higher quality in the vertical component. Results vary negligibly with location (latitude) within the bounds of NSW and have a high degree of predictability/repeatability at sites with good sky view. AUSPOS solutions at those sites with substantial tree cover achieve acceptable HPU and heights with a VPU of better than 0.1 m. It was also shown that the derived AHD-PU values reported by AUSPOS appear to be overly conservative for the data investigated, due to the conservative AUSGeoid2020 uncertainty grid values applied.

In order to enhance the understanding of AUSPOS as a tool for everyone to use, NSW Spatial Services encourages Geoscience Australia to document and release detailed information on how PU values reported by AUSPOS are calculated and scaled.

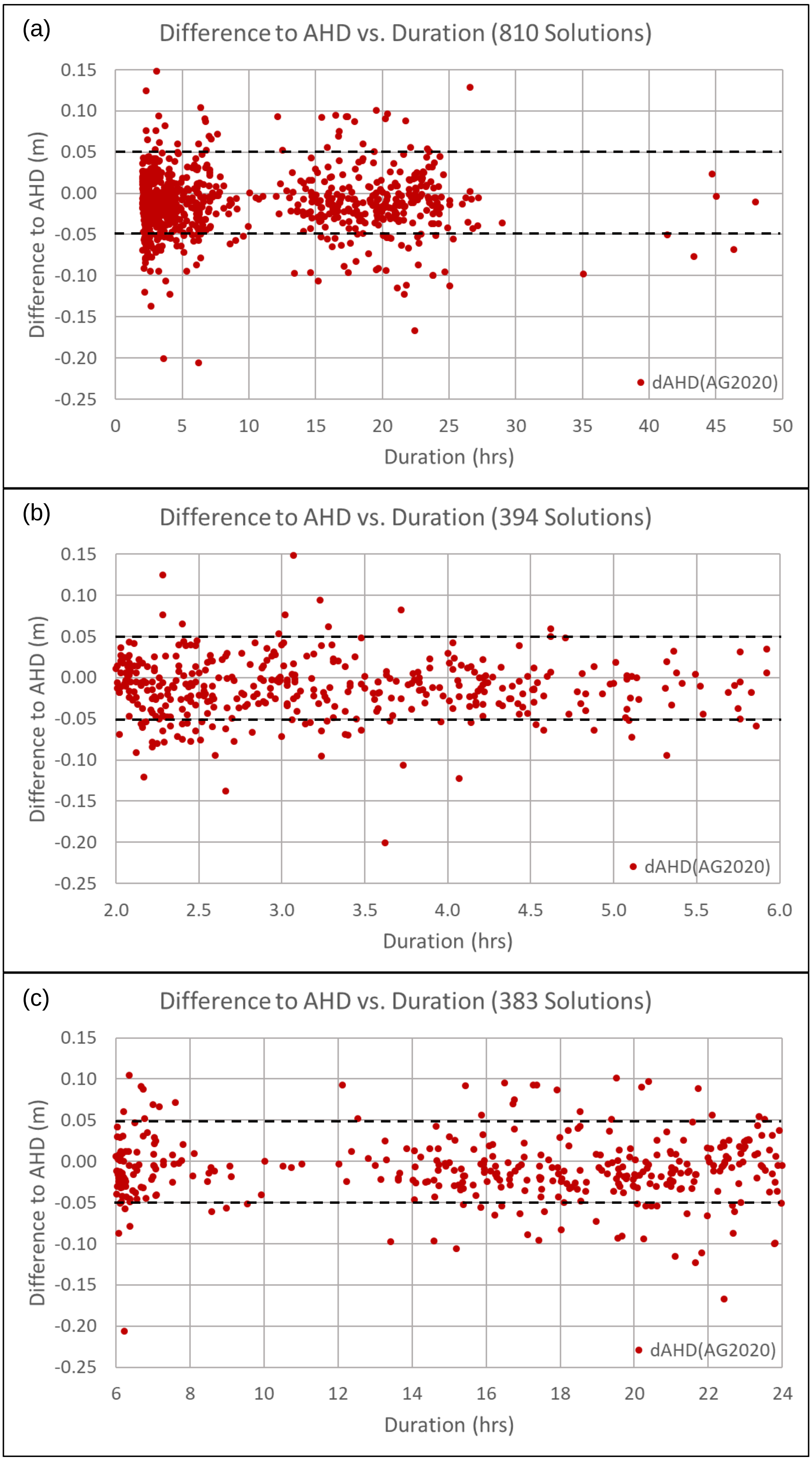


Figure 11: Agreement to levelled AHD vs. duration for (a) the entire subset, (b) 2-6 hour data, and (c) 6-24 hour data.

The results illustrate why Geoscience Australia stipulates, and NSW supports, a minimum observation span of 6 hours for direct inclusion into the national GDA2020 adjustment via the NGCA to propagate the Survey Control Network. They also show that shorter observation sessions are of sufficient quality to improve and strengthen the state survey infrastructure, provided sky view conditions are reasonable. This justifies the approach taken by NSW Spatial Services to use AUSPOS as one of several suitable methods to maintain and extend the State's Survey Control Network as well as the request for NSW users to submit data via our online collection tool to further the benefits for all.

REFERENCES

Altamimi Z., Rebischung P., Métivier L. and Collilieux X. (2016) ITRF2014: A new release of the International Terrestrial Reference Frame modelling nonlinear station motions, *Journal of Geophysical Research: Solid Earth*, 121, 6109-6131.

Brown N.J., McCubbine J.C., Featherstone W.E., Gowans N., Woods A. and Baran I. (2018) AUSGeoid2020 combined gravimetric-geometric model: Location-specific uncertainties and baseline-length-dependent error decorrelation, *Journal of Geodesy*, 92(12), 1439-1456 & 1467.

Dach R., Lutz S., Walser P. and Fridez P. (2015) Bernese GNSS software version 5.2, Astronomical Institute, University of Bern, Switzerland, http://www.bernese.unibe.ch/docs/DOCU52.pdf (accessed May 2020).

Featherstone W.E., McCubbine J.C., Claessens S.J., Belton D. and Brown N.J. (2019) Using AUSGeoid2020 and its error grids in surveying computations, *Journal of Spatial Science*, 64(3), 363-380.

GA (2020a) AUSPOS – Online GPS processing service, http://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/auspos (accessed May 2020).

GA (2020b) Asia-Pacific Reference Frame (APREF), https://www.ga.gov.au/scientific-topics/positioning-navigation/geodesy/asia-pacific-reference-frame (accessed May 2020).

Gakstatter E. and Silver M. (2013) A comparison of free GPS online post-processing services, *GPS World*, https://www.gpsworld.com/a-comparison-of-free-gps-online-post-processing-services/ (accessed May 2020).

Gowans N., McElroy S. and Janssen V. (2015) Survey infrastructure preservation and upgrade: Trigonometrical stations in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2015)*, Coffs Harbour, Australia, 16-18 March, 67-84.

ICSM (2007) Standards and practices for control surveys (SP1), version 1.7, http://www.icsm.gov.au/sites/default/files/2017-05/sp1v1-7.pdf (accessed May 2020).

ICSM (2014) Standard for the Australian survey control network (SP1), version 2.1, http://www.icsm.gov.au/publications/standard-australian-survey-control-network-special-publication-1-sp1 (accessed May 2020).

ICSM (2020a) GDA2020 and GDA94 technical manuals, http://icsm.gov.au/datum/gda2020-and-gda94-technical-manuals (accessed May 2020).

ICSM (2020b) Australian Vertical Working Surface, https://www.icsm.gov.au/australian-vertical-working-surface (accessed May 2020).

IGS (2020) International GNSS Service products, http://www.igs.org/products (accessed May 2020).

Janssen V., Gowans N., Hine S. and McElroy S. (2019) Removing the uncertainty surrounding Positional Uncertainty and Local Uncertainty in SCIMS, *Azimuth*, 58(8), 28-32.

Janssen V., Haasdyk J. and McElroy S. (2016) CORSnet-NSW: A success story, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 10-28.

Janssen V. and Watson T. (2018) Evaluating the performance of AUSGeoid2020 in NSW, *Proceedings of Association of Public Authority Surveyors Conference (APAS2018)*, Jindabyne, Australia, 9-11 April, 3-18.

Jia M., Dawson J. and Moore M. (2014) AUSPOS: Geoscience Australia's on-line GPS positioning service, *Proceedings of 27th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS+ 2014)*, Tampa, Florida, 8-12 September, 315-320.

Jia M., Dawson J. and Moore M. (2016) Upgraded AUSPOS and refined solution uncertainty, presented at IGNSS Symposium 2016 (IGNSS2016), Sydney, Australia, 6-8 December.

NSW Spatial Services (2019) Surveyor General's Direction No 12: Control Surveys and SCIMS, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed May 2020).

NSW Spatial Services (2020a) CORSnet-NSW, http://www.corsnet.com.au/ (accessed May 2020).

NSW Spatial Services (2020b) AUSPOS submission, https://www.spatial.nsw.gov.au/surveying/surveying_services/forms_and_applications/auspos_submission (accessed May 2020).

Roelse A., Granger H.W. and Graham J.W. (1971) The adjustment of the Australian levelling survey 1970-1971, *Technical Report 12*, Division of National Mapping, Canberra, Australia, 81pp.

GDA2020 and the AGRS: Hindsight and Foresight for Datum Modernisation in NSW

Joel Haasdyk
Spatial Services
NSW Department of Customer Services
Joel.Haasdyk@customerservice.nsw.gov.au

ABSTRACT

1 January 2020 was the nominal date for the adoption of the Geocentric Datum of Australia 2020 (GDA2020) in NSW and across Australia. This new static datum represents just one step towards the high-precision capabilities planned and required for the Australian Geospatial Reference System (AGRS). This presentation provides a hindsight review of what has been accomplished for the roll-out of GDA2020 across a range of spatial data platforms and legislative amendments supported by the Office of the Surveyor General, and what this means for practices in NSW. In foresight, the year 2020 also ushers in the Australian Terrestrial Reference Frame (ATRF) to support time-dependent coordination, and the Australian Vertical Working Surface (AVWS) to support wide-area height requirements. Both products are available from 2020 but will be subject to further development of software and standards before wide-spread adoption.

KEYWORDS: *GDA2020, AGRS, ATRF, AVWS, time-dependent, datum modernisation.*

A Dawning Realisation: GDA2020 and the Surveying and Spatial Information Regulation 2017

Simon Hine
Spatial Services
NSW Department of Customer Service
Simon.Hine@customerservice.nsw.gov.au

ABSTRACT

The Geocentric Datum of Australia 2020 (GDA2020) was enabled for NSW via the Survey Control Information Management System (SCIMS) on 1 July 2019. Amendments to the Surveying and Spatial Information Act 2002 ("the Act") and the Surveying and Spatial Information Regulation 2017 ("the Regulation") came into force on 1 January 2020, legislating GDA2020 to be the official datum for NSW. Survey plans having a date of survey on or after 1 January 2020 that are required by the Regulation to adopt an accurate Map Grid of Australia (MGA) orientation must adopt a GDA2020 orientation. This paper outlines the legislation changes, how they apply to surveys and survey plans under the Regulation, and a practical perspective on the use of SCIMS Online for cadastral purposes. Included are examples of how to use uncertainties and approved schedule changes, discussion of the new general exemption policy 2020-94 and use of the new 'GridCalc (GDA2020) for NSW' spreadsheet.

KEYWORDS: *Regulation, GDA2020, orientation, SCIMS, uncertainties.*

1 INTRODUCTION

The Geocentric Datum of Australia 2020 (GDA2020) was adopted as the national datum on 11 October 2017 (Federal Legislation, 2017). Amendments to the Surveying and Spatial Information Act 2002 ("the Act") (NSW Legislation, 2020a) and the Surveying and Spatial Information Regulation 2017 ("the Regulation") (NSW Legislation, 2020b) came into force on 1 January 2020, legislating GDA2020 to be the official datum for NSW.

For survey plans lodged on public record within NSW, the Regulation requires the datum line of orientation for the majority of those plans to be aligned to the Map Grid of Australia (MGA) and report an MGA position to, at a minimum, Class D standard. In particular, *all* rural surveys and the majority of urban surveys must have an MGA orientation and MGA position.

As the official datum for NSW is now GDA2020, the MGA coordinates adopted by, or reported on, NSW survey plans lodged on public record must be MGA2020 coordinates. Section 1.6 of the GDA2020 technical manual (ICSM, 2020) provides a technical definition of MGA2020 coordinates.

This paper describes some legislative changes, a brief description of the uncertainty values reported by the Survey Control Information Management System (SCIMS), use of SCIMS Online for cadastral purposes, the updated approved coordinate and height schedules, the Exemption Policy 2020-94, the new 'GridCalc (GDA2020) for NSW' spreadsheet and the differences expected for datum lines between GDA94 and GDA2020.

2 LEGISLATIVE CHANGES

Amendments to the Act and the Regulation came into force on 1 January 2020, legislating GDA2020 to be the official datum for NSW. While enabling GDA2020 as the official datum for NSW, the amendments also streamlined the process for any future NSW state datum changes in response to national datum changes.

Definitions for the "Geocentric Datum of Australia" and "Australian Height Datum" in section 3 of the Act were amended so that they referred to the definition for these terms in the Regulation. The Regulation was amended so that the above terms, and their definitions, were inserted into clause 5 of the Regulation. The definition of "Geocentric Datum of Australia" was amended to refer to GDA2020.

3 UNCERTAINTY VALUES REPORTED BY SCIMS

In 2002, the Intergovernmental Committee on Surveying and Mapping (ICSM) adopted Positional Uncertainty (PU) and Local Uncertainty (LU) as methods to classify the accuracy of coordinates while Class remained unchanged (Janssen et al., 2019).

The Standards and Practices for Control Surveys (SP1) version 1.7 (ICSM, 2007) defines PU as "the uncertainty of the coordinates or height of a point, in metres, at the 95% confidence level, with respect to the defined reference frame" and LU as "the average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates, or height, of a point(s), with respect to the survey connections to adjacent points in the defined frame."

SCIMS reports the quality of coordinates in the new GDA2020 using Class, Horizontal Positional Uncertainty (HPU), Vertical Positional Uncertainty (VPU), Horizontal Local Uncertainty (HLU), Vertical Local Uncertainty (VLU), AHD-PU and AHD-LU. For more detail regarding PU and LU in SCIMS, the reader is referred to Janssen et al. (2019).

4 USE OF SCIMS ONLINE FOR CADASTRAL PURPOSES

While there are many and various pieces of information contained in a SCIMS report, there is usually only a small subset that comprises the minimum required by cadastral surveyors in NSW for completion of a land survey plan. Typically, the priority of a cadastral surveyor completing a land survey plan is to determine the position of any established survey marks so that the orientation of the datum line required by the Regulation can be determined.

Currently, the determiners of what constitutes an "established survey mark" as defined under clause 5 of the Regulation can be summarised as:

- The mark must be a "survey mark" as defined in clause 27 of the Regulation.
- The mark must be described in SCIMS as having a horizontal position equal to or better than Class D.

As an example, the intersection of two lines painted on a tennis court being an imaging control point (CP) reported as Class D in SCIMS is *not* an established survey mark as the form and style of the mark is *not* a "survey mark" as defined in clause 27 of the Regulation.

Currently, the second determiner above of an "established survey mark" remains the Class as reported in SCIMS. However, it is intended that the future definition will include a HPU range. This is dependant on sufficient marks in the State's Survey Control Network being populated with HPU. Within the Regulation currently in force, HPU is only explicitly stipulated in clause 70(2)(c) regarding the accuracy of coordinates to be shown in the coordinate schedule, though PU is now part of the approved coordinate and height schedules (see section 5 of this paper).

It should be noted that LU is not used as a stipulation in either the Regulation or Surveyor-General's Direction No. 7 (Surveying and Spatial Information Regulation 2017 – Applications) (NSW Spatial Services, 2019). Surveyors must not show LU on survey plans. LU is only intended as a client service for surveyors by providing "a single summary measure of how well the subject mark fits into the existing local network" (Janssen et al., 2019). As an example, HLU might assist surveyors in choosing established survey marks to connect to in a land survey prior to fieldwork, via assessment of their likely compliance under clause 12(7) of the Regulation (connection comparisons exceeding 40 mm + 175 ppm).

5 UPDATED COORDINATE AND HEIGHT SCHEDULES

With the adoption of GDA2020 as the official datum for NSW, the approved coordinate and height schedules have been updated to reflect the removal of Order as a coordinate quality. The only change to the schedules is the replacement of Order with PU (Figures 1 & 2).

COORDINATE SCHEDULE						
MARK	MGA COORDINATES		CLASS	PU	METHOD	STATE
	EASTING	NORTHING				
TS 5112	744 967.495	6 298 524.697	2A	0.02	SCIMS	FOUND
SS 29508	745 309.567	6 299 025.436	C	N/A	SCIMS	FOUND
PM 78165	744 323.423	6 298 970.037	B	N/A	SCIMS	FOUND
SS 205652	744 084.045	6 299 017.814	C	N/A	CAD. TRAV	PLACED
SS 195799	744 061.715	6 298 879.024	C	N/A	CAD.TRAV	FOUND
DATE OF SCIMS COORDINATES: 1-1-2020 MGA ZONE: 55 MGA DATUM: GDA2020						
COMBINED SCALE FACTOR: 1.000223						

Figure 1: New GDA2020 approved coordinate schedule example.

HEIGHT SCHEDULE					
MARK	AHD VALUE	CLASS	PU	HEIGHT DATUM VALIDATION	STATE
PM 3570	680.182	LA	0.01	SCIMS ADOPTED	FOUND
PM 3571	691.290	LA	0.01	FROM SCIMS - DATUM VALIDATION	FOUND
SS 57633	682.201	LD	N/A		FOUND
BM 3	680.128	LD	N/A		PLACED
DATE OF SCIMS AHD VALUES: 1-1-2020 HEIGHT DATUM: AHD71					

Figure 2: New approved height schedule example.

"For established survey marks, the Class and PU as shown in SCIMS is required to be shown; if the PU is reported in SCIMS as null (empty), "N/A" should be shown for PU. For survey marks with MGA coordinates or heights determined by the surveyor (excluding established survey marks), Class is required to be shown and *PU is optional*. If the surveyor does not wish to show PU in this case, "N/A" should be placed in the PU column" (NSW Spatial Services, 2019). Section 3.31.3 of Surveyor-General's Direction No. 7 (NSW Spatial Services, 2019) has further detail regarding the determination of PU.

For further detail and examples regarding the GDA2020 approved schedules required to be shown on a survey plan, the reader is referred to section 3.31 of Surveyor-General's Direction No.7 (NSW Spatial Services, 2019).

6 EXEMPTION POLICY 2020-94

From 1 January 2020, survey plans required to adopt an "accurate MGA orientation" under the Regulation must adopt MGA2020 coordinates unless an exemption applies. To enable a smooth transition between the GDA94 and GDA2020 datums for survey plans, a general exemption policy, "Policy 2020-94 Exemption" has been made available. "A Policy 2020-94 Exemption allows a survey plan with a date of survey between 1 January 2020 and 30 June 2020 (inclusive) to adopt, as orientation of the datum line, the grid bearing derived from the MGA94 coordinates of two survey marks" (NSW Spatial Services, 2019).

Survey plans proposing to apply a "Policy 2020-94 Exemption" *must* adopt an "accurate MGA orientation" under the Regulation and *must* have a date of survey between 1 January 2020 and 30 June 2020 (inclusive). Plans of survey with a date of survey after 30 June 2020 adopting MGA94 coordinates will require a plan-specific exemption. For further detail regarding the "Policy 2020-94 Exemption", the reader is referred to section 3.34.6 of Surveyor-General's Direction No.7 (NSW Spatial Services, 2019).

7 'GridCalc (GDA2020) for NSW' SPREADSHEET

Following on from the 'GridCalc (GDA94) for NSW' spreadsheet (NSW Spatial Services, 2018), a GDA2020 version of the spreadsheet has been developed by the Office of the Surveyor-General (NSW Spatial Services, 2020). The 'GridCalc (GDA2020) for NSW' spreadsheet has a subset of the AUSGeoid2020 model embedded within, allowing rigorous calculation of geodetic elements including grid bearings, a ground distance and Combined Scale Factor (CSF).

Use of the 'GridCalc (GDA2020) for NSW' spreadsheet requires input of MGA2020 coordinates, their projection zone and Australian Height Datum 1971 (AHD71) heights. Use of MGA94 coordinates with the 'GridCalc (GDA2020) for NSW' spreadsheet will result in incorrect AUSGeoid values (N-values) though the impact on the grid bearings, ground distance and CSF will be negligible for the majority of cadastral surveys (compared to the results obtained from the 'GridCalc (GDA94) for NSW' spreadsheet using the same MGA94 coordinates).

It should be noted that the grid bearing, ground distance and CSF for a line computed using MGA94 coordinates from SCIMS might differ from those same elements computed using

MGA2020 coordinates from SCIMS due to small differences in relativity between the coordinates expressed in the different datums in SCIMS (see section 8).

8 DATUM LINE DIFFERENCES GDA94 TO GDA2020

Lines between established survey marks that might, for example, be adopted as datum lines of orientation for survey plans, will show small differences in relativity (grid bearing, ground distance and CSF) when comparing SCIMS MGA94 coordinate pair calculations with SCIMS MGA2020 coordinate pair calculations for the same line. The differences are present due to the differing adjustment and transformation methodologies between the GDA94 and GDA2020 datasets within SCIMS.

The Office of the Surveyor-General has investigated these differences so that cadastral surveyors can be aware of the difference values that might be expected in the transition from GDA94 to GDA2020.

8.1 Methodology

The methodology employed to examine line pair differences between SCIMS MGA94 and SCIMS MGA2020 was as follows:

1. Use only established survey marks to examine line pairs.
2. Divide line distances into three distance ‘bins’:
   (a) 100 m to 1,000 m
   (b) 1,000 m to 5,000 m
   (c) 5,000 m to 15,000 m
3. Determine random pairs of established survey marks for examination, i.e. 5,000 random pairs for each bin comprising:
   (a) 1,000 random pairs from MGA zone 54 for each bin
   (b) 2,000 random pairs from MGA zones 55 and 56 for each bin
4. Retrieve the MGA94 coordinates, MGA2020 coordinates and AHD71 values from SCIMS for each random pair generated.
5. Enter the MGA94 coordinates and AHD71 values into the ‘GridCalc (GDA94) for NSW’ spreadsheet and retrieve the grid bearings, ground distance and CSF for the line.
6. Enter the MGA2020 coordinates and AHD71 values into the ‘GridCalc (GDA2020) for NSW’ spreadsheet and retrieve the grid bearings, ground distance and CSF for the line.
7. Calculate and visualise relevant statistics for the differences found.

The above procedure was automated using the interpreted high-level programming language Python.

8.2 Results

It should be noted that for the purposes of plotting clarity, each of the distributions below shows the majority of each dataset rather than its entirety. Very few outliers were found and are considered anomalies that have been resolved in the GDA2020 state adjustment or are being investigated.

8.2.1 Distances 100 m to 1,000 m

The distributions for the 100 m to 1,000 m line pairs (Figures 3 & 4, Table 1) represent the distance bin in which the majority of datum lines found on survey plans would fall.

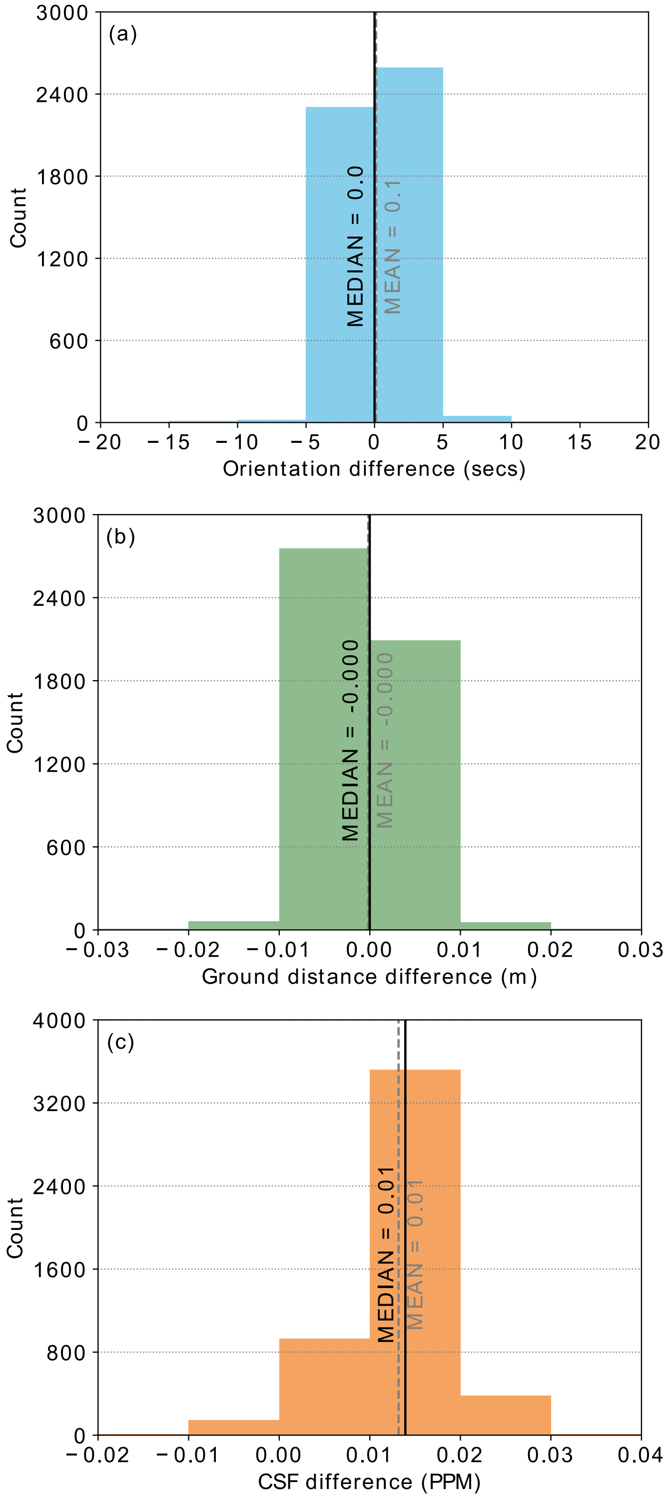


Figure 3: Distribution of (a) orientation difference, (b) ground distance difference and (c) CSF difference values between 5,000 pairs of SCIMS MGA94 and MGA2020 lines of length within 100 m to 1,000 m.

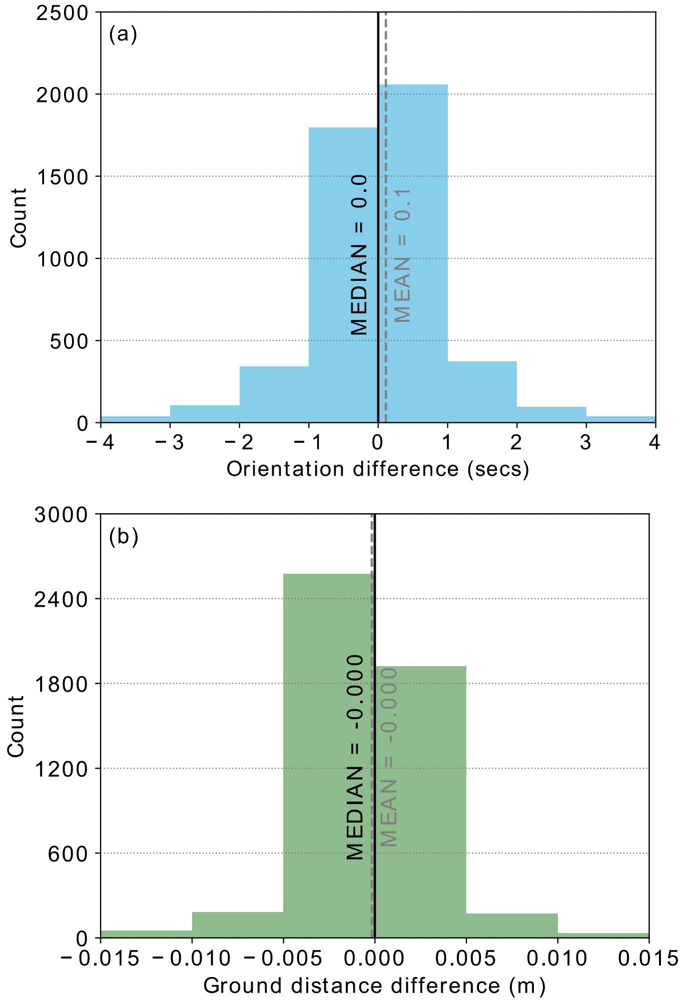


Figure 4: Higher resolution distribution of (a) orientation difference and (b) ground distance difference values between 5,000 pairs of SCIMS MGA94 and MGA2020 lines of length within 100 m to 1,000 m.

Table 1: Statistics for the differences in the 100 m to 1,000 m pair distance bin. IQR is the Interquartile Range.

Quantity	**Mean**	**Median**	**Std. Dev.**	**IQR**
Grid bearing differences (sec)	0.1	0.0	4.8	0.9
Ground distance differences (m)	0.0	0.0	0.008	0.002
CSF differences (PPM)	0.01	0.01	0.01	0.01

It can be seen from Figures 3 & 4 and Table 1 that the orientation differences for the 100 m to 1,000 m distance bin can be considered minor to negligible in a cadastral context, with the majority of differences falling between -1 second of arc and +1 second of arc. Similarly, the ground distances show only minor differences with the majority of differences falling between -0.005 m and +0.005 m. The CSF shows extremely small differences with the majority falling between -0.02 and +0.02 parts per million (PPM), which is negligible in a cadastral context and can be attributed mainly to the effect of the difference between AUSGeoid09 and AUSGeoid2020 values on the height factor component of the CSF.

8.2.2 Distances 1,000 m to 5,000 m

The distributions for the 1,000 m to 5,000 m line pairs (Figures 5 & 6, Table 2) represent the distance bin in which a minority of datum lines found on survey plans would fall.

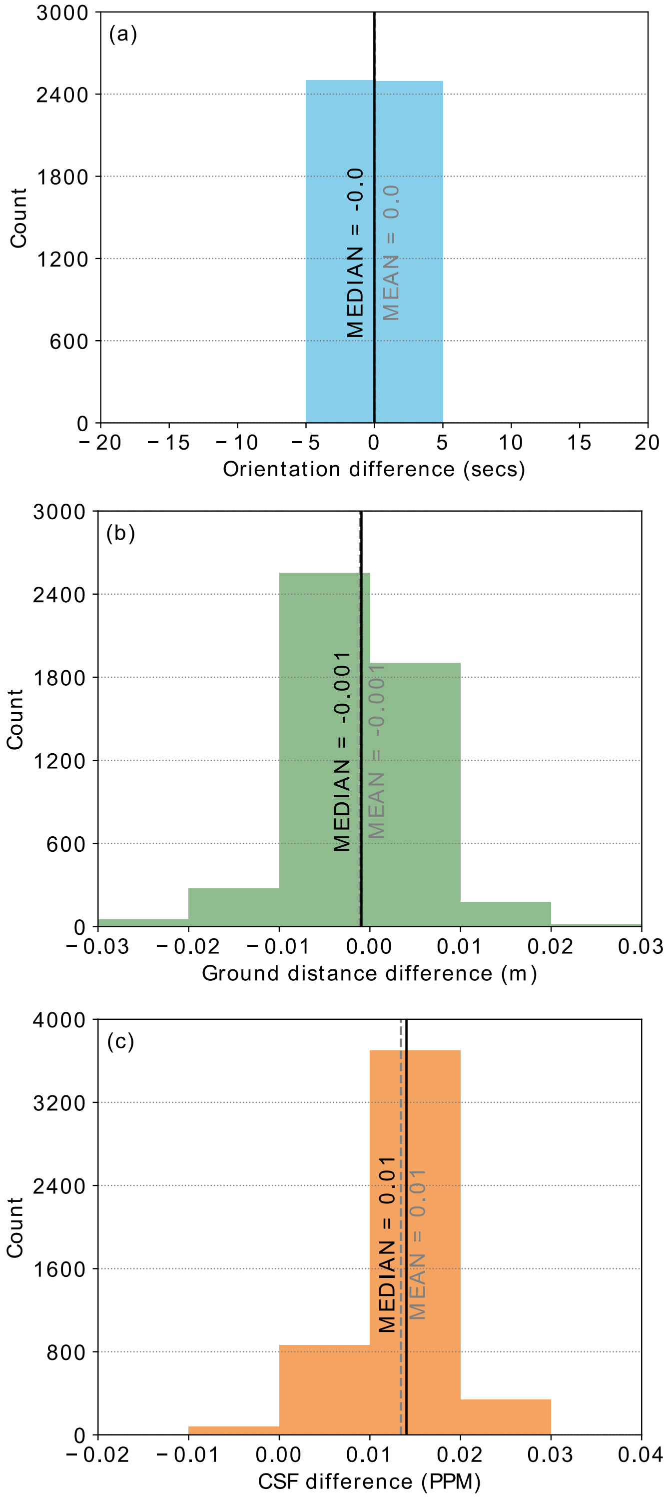


Figure 5: Distribution of (a) orientation difference, (b) ground distance difference and (c) CSF difference values between 5,000 pairs of SCIMS MGA94 and MGA2020 lines of length within 1,000 m to 5,000 m.

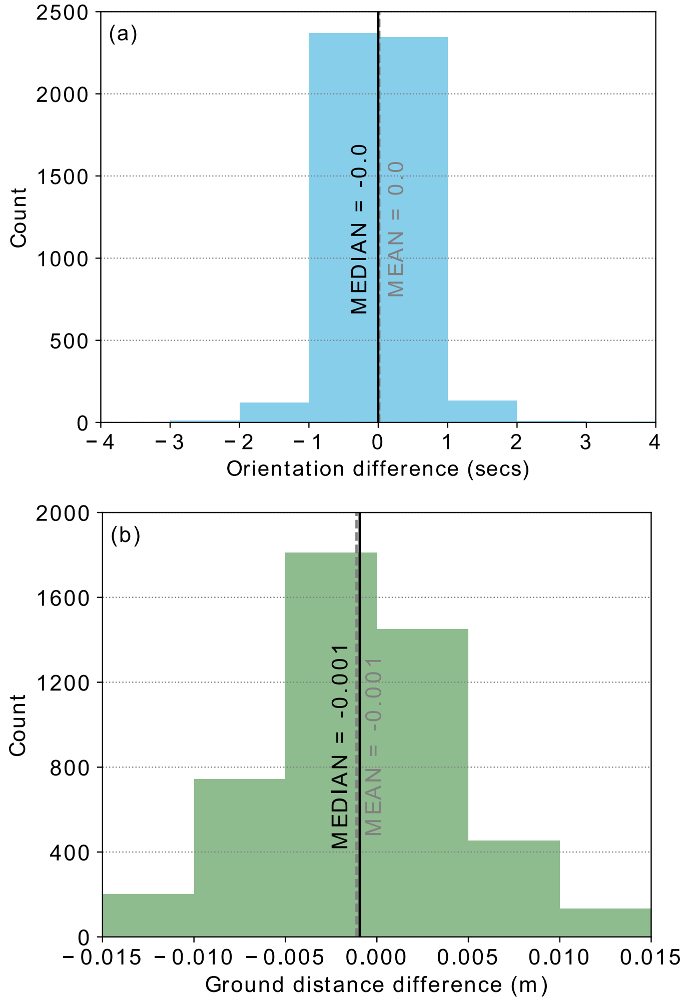


Figure 6: Higher resolution distribution of (a) orientation difference and (b) ground distance difference values between 5,000 pairs of SCIMS MGA94 and MGA2020 lines of length within 1,000 m to 5,000 m.

Table 2: Statistics for the differences in the 1,000 m to 5,000 m pair distance bin. IQR is the Interquartile Range.

Quantity	**Mean**	**Median**	**Std. Dev.**	**IQR**
Grid bearing differences (sec)	0.0	0.0	0.9	0.5
Ground distance differences (m)	-0.001	-0.001	0.007	0.007
CSF differences (PPM)	0.01	0.01	0.01	0.01

Again, it can be seen from Figures 5 & 6 and Table 2 that the majority of orientation differences for the 1,000 m to 5,000 m distance bin can be considered minor to negligible in a cadastral context. As expected, the orientation difference distribution shows a tighter grouping than the 100 m to 1,000 m bin due to the lesser impact of relative differences on orientation over a longer line. As before, the majority of ground distances show only minor differences with the distribution showing a slightly larger spread, which can be attributed to the longer distances spanning disparate adjustments in GDA94 with greater frequency. The CSF differences are again negligible.

8.2.3 Distances 5,000 m to 15,000 m

The distributions for the 5,000 m to 15,000 m line pairs (Figure 7 and Table 3) represent the distance bin in which very few datum lines found on survey plans would fall.

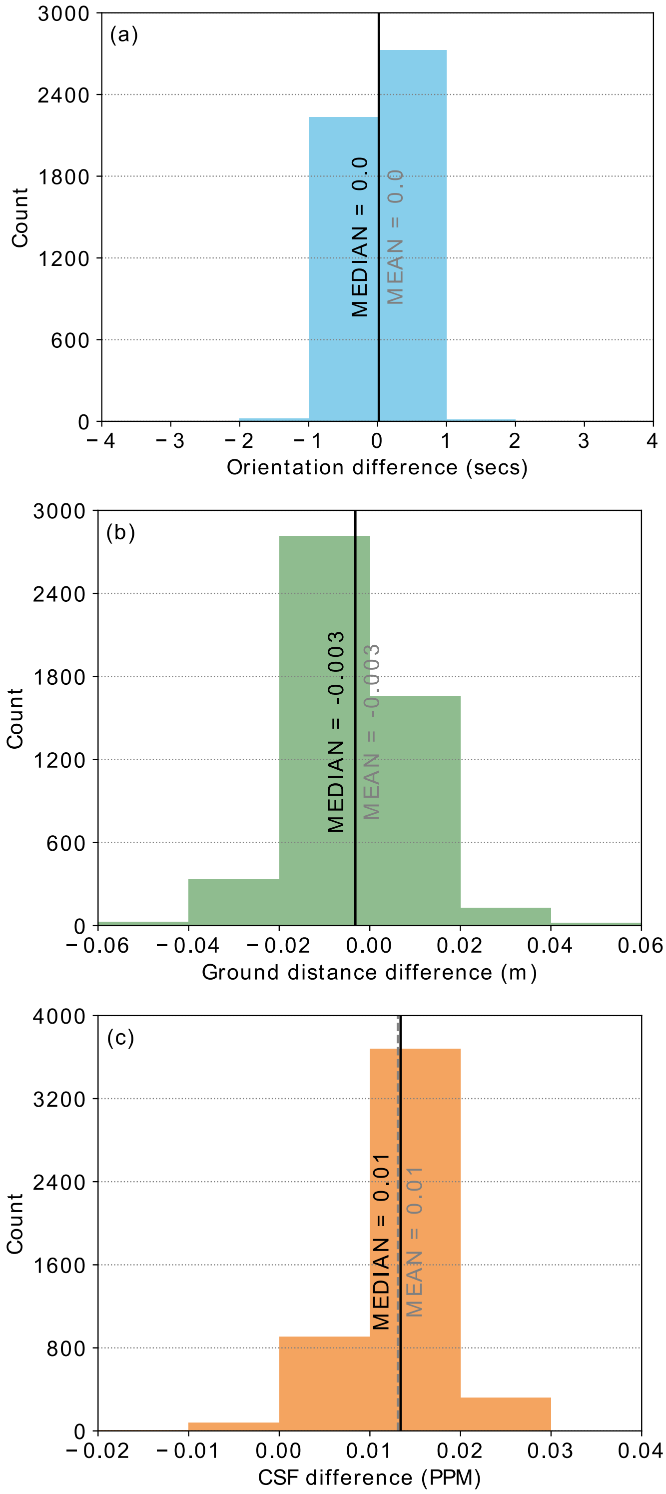


Figure 7: Distribution of (a) orientation difference, (b) ground distance difference and (c) CSF difference values between 5,000 pairs of SCIMS MGA94 and MGA2020 lines of length within 5,000 m to 15,000 m.

Table 3: Statistics for the differences in the 5,000 m to 15,000 m pair distance bin. IQR is the Interquartile Range.

Quantity	**Mean**	**Median**	**Std. Dev.**	**IQR**
Grid bearing differences (sec)	0.0	0.0	0.3	0.2
Ground distance differences (m)	-0.003	-0.003	0.013	0.013
CSF differences (PPM)	0.01	0.01	0.01	0.01

As found for the prior two distance bins, it can be seen from Figure 7 and Table 3 that the majority of orientation differences for the 5,000 m to 15,000 m distance bin can be considered minor to negligible in a cadastral context. As expected, the orientation distribution shows the tightest grouping of the three distance bins. Again, the majority of ground distances show only minor differences with the distribution having the largest spread of the three distance bins due to the frequency with which the longer distances span disparate adjustments in GDA94. The CSF differences are again negligible.

9 CONCLUDING REMARKS

Much effort has been expended to ensure the transition from GDA94 to GDA2020 for cadastral surveyors producing survey plans under the Regulation should be smooth and orderly with only minor alterations to workflow needed. The relevant legislation has been amended to enable GDA2020 and to streamline future datum changes.

Minor changes to approved schedules under the Regulation have been detailed and are available to all surveyors, as is the general "Exemption Policy 2020-94", giving a soft transition from GDA94 to GDA2020. The 'GridCalc (GDA2020) for NSW' spreadsheet is available to allow easy calculation of the grid bearings, ground distance and the Combined Scale Factor for a chosen MGA2020 line. Differences in orientation, ground distance and the CSF between MGA94 and MGA2020 for the vast majority of NSW survey plan datum lines should be minor to negligible. Given the above, cadastral surveyors can begin to adopt GDA2020 as a survey plan orientation with little alteration to their workflows for a smooth transition to a GDA2020 enabled cadastre.

REFERENCES

Federal Legislation (2017) National Measurement (Recognized-Value Standard of Measurement of Position) Determination 2017, https://www.legislation.gov.au/Details/F2017L01352 (accessed May 2020).

ICSM (2007) Standards and Practices for Control Surveys (SP1), version 1.7, https://www.icsm.gov.au/sites/default/files/2017-05/sp1v1-7.pdf (accessed May 2020).

ICSM (2020) Geocentric Datum of Australia 2020 technical manual, version 1.3, https://www.icsm.gov.au/publications/gda2020-technical-manual-v13 (accessed May 2020).

Janssen V., Gowans N., Hine S. and McElroy S. (2019) Removing the uncertainty surrounding Positional Uncertainty and Local Uncertainty in SCIMS, *Azimuth*, 58(8), 28-32.

NSW Legislation (2020a) Surveying and Spatial Information Act 2002, https://www.legislation.nsw.gov.au/#/view/act/2002/83 (accessed May 2020).

NSW Legislation (2020b) Surveying and Spatial Information Regulation 2017, https://www.legislation.nsw.gov.au/#/view/regulation/2017/486 (accessed May 2020).

NSW Spatial Services (2018) GridCalc (GDA94) for NSW – spreadsheet & user guide, https://github.com/icsm-au/DatumSpreadsheets/blob/master/GridCalc_GDA94_NSW.zip (accessed May 2020).

NSW Spatial Services (2019) Surveyor-General's Direction No. 7: Surveying and Spatial Information Regulation 2017 – Applications, https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0017/221741/SG_Direction_07.pdf (accessed May 2020).

NSW Spatial Services (2020) GridCalc (GDA2020) for NSW – spreadsheet & user guide, https://github.com/icsm-au/DatumSpreadsheets/blob/master/GridCalc_GDA2020_NSW.zip (accessed May 2020).

The State of Surveying

Michelle Blicavs
Association of Consulting Surveyors
michelle@acsnsw.com.au

ABSTRACT

The Association of Consulting Surveyors (ACS) continues to support private businesses in surveying. This presentation provides the current 'state of surveying' from across New South Wales, including our most recent research into hourly rates, staffing challenges, business opportunities and what is on the horizon for consulting surveying firms. Private and public surveyors have always worked together, and as seen at the 2019 Excellence in Surveying and Spatial Information (EISSI) Awards, that collaboration continues to be recognised publicly as 11 transport projects were highlighted with 4 wins. This presentation outlines why EISSI and the Surveying Taskforce are critical to the future of surveying, also bringing a national perspective to the current state and the future of our profession.

KEYWORDS: *Future, research, EISSI, Surveying Taskforce, promotion, relevance.*

What is a Teaching Academic?

Craig Roberts
School of Civil and Environmental Engineering
University of New South Wales
c.roberts@unsw.edu.au

ABSTRACT

The opportunity to teach the next generation of enthusiastic young people the wonderful world of surveying and spatial information is a privilege. Academics teaching surveying are hard to source for various reasons, but primarily because it is expected that academics have a PhD and a fruitful research trajectory. The ability to teach undergraduate surveying students appears to be a secondary consideration. These students will become members of the professional surveying industry and are required to have certain skills, which often do not lend themselves to a research-focussed academic. This disconnect was becoming more and more pronounced, until now. At the University of New South Wales (UNSW), new education-focussed roles have become an important part of the staff cohort. The requirement for a PhD for new education-focussed academics is being relaxed and replaced by industry experience for teaching-focussed roles. This welcome change in policy opens the way for potential new staff members from an industry background who may want to contemplate a career change or consider a fractional position. But what does all this mean? Can a professional surveyor really transform themselves into a teaching academic and maybe more? What is the job really like? What opportunities are there and what challenges must be faced? This paper hopes to enlighten and possibly attract potential new teaching staff to UNSW for succession planning and refreshment of our academic staff teaching into the Bachelor of Engineering (Surveying) discipline.

KEYWORDS: *Teaching, surveying, education, university.*

1 INTRODUCTION

The term ‘academic’ is used variously as endearing or as a pejorative. Academic achievement could mean educational or scholarly, whilst conversely if an exercise is considered ‘largely academic’, then it would imply that it is impractical or only theoretical. However, to be called an academic simply means a teacher or scholar in a university or institute of higher education. Research is implicit in the title but in recent years has become the most important qualification when seeking new staff. For a practical profession such as surveying, this research focus poses a problem as the fertile ground for research in surveying or geospatial engineering departs further from the basic training that an undergraduate student requires as part of their university surveying degree. Sourcing and employing suitably skilled and qualified new academic staff has therefore become much more difficult (Roberts and Harvey, 2019).

The University of New South Wales (UNSW) is committed to becoming a university that is focussed on fostering both research *and* educational excellence, and this has been the genesis of the new Education Focussed (EF) roles offered to existing staff and now more recently new staff (UNSW, 2015, 2020). In practical terms, this means that a registered land surveyor with sufficient industry experience and a desire for a change in career could apply to become a teaching academic at UNSW and embark on a fulfilling and satisfying academic career with a focus on teaching surveying. This was not previously possible.

This paper hopes to enlighten and possibly attract potential new teaching staff to UNSW for succession planning and refreshment of our academic staff teaching into the Bachelor of Engineering (Surveying) discipline.

2 WHAT DOES IT MEAN TO BE AN ACADEMIC?

Academic staff (teaching and research) are generally required to conduct teaching, research and service in proportions of 40%, 40% and 20% respectively. Academic promotion from Lecturer to Senior Lecturer, Associate Professor and Professor is based on making a case for excellence in these various tasks. Some academics are research-only and are assessed much more for their research performance. Education-focussed roles have swung the balance more towards teaching excellence and the promotional metrics reflect this change. It should be noted that service is expected and can vary between many tasks from contributions to internal committees, assessing scholarship applications to service on external industry committees such as the Surveying and Mapping Industry Council (SMIC) or tasks that engage the university with the wider community.

A teaching academic would be expected to undertake more teaching than an equivalent teaching/research academic. The BE (Surveying) program contains 12 surveying courses as well as a number of courses in maths, physics, computing and engineering that are compulsory for all engineering students in the School of Civil and Environmental Engineering (CVEN). Courses most likely to suit a new teaching academic with industry experience (and most important for the program) would include 1st year surveying, 2nd year survey computations and Computer-Aided Design (CAD), cadastral surveying and land development which prepares students as candidates for registration, if this is the path they choose.

UNSW now offers 3 x 10-week terms to students, whereby Term 1 spans mid-February to the end of April, Term 2 spans the start of June to mid-August and Term 3 spans mid-September to the end of November.

3 DO I NEED TEACHING QUALIFICATIONS?

Most academics do not have formal teaching qualifications. Unlike TAFE, where a minimum Cert IV in Teaching is required, at university many academics complete their PhD and are let loose on their first class of undergraduates with little teaching preparation. In reality, whilst completing a PhD, the candidate will have prepared numerous conference presentations and probably tutored students, so will have some experience, but nothing formal. That said, at UNSW there are numerous internal courses, resources and support for new and continuing teaching staff. Some academic staff have completed a Diploma in Education, but this is purely personal and not required. For an EF academic, a teaching qualification either internal or external would certainly be encouraged.

Similarly, a professional surveyor may have served as an examiner for Board of Surveying and Spatial Information (BOSSI) candidate surveyors, may prepare presentations for the Kurri Kurri workshop or various Continuing Professional Development (CPD) events (conferences, seminars and webinars) held regularly in NSW and beyond. These all provide good exercises and preparation for a teaching career.

The recent change to EF roles has created an EF community with many opportunities for mentoring, exchange of ideas and support for new, innovative teaching initiatives. It is a very positive development and a great opportunity to learn from other academics from different disciplines about how to design and improve teaching delivery and outcomes.

4 ISN'T IT BORING TEACHING THE SAME MATERIAL EVERY YEAR?

Surveying is a high-technology field. Not only is equipment and software changing rapidly, so too is the underlying policy and representation of new spatial data (e.g. Global Navigation Satellite System – GNSS, Continuously Operating Reference Station – CORS, terrestrial, airborne and handheld laser scanning, Unmanned Aerial Vehicles – UAVs, LandXML, 3D cadastre and modern geodesy). Every year changes need to be made to teaching resources to keep up-to-date with changes in the industry.

Teaching academics should interface with industry and researchers and adapt their courses to suit but conversely challenge industry with new advances that can be shared with industry. Universities are lightning rods for all sorts of experts. Academics are therefore exposed to a lot of new ideas and information on a daily basis. It is far from boring, rather exciting, inspiring and even exhausting.

5 THE ROLE IS TOO INTIMIDATING

Like all roles, you do not start knowing everything. Initially, there is a steep learning curve and thankfully the learning never stops. This keeps the role interesting. Industry experience as a registered surveyor is a great first step from which to build a career as a teaching academic. Undergraduate students certainly value the experience of a teacher who has worked in the industry.

A lack of experience in research can be developed initially through supervising undergraduate Honours projects and with appropriate mentorship from academic colleagues. There are opportunities to undertake part-time Masters or PhD studies as part of the role, which will provide excellent research training. Further study is optional but encouraged. Education-focussed academics can still be active researchers and there are opportunities to convert to a research/teaching academic later in the career if desired.

6 WHAT'S IT LIKE WORKING AT A UNIVERSITY?

Teaching at university can feel seasonal as student terms start and finish and the population of the university fluctuates. You will certainly feel the buzz with a university full of young people eager to learn. The environment is very nice to work in, and the salary and conditions are good. Workplace flexibility is very attractive. It is possible (but not guaranteed) to structure teaching around some outside commitments (e.g. no teaching after 4 pm on Wednesdays because you coach footy). University superannuation schemes are very generous. The School of Civil and Environmental Engineering is very large and attracts a lot of students. As a consequence, there is a lot of support for the purchase of new equipment and resources all of which is available to academic staff for use in teaching and research projects. There are also many opportunities to work with like-minded academics and engineers on interesting and diverse projects, using your skills in surveying and geospatial engineering.

Access to the library resources (both online and books) and the encouragement to purchase new items for the collection that will enhance teaching and research is also encouraged. UNSW has a large AutoCAD, ESRI and NearMap licence for *all* students (and staff) to use as part of their enrolment. There is budget to purchase new and specialist software that supports teaching and research.

The downside of a large school is large class sizes. Most lectures are now recorded, so students can review them on Moodle (online education platform used at UNSW). However, the challenge is encouraging students to actually attend the lectures. Thankfully student numbers in the surveying cohort are much smaller, so classes are small, although 1st year surveying is likely to become a recommended elective to all 1st year civil engineering students, which will require large class teaching (up to 300 students in a class). There are a lot of support services to provide the best possible teaching, given these larger numbers.

There has been a high demand for graduate surveying students across the profession for more than a decade. Compared to civil engineering, surveying is a niche profession with much smaller numbers, therefore marketing of the career is another important task for an EF academic. There are many activities, such as information days for high school students, where academics prepare hands-on tasks to encourage students to consider studying surveying. The annual UNSW Open Day is an important marketing activity. The Institution of Surveyors NSW (ISNSW) supported Maths in Surveying days, and various similar events supported by the Association of Consulting Surveyors (ACS) should be supported by EF academics who can provide important information to potential new students. Internally at UNSW, there is no shortage of other marketing activities requiring creativity and energy from a teaching academic.

7 CONCLUDING REMARKS

Surveying has been taught for over 50 years at UNSW, and new staff will benefit from the existing resources that have been developed and updated over time. The opportunity to teach bright, enthusiastic young people is a privilege. The teaching academic should embrace the challenge and always seek to use their creativity and experience to develop new, engaging tasks for students. An element of challenge and fun is always appreciated by students and makes for a satisfying career.

With experience, a teaching academic can make a significant and positive contribution to the wider profession and enmesh student teaching and research into a relevant curriculum. Issues such as LandXML uptake, Cadastre 2034, new developments in CORS and Satellite Based Augmentation System (SBAS) and their impacts on surveyors, datum modernisation and professionalism can all be investigated more deeply in partnership with student projects to help deepen the students' knowledge as well as the academic's and possibly contribute to furthering the development of surveying and mapping in NSW, Australia and beyond. This can be done initially through the supervision of Honours and Masters projects and perhaps later with PhD projects. EF academics can apply for support for conference travel and attendance and are encouraged to present their work to a wider audience with opportunities for networking.

Opportunities to contribute to the profession on professional/industry committees and the various marketing activities enable the teaching academic to keep up with industry developments, which can be reflected in the curriculum taught to students. Succession planning of academic teaching staff at UNSW is a longer-term goal, and hopefully this paper dispels some myths about the role of a teaching academic and might encourage suitable applicants to apply as opportunities arise.

REFERENCES

Roberts C. and Harvey B. (2019) The critical importance of practical exercises in a modern surveying curriculum, *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 139-151.

UNSW (2015) UNSW strategy 2025: Our strategic priorities and themes, https://www.2025.unsw.edu.au/sites/default/files/uploads/unsw_2025strategy_201015.pdf (accessed May 2020).

UNSW (2020) Education focussed careers, https://teaching.unsw.edu.au/education-careers (accessed May 2020).

The Skeletons in Shrimpton's Creek

Fred de Belin
City of Ryde
fdebelin@ryde.nsw.gov.au

ABSTRACT

Shrimpton's Creek flows through the major drainage catchment in the Local Government Area of City of Ryde. The question of ownership of the bed of Shrimpton's Creek was raised, discussed and resolved in a previous paper at APAS2019 ("Status of a stream: Who owns the creek?"). This involved collecting every title and every Deposited Plan for the entire five-kilometre length of Shrimpton's Creek. In addition to discovering the ownership issues within the various sections of Shrimpton's Creek, many anomalies and side stories were uncovered: the skeletons in Shrimpton's Creek, which suggested further elaboration and in-depth discussion. Problems began to surface after the creation of natural boundaries in the Old System subdivisions, and the Primary Applications which followed them. Some surveys adopted, as the natural boundary, either bank or centreline of Shrimpton's Creek. Other surveys adopted a right line boundary beside the creek, and some surveys retained the whole of the bed of the creek within one land parcel or created drainage easements. This paper delves into some of the interesting and fascinating cadastral questions raised from pawing through all of the land titles and Deposited Plans. It describes in detail some of the anomalies and strange happenings uncovered during the research into the determination of ownership of the bed along the course of Shrimpton's Creek.

KEYWORDS: *Middle thread, Primary Application, natural boundary, drainage easement.*

1 INTRODUCTION

The many issues related to riparian boundaries in regards to the integrity of the cadastre have been previously discussed, e.g. most recently in Songberg (2016, 2019), de Belin (2019) and Thompson (2019). This paper expands on these discussions, using each time a particular case as an example.

Shrimpton's Creek is approximately 5 km long and flows through the largest stormwater catchment area within the Local Government Area of the City of Ryde. Issues uncovered by de Belin (2019) have produced an abundant array of anomalies and strange happenings when it comes to such straightforward processes as the definition of land subject to a Primary Application, the creation of natural boundaries for land parcels and the creation of drainage easements for the benefit of City of Ryde. These anomalies and strange happenings are the skeletons in Shrimpton's Creek (Figure 1).

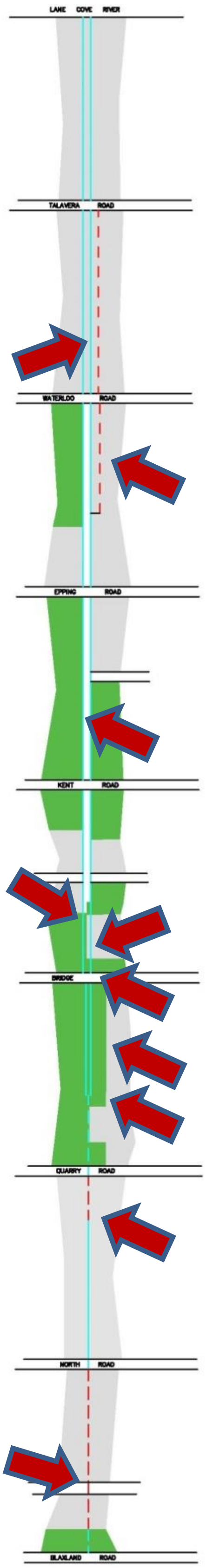


Figure 1: Schematic diagram of Shrimpton's Creek, showing ownership by City of Ryde (green) and the whereabouts of the skeletons.

2 IDENTIFYING THE SKELETONS IN SHRIMPTON'S CREEK

2.1 How did the Drainage Easement Change Width?

Deposited Plan DP 7465 (1913) showed both a "*Drainage Easement 5ft wide*" (1.52 m) and a "*Drainage Easement 8ft wide*" (2.44 m). Lot 36 in this DP contained the 1.52 m wide easement, which then widened to the 2.44 m wide easement after it crossed the rear boundary of Lot 36 (Figure 2).

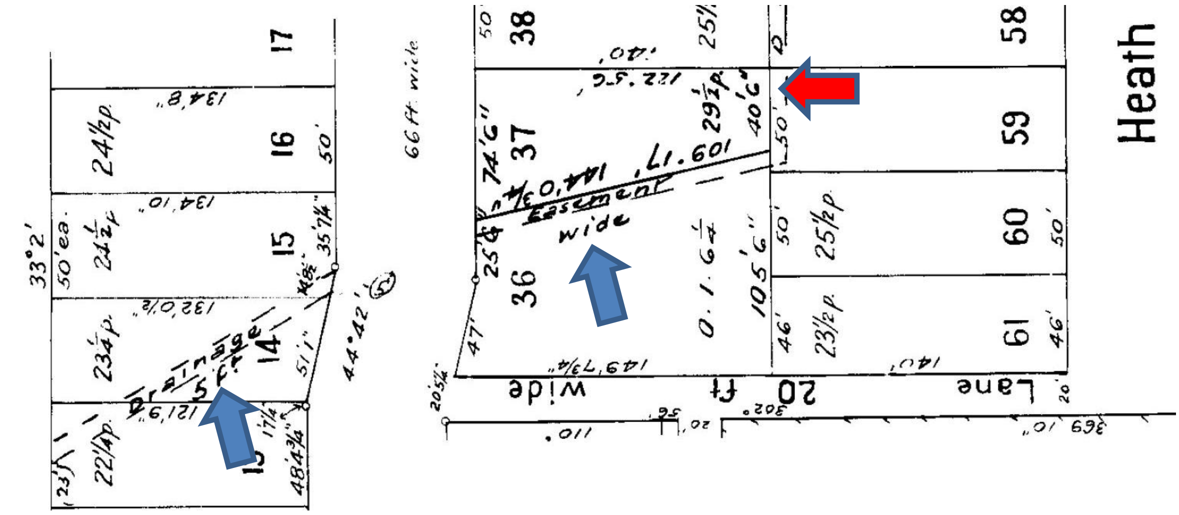


Figure 2: Detail of DP 7465 (1913), showing "Drainage Easement 5ft wide" (1.52 m) in Lot 36.

The First Memorandum of Transfer on Lot 36, which was dealing A 217981 (1915), reserved a "*Right of Drainage over the Drainage Easement 5ft wide as shown on plan*". A later Memorandum of Transfer on Lot 36 was dealing Q 629117 (1978), which created a new "*Easement for Drainage and a Right to Use for Drainage Purposes 1.52 m wide*", with terms and conditions for the benefit of City of Ryde. This easement was based on DP 451389 (1977), which showed "*Easement to Drain Water 1.52 m wide*" (Figure 3).

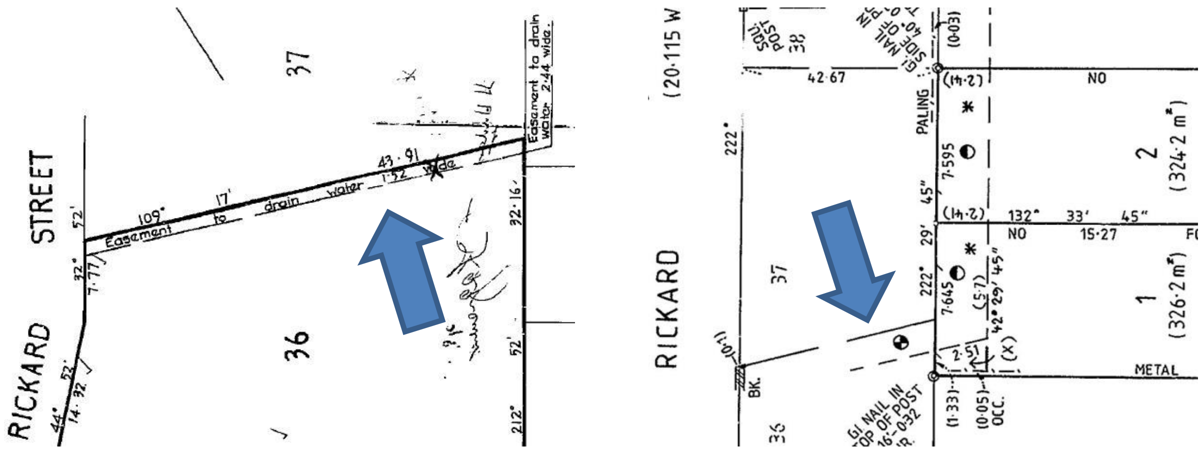


Figure 3: Detail from DP 451389 (1977) and detail from DP 843527 (1994), showing 1.52 m wide easement.

A subsequent subdivision of Lot 36, by DP 1016711 (1999) into Lot 102 and Lot 103, showed "*Easement for Drainage 2.44 wide*" (Figure 4), citing the original DP 7465 (1913) and the two transfers above.

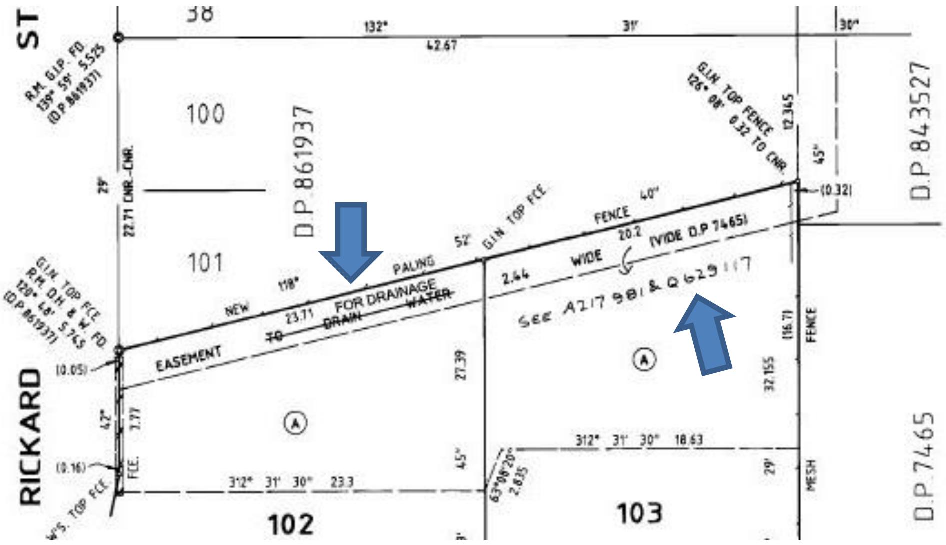


Figure 4: Detail of DP 1016711 (1999), showing "Easement for Drainage 2.44 wide".

How did this easement suddenly become 2.44 m wide? No new easement was created! Recent Strata Plan 91335 (2016) shows "*Right of Drainage*" and "*Easement for Drainage*", both 2.44 m wide (Figure 5), and the Certificate of Title also cites to the two original transfers mentioned previously.

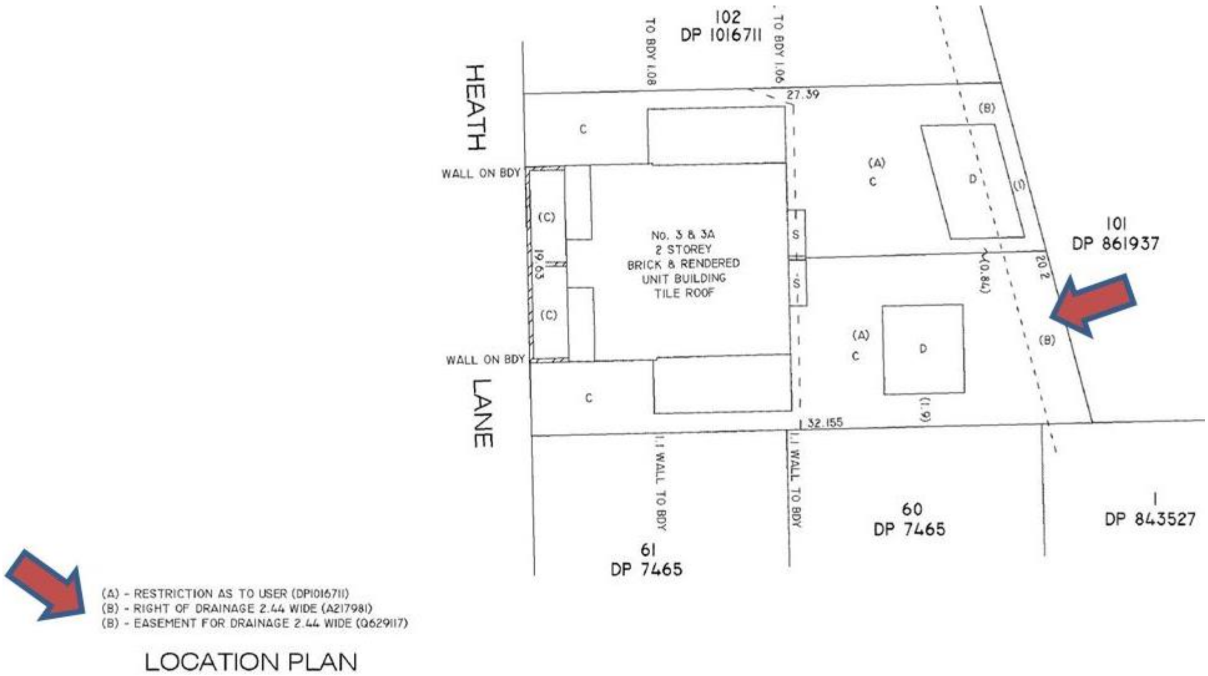


Figure 5: Detail from SP 91335, showing "Right of Drainage" and "Easement for Drainage", both 2.44 m wide.

2.2 Why not Variable Width in the First Place?

DP 389640 (1954) and DP 27088 (1956) created adjoining lots with a natural boundary between, being the centreline of a "*small watercourse*". Dimensions in these two DPs, surveyed by two different firms, indicate that the creek has no width. DP 393494 (1955) and DP 27088 (1956) show dimensions "*to creek*" but mean to the centreline of creek (Figure 6).

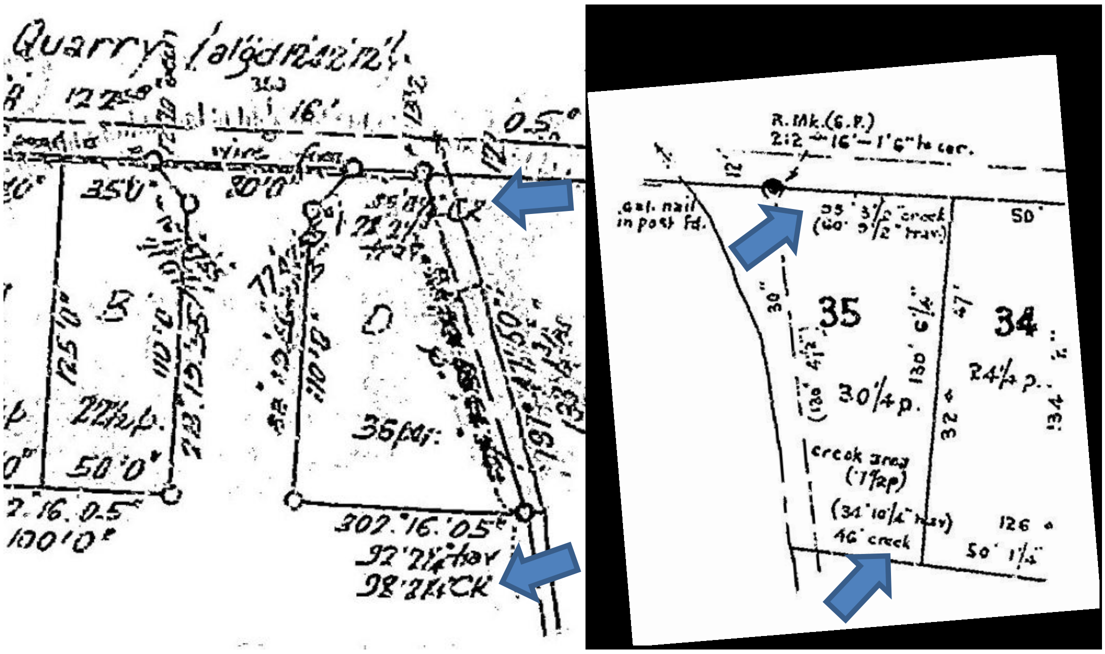


Figure 6: Detail of DP 393494 (1955) and DP 27088 (1956), showing boundaries, Lot D and Lot 35, “to creek”.

DP 701738 (1982), a 2-lot subdivision of Lot D and Lot 35, created a single right line boundary, generally following along a fence occupation, between the new Lots 1 and 2, which effectively eliminated the previous natural boundary (Figure 7).

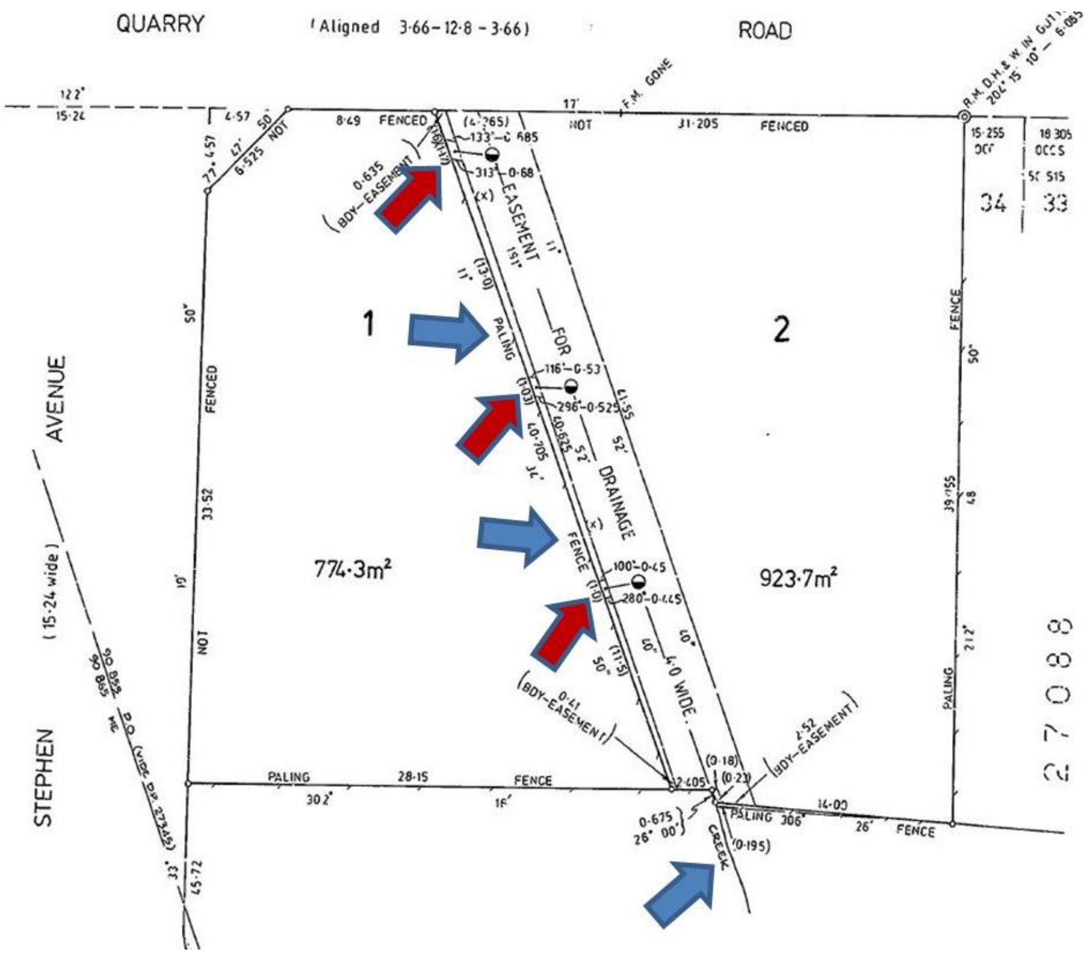


Figure 7: Detail of DP 701738 (1982), showing right line boundary between Lots 1 and 2.

This DP 701738 (1982) created an "*Easement for Drainage 4.0 wide*", for the benefit of City of Ryde, over a large concrete stormwater drainage culvert, which was constructed roughly along the centreline of the original small watercourse. The western edge of this Easement for Drainage fell short of the new lot boundary by between 0.41 m and 0.635 m.

DP 701738 (1982) also created three "*Easement for Drainage 1.0 wide*" for the benefit of Lot 1. It seems strange that the Easement for Drainage on Lot 2 was not created as variable width right up to the new boundary in the first place, which would have eliminated the need for the other three easements.

2.3 What about the 5 Feet?

A residential subdivision, DP 29029 (1958), created four lots, each having a rear natural boundary, being the bank of Shrimpton's Creek, with Lot 22 showing a side boundary dimension of 115 feet (Figure 8). An adjoining subdivision, DP 30420 (1959), created lots having a rear right line boundary with Lot 18, which abuts Lot 22, showing a side dimension of 120 feet (Figure 9). How is the 5-feet difference in side boundary length accounted for? One survey states "*bank of creek is boundary*", the other is 5 feet longer and shows a right line boundary and no creek. What happened to the creek bank in the intervening 12 months?

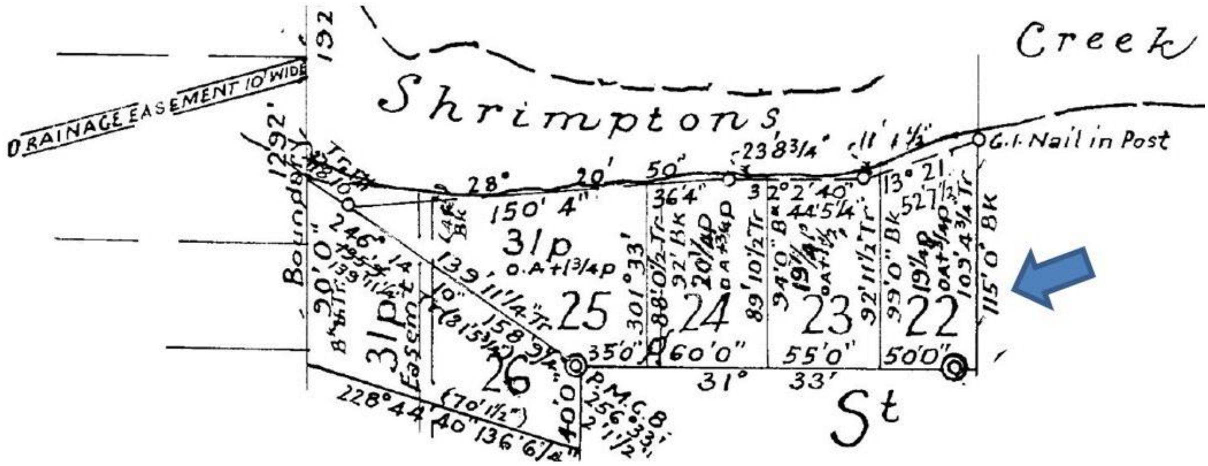


Figure 8: Detail of DP 29029 (1958), showing 115 feet and natural boundary at rear.

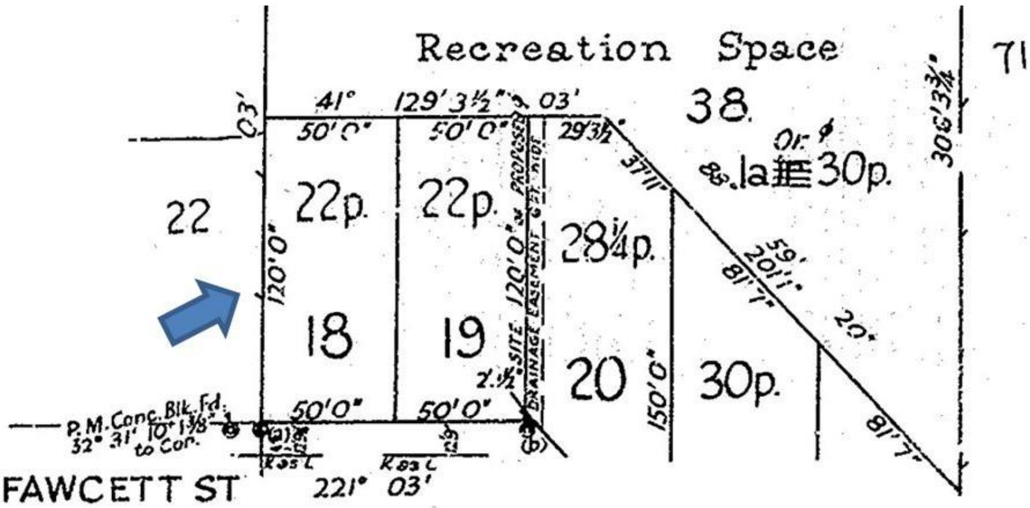


Figure 9: Detail of DP 30420 (1959), showing 120 feet and right line boundary at rear.

2.4 Why is City of Ryde not on Title?

This question is currently being pursued by City of Ryde as the Department of Housing is recorded as the registered proprietor of 6 acres (2.4 ha) within Santa Rosa Park, being Lot 71 in DP 36579 (1956) which contains the whole of the bed of the creek. Lot 71 was supposedly vested to Council in June 1962 (Figure 10), but title was never issued to City of Ryde. In the meantime, Council has invested huge funds in the ongoing development of this park. What process is required to make this happen? Firstly, a request is made to the Department of Housing (or its modern-day equivalent) to release the Certificate of Title held in its possession, together with a statutory declaration stating the fact of their vesting to Council in 1962. City of Ryde then writes a request to NSW Land Registry Services (LRS), asking for the Certificate of Title to be updated and show City of Ryde as the registered proprietor.

NOTIFICATION OF DEDICATION AND VESTING
PURSUANT TO SECTION 6(b) OF THE HOUSING
ACT, 1912, AS AMENDED

Land at North Ryde

IN pursuance of the provisions of Section 6(b) of the Housing Act, 1912, as amended, the Housing Commission of New South Wales by this notification dedicates as a reserve for public recreation all that piece or parcel of land situate in the Municipality of Ryde, Parish of Hunters Hill and County of Cumberland being Lot 71 as shown in Housing Commission Plan No. 1579 and by this notification vests such reserve in the Council of the Municipality of Ryde. (L.A. 57-318)

Dated at Sydney this twenty fifth day of June, 1962.

Figure 10: Detail from Notification on Certificate of Title Volume 8145 Folio 116.

2.5 Why was the Creek Bed Excluded from two IVAs?

Part IVA action, under the Real Property Act, was initiated (circa 1972) on titles in DP 39133 (1957) to convert Old System titled land to Torrens Title. Lots 1, 4, 4A and 5 to 10 (inclusive) in DP 39133 were 9 such lots, each with a natural boundary and title extending to the *centreline* of Shrimpton's Creek. Part IVA action was completed over time (Figure 11).

```
LAND
----
LOT 6 IN DEPOSITED PLAN 39133
   AT NORTH RYDE
   LOCAL GOVERNMENT AREA RYDE
   PARISH OF HUNTERS HILL   COUNTY OF CUMBERLAND
   TITLE DIAGRAM DP39133

FIRST SCHEDULE
--------------
TIMOTHY DAVID PICKARD
SHAELYN JACKSON
   AS JOINT TENANTS                                       (T AK833165)

SECOND SCHEDULE (2 NOTIFICATIONS)
---------------
1   RESERVATIONS AND CONDITIONS IN THE CROWN GRANT(S)
2   AK833166  MORTGAGE TO WESTPAC BANKING CORPORATION
```

Figure 11: Extract from the current Full Certificate of Title for Lot 6 in DP 39133.

The exceptions are two titles that have a notation "*excluding the bed*" and "*excepting the bed*" of the creek (Figure 12). Perhaps an oversight on the part of the team at LRS?

```
        NEW SOUTH WALES LAND REGISTRY SERVICES - TITLE SEARCH
        -----------------------------------------------------

FOLIO: 8/39133
------

            SEARCH DATE       TIME              EDITION NO    DATE
            -----------       ----              ----------    ----
            16/11/2018        10:22 AM              12        15/11/2018

NO CERTIFICATE OF TITLE HAS ISSUED FOR THE CURRENT EDITION OF THIS FOLIO.
CONTROL OF THE RIGHT TO DEAL IS HELD BY HSBC BANK AUSTRALIA LIMITED.

LAND
----
LOT 8 IN DEPOSITED PLAN 39133
   LOCAL GOVERNMENT AREA RYDE
   PARISH OF HUNTERS HILL    COUNTY OF CUMBERLAND
   TITLE DIAGRAM DP39133

FIRST SCHEDULE
--------------
RYAN BATTCHOO RATILAL
JESSIE MEI YEN LOW
    AS TENANTS IN COMMON IN EQUAL SHARES                       (T AK67107)

SECOND SCHEDULE (3 NOTIFICATIONS)
---------------
1   RESERVATIONS AND CONDITIONS IN THE CROWN GRANT(S)
2   LAND EXCLUDES THE BED OF THE CREEK SHOWN ON THE TITLE DIAGRAM
3   AN861088  MORTGAGE TO HSBC BANK AUSTRALIA LIMITED

NOTATIONS
---------

UNREGISTERED DEALINGS: NIL

         ***  END OF SEARCH  ***
```

```
        NEW SOUTH WALES LAND REGISTRY SERVICES - TITLE SEARCH
        -----------------------------------------------------

FOLIO: 1/39133
------

            SEARCH DATE       TIME              EDITION NO    DATE
            -----------       ----              ----------    ----
            25/9/2018         7:30 AM               4         27/6/2003

LAND
----
LOT 1 IN DEPOSITED PLAN 39133
   LOCAL GOVERNMENT AREA RYDE
   PARISH OF HUNTERS HILL    COUNTY OF CUMBERLAND
   TITLE DIAGRAM DP39133

FIRST SCHEDULE
--------------
THE COUNCIL OF THE CITY OF RYDE                                (T 9736484)

SECOND SCHEDULE (2 NOTIFICATIONS)
---------------
1   RESERVATIONS AND CONDITIONS IN THE CROWN GRANT(S)
2   EXCEPTING THE BED OF SHRIMPTONS CREEK

NOTATIONS
---------
NOTE: THE CERTIFICATE OF TITLE FOR THIS FOLIO OF THE REGISTER DOES
    NOT INCLUDE SECURITY FEATURES INCLUDED ON COMPUTERISED
    CERTIFICATES OF TITLE ISSUED FROM 4TH JANUARY, 2004. IT IS
    RECOMMENDED THAT STRINGENT PROCESSES ARE ADOPTED IN VERIFYING THE
    IDENTITY OF THE PERSON(S) CLAIMING A RIGHT TO DEAL WITH THE LAND
    COMPRISED IN THIS FOLIO.

UNREGISTERED DEALINGS: NIL

         ***  END OF SEARCH  ***
```

Figure 12: The current Certificates of Title for Lot 1 and Lot 8 in DP 39133.

It should be noted that these two Torrens Titles refer respectively to Lot 1 and Lot 8 of DP

39133 (1957), which, at the time of subdivision, was Old System land and title extended to the centreline of the creek. Obviously, for each of these lots, half the width of the bed remains in Old System Title and still forms part of the lot, as nominated in the current Certificates of Title. Does that strip of Old System Title belong to the current owners of Lot 1 and Lot 8? Should that strip be included on the Torrens Certificate of Title?

2.6 How can Real Property Applications Overlap?

This is a cautionary tale of creek bed shift, occurring as it did over the years between 1908, 1943, 1957, 1971 and 2018. The land in DP 65830 (1908) (Figure 13) was the subject of Real Property Application 15830 which created Certificate of Title Volume 2059 Folio 121 in 1910, with the description "*to the centre of Shrimpton's Creek thence by the centre of that creek*".

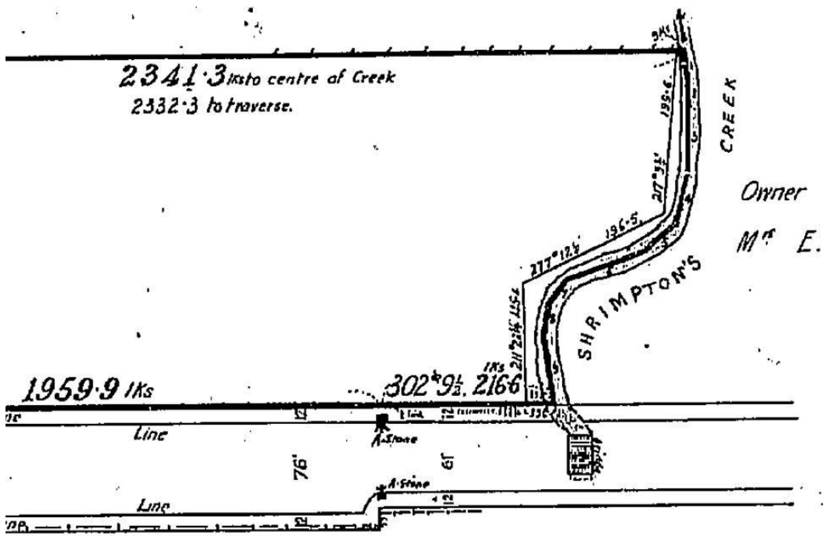


Figure 13: Detail of DP 65830 (1908), showing boundary is centreline of creek.

On the opposite side of the creek, DP 150926 (1926) (Figure 14) was the whole of land in conveyance Registered No. 990 Book 1147 (1919), which contained the description "*to Shrimpton (sic) Creek thence on the North West by the said Shrimpton Creek*".

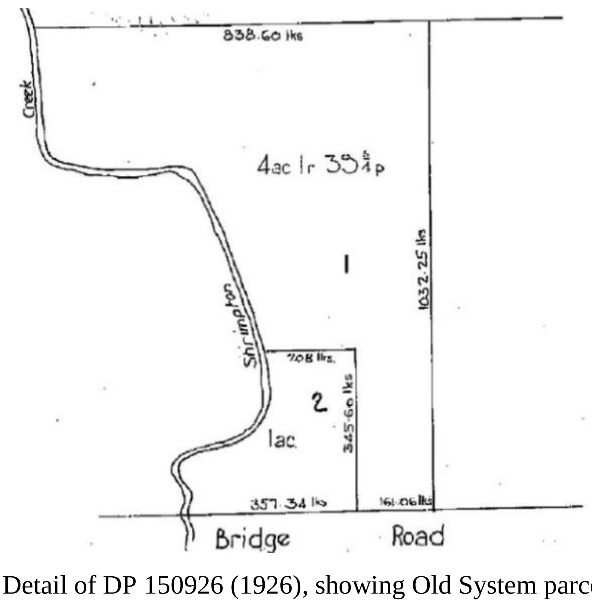


Figure 14: Detail of DP 150926 (1926), showing Old System parcels of land.

The 1943 aerial image (Figure 15) shows the flow path of Shrimpton's Creek.

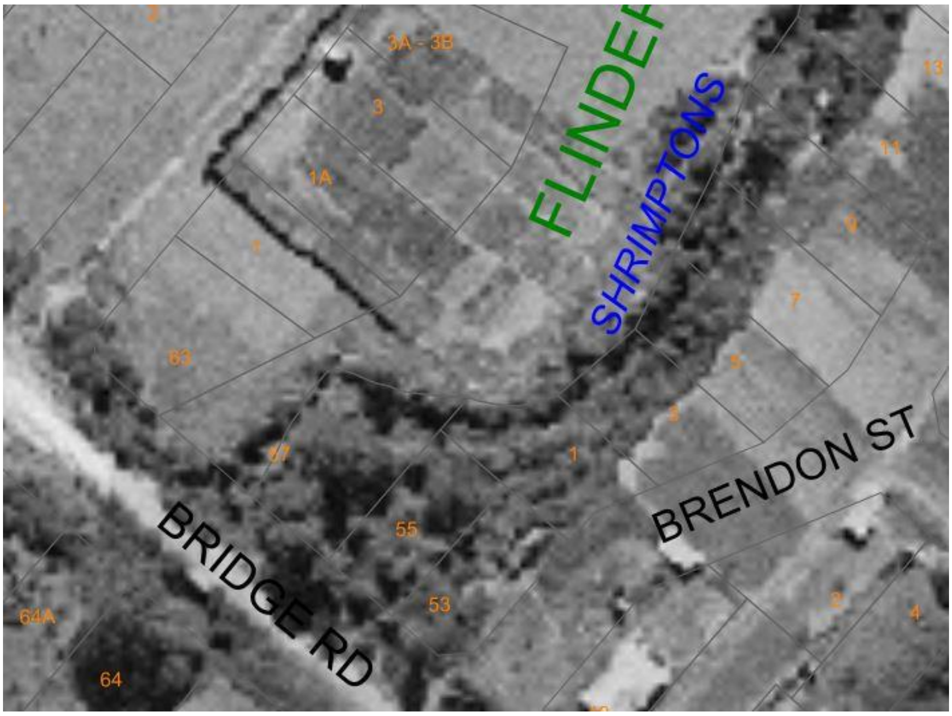


Figure 15: Detail from 1943 aerial image, showing the flow path of Shrimpton's Creek.

DP 39133 (1957) created lots with natural boundary clearly being centre of creek (Figure 16), while DP 552490 (1971) was another later plan that also defined the centreline (Figure 17).

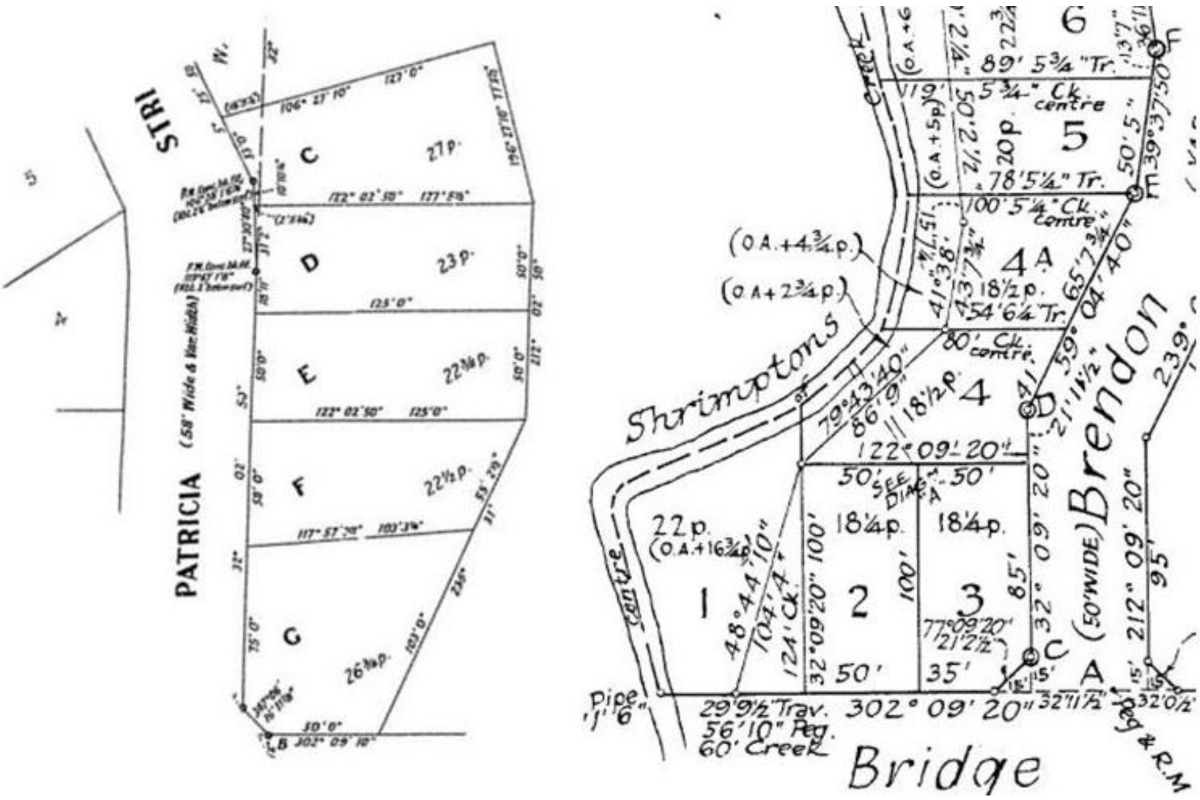


Figure 16: Detail from DP 39133 (1957), on the right, shows boundaries to centreline of creek, while detail from DP 36767 (1959), on the left, shows no reference to the creek.

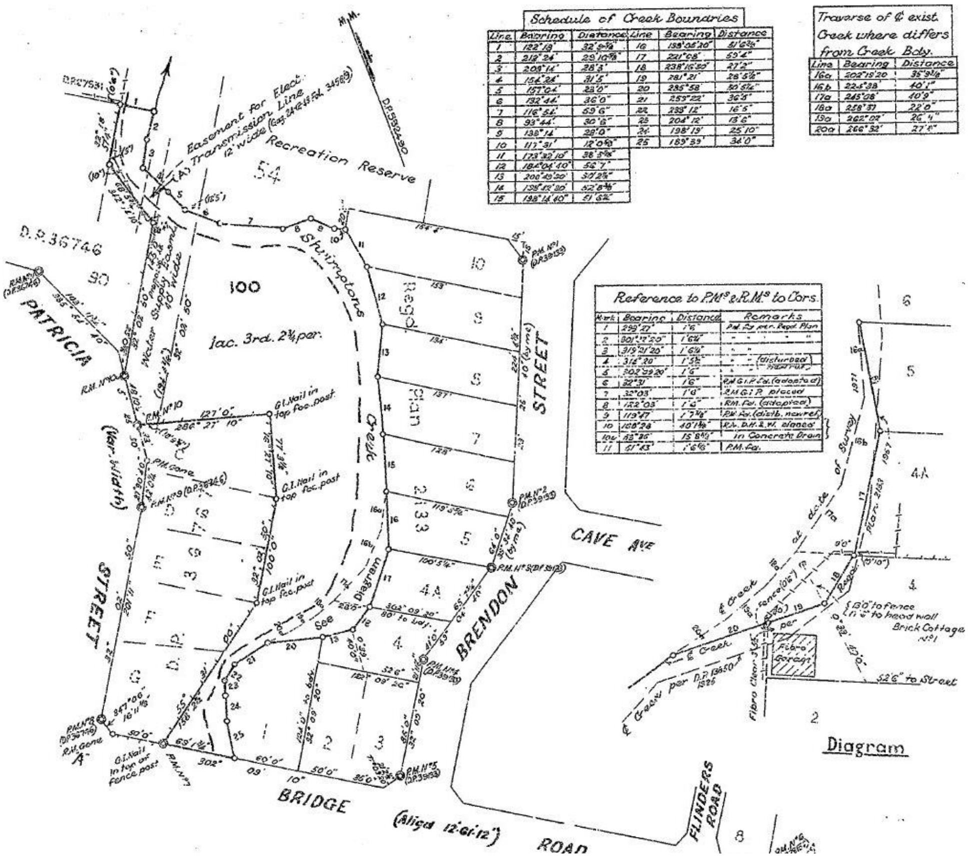


Figure 17: DP 552490 (1971), showing definition of centreline of creek.

DP 552490 (1971) is a plan of consolidation for the Department of Housing, comprising remnant land along the creek, left over from its residential subdivisions, and shows a history of the position of the creek centreline (Figure 18). The current position, as shown in Figure 18, appears to be shaping back towards earlier times.

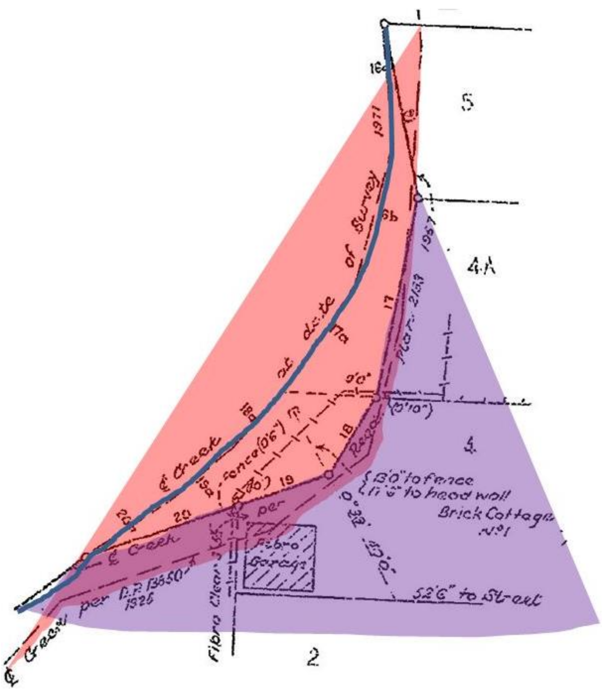


Figure 18: Diagram from DP 552490 (1971), showing centrelines and overlap.

A modern aerial image from 2010 (Figure 19) shows the relevant section of Shrimpton's Creek. For those wondering why the latest up-to-date image was not used to show the course of the modern creek, Figure 20 illustrates the result of 8 years of reforestation.

Figure 19: Detail of the creek from a 2010 aerial image.

Figure 20: Detail from an aerial image in 2018, showing the result of 8 years of reforestation.

2.7 How is Title Affected by Creek Deviation?

In the case of natural boundaries, if the bed (and therefore the bank) movement is incrementally imperceptible, the boundary moves with the bank. However, in this example, the movement is certainly greater and faster than gradual. DP 29229 (1956) is a subdivision that shows the left bank as title boundary (Figure 21). Notice the dramatic direction change in the creek at Lot 8. Notice also the 6-feet wide drainage easement along the southern boundary of Lot 8, which runs 100 feet to the creek bank.

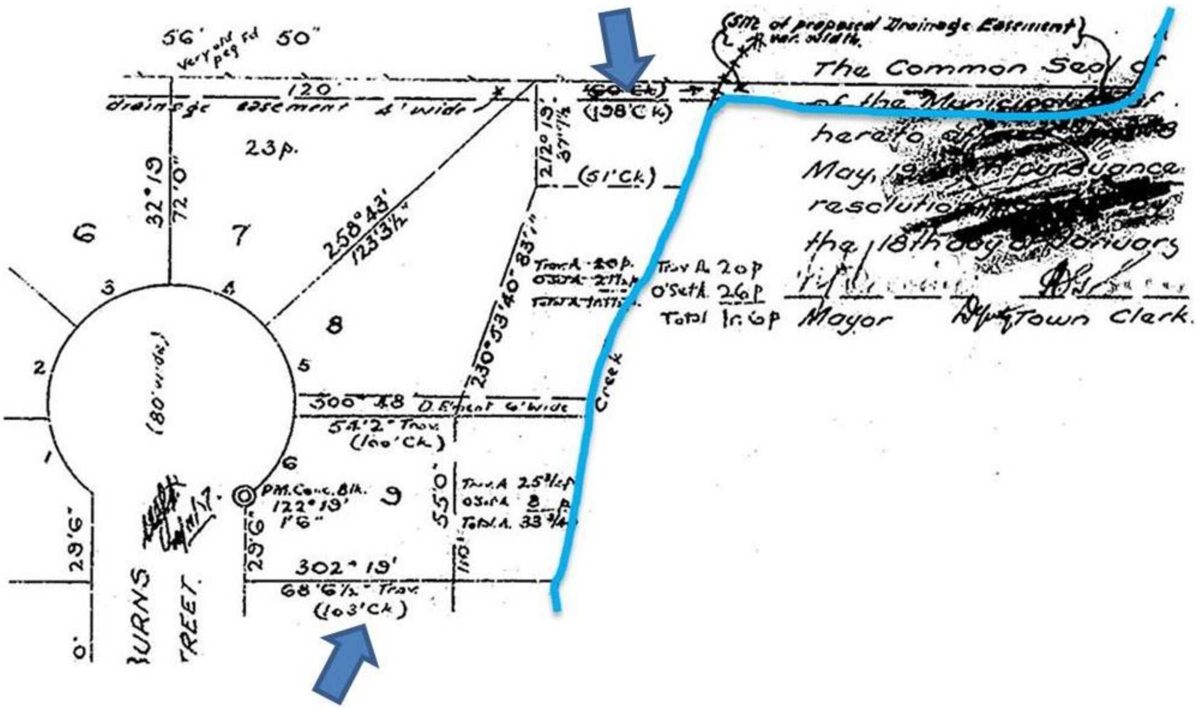


Figure 21: Detail from DP 29229 (1956), showing left bank as title boundary.

DP 26924 (1956) is a subdivision directly opposite, which shows the right bank as title boundary (Figure 22).

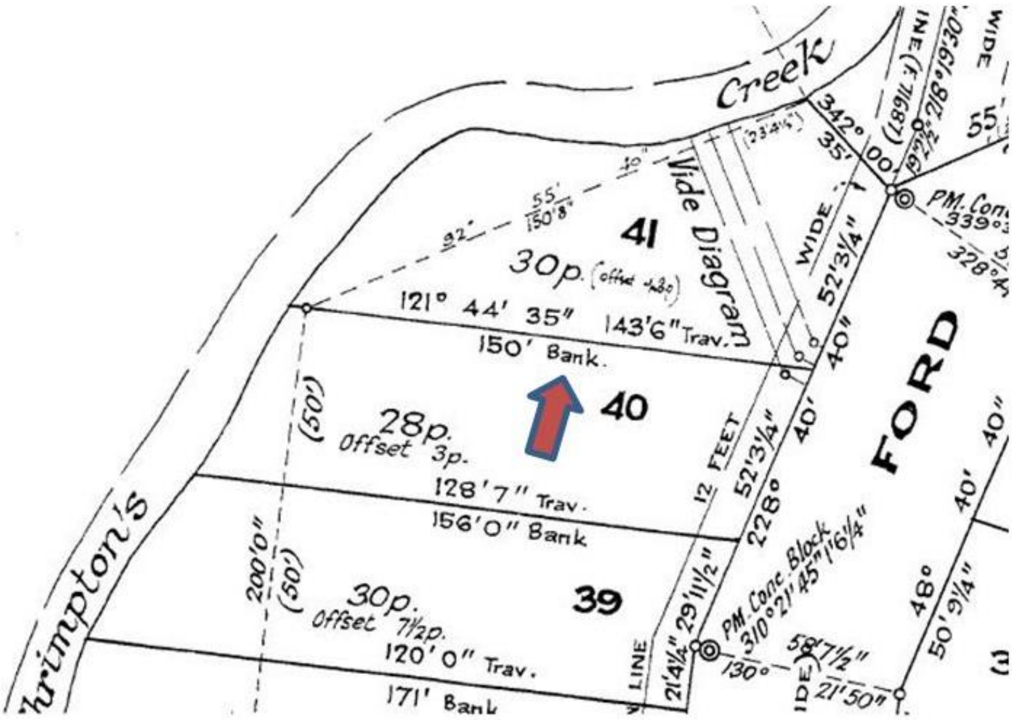


Figure 22: Detail from DP 26924 (1956), showing right bank as title boundary.

When DP 709174 (1984) created a subdivision involving Lot 8 and Lot 41 on either side of Shrimpton's Creek, the centreline of the creek was adopted as a natural boundary (Figure 23).

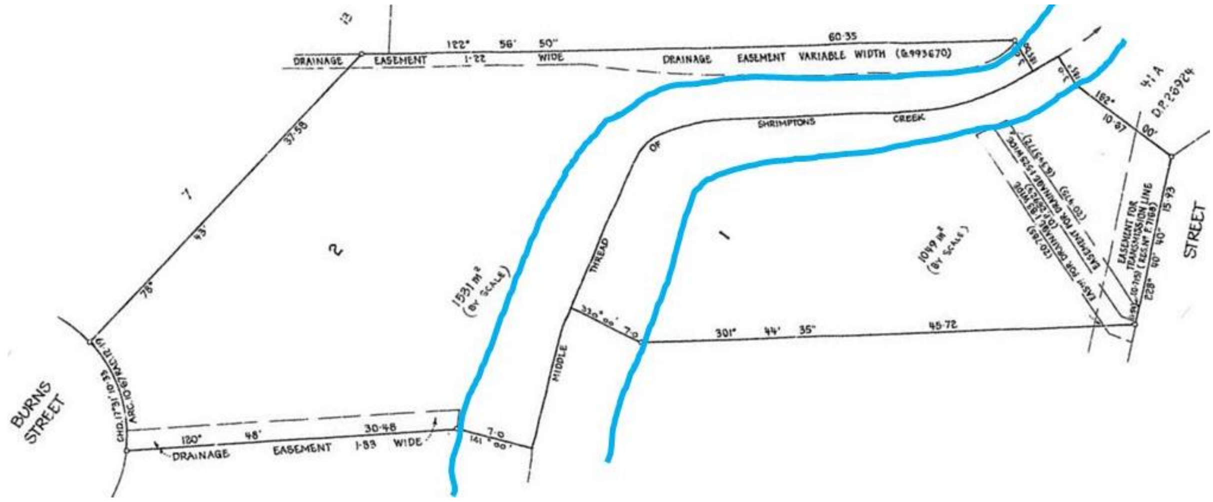


Figure 23: Detail from DP 709174 (1984), showing creek centreline as subdivision boundary.

A line was extended from the side boundary, at the end of the drainage easement in Lot 2 (formerly Lot 8 in DP 26924), running at right angles to the creek centreline. In similar fashion, lines extended from each of the other side boundaries in a direction at right angles to the creek centreline.

The two lots in DP 709174 (1984) were re-subdivided by DP 778388 (1985), which maintained the middle thread as boundary and created three new lots, two of which encompassed the bed of the creek (Figure 24): Lot 1 and Lot 3.

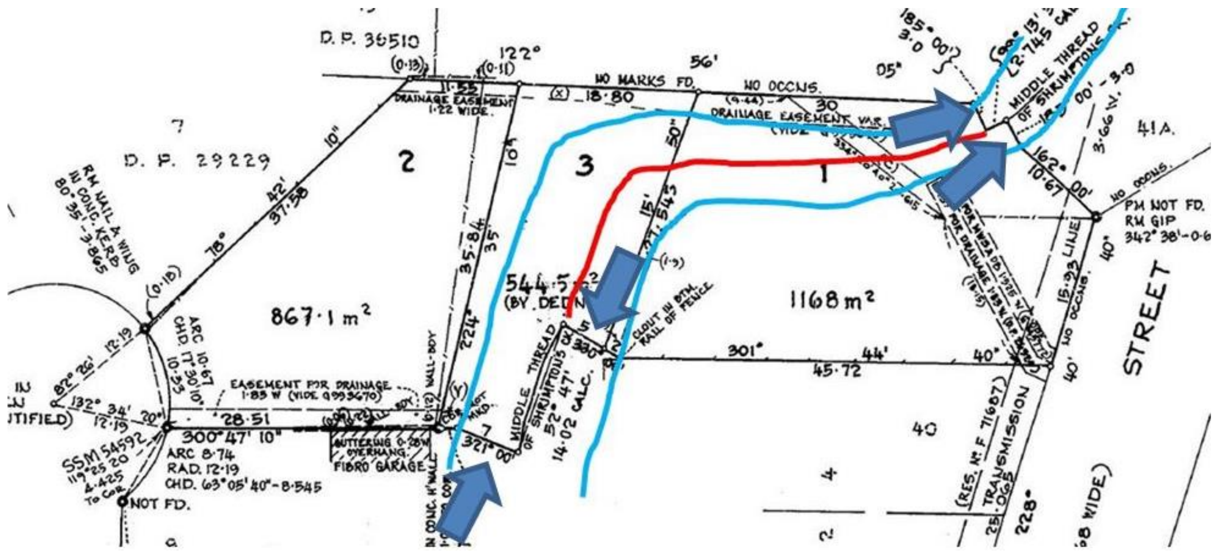


Figure 24: Detail from DP 778388 (1985) with overlay of creek centreline as it was in 1984.

The creek bed has since been shifted over 40 m and re-directed completely away from Lot 1 (Figure 25). City of Ryde owns Lot 3, which now contains the whole of the bed of Shrimpton’s Creek. Notice Lot 1 now shows no evidence, nor the whereabouts, of a previous creek bed (Figure 26). This is all very well, but what is the effect of a 40 m shift on riparian boundaries downstream? Luckily, there is only one lot affected, Lot 41A in DP 26924, which is owned by City of Ryde and forms part of Tindarra Reserve. Other residential subdivisions downstream have right line rear boundaries and do not have a natural boundary being Shrimpton’s Creek.

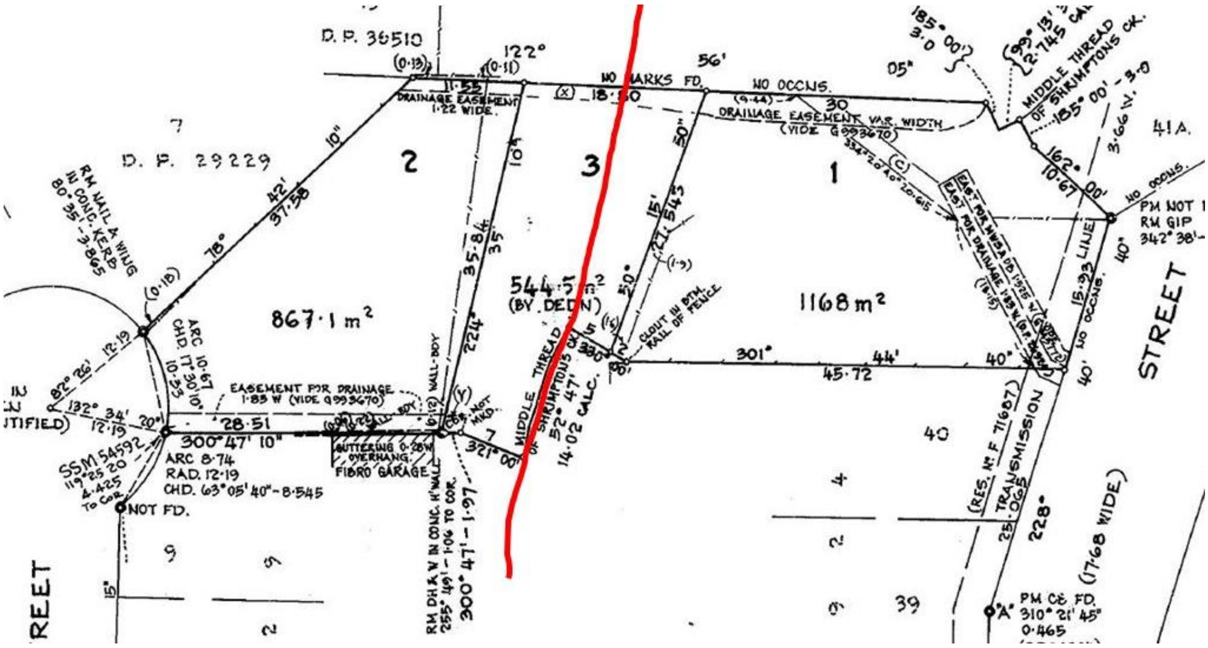


Figure 25: Detail from DP 778388 (1978) with overlay of creek centreline as it is today.

Figure 26: Detail from aerial image (2018) with overlay of creek centreline.

2.8 How did the Macquarie Shopping Centre Acquire the Bed?

The Crown Grants in 1887 for Portions 549, 550, 551 and 552 together with Portions 555, 556, 557 and 558 (Figure 27) each carried both a margin plan and a written metes and bounds description. The bed of Shrimpton's Creek, which separated these portions, was not included in the Crown Grants. The Crown Grants clearly indicate "*right bank*" and "*left bank*". However, the status eventually changed when one owner acquired the land on either side of Shrimpton's Creek.

Because the Crown Grants occurred prior to 1918, there was a presumption that title *ad medium filum aquae* may apply. Although no direct evidence can be found, it seems that ownership of the bed was acquired by this method (Figures 28-30).

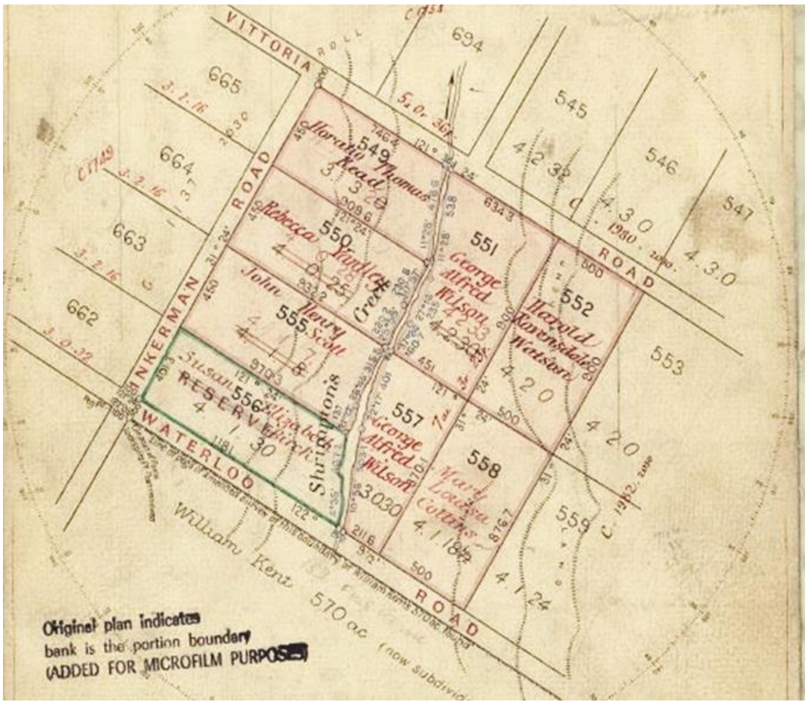


Figure 27: Crown Plan 1983.2030 (1887), showing original granted portions.

Portions 551 and 557 on the Eastern side of Shrimpton's Creek were subdivided by DP 559303 (1972) into two lots (Figure 28), with the natural boundary being the right bank of the creek. An "*Easement for Drainage 40 ft wide*" (12.19 m) was created, which was parallel to and abutted the right bank of the creek. DP 565709 (1973) consolidated some of the land on either side of Shrimpton's Creek (Figure 29): Lot 1 from DP 559303 (1972) with Portions 549, 550, 555 and 556. The original natural boundaries of Portion 549 and part of Portion 551 were abolished, and the bed became part of the land within the consolidation.

Figure 28: DP 559303 (1972) subdivided Portions 551 and 557 into two lots (Lot 1 highlighted).

Figure 29: DP 565709 (1973) consolidated land on either side of Shrimpton's Creek.

DP 571381 (1974) subdivided Lot 2 and created one new lot as a narrow strip of land along the right bank of Shrimpton's Creek (Figure 30), with one side being defined by the natural boundary of the creek and the other side being defined by right lines. This new lot partially covered the easement for drainage 12.19 m wide.

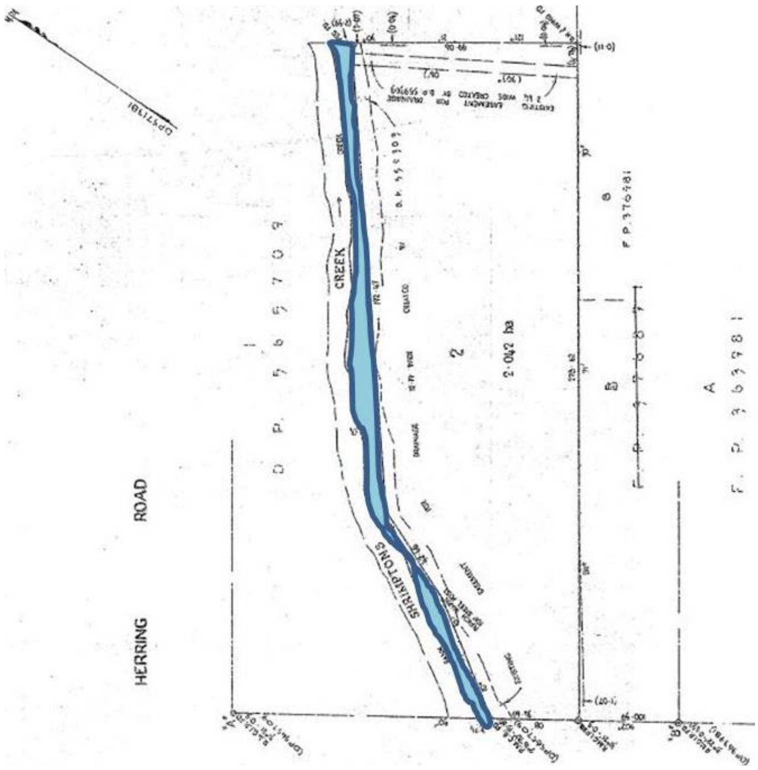


Figure 30: Lot 1 in DP 571381 (1974) is a narrow strip of land abutting the right bank of Shrimpton's Creek.

At this point, all of the land was consolidated into one parcel and all reference to a *bank as natural boundary* ceased (Figure 31). DP 614852 (1979) completed the last piece of the consolidation puzzle (Figure 32) and a fresh, right line "*Easement to Drain Water*" was created over the approximate site and route of the "*Easement for Drainage*", which had been created adjacent to the original creek bank.

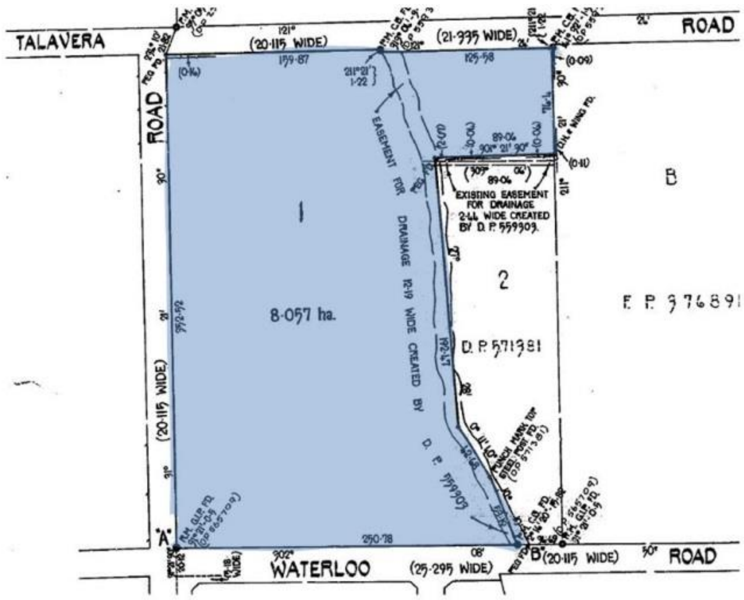


Figure 31: Detail from DP 576355 (1975).

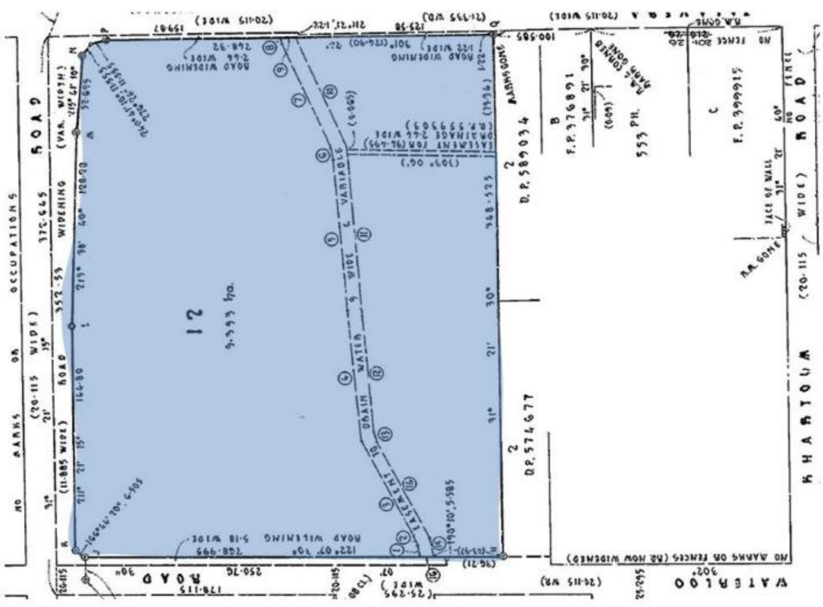


Figure 32: Detail from DP 614852 (1979).

The large Macquarie Centre shopping mall was constructed upon the whole of this parcel of land. As a consequence, Shrimpton's Creek disappeared completely as an open channel, now flowing underground within a "*Drainage Easement, 9 wide and variable*", in which City of Ryde has the benefit. The bed of Shrimpton's Creek, which had originally been excluded from the Crown Grants, is now fully contained in the consolidated parcel.

2.9 What Land is Included in a Real Property Application?

If the Old System subdivision boundary went to the middle thread of Shrimpton's Creek, then why did the Real Property Application (RPA) stop at the bank? Who knows? The authorising authority was the Registrar General. In one case, a Primary Application was made to the centre of the creek, but the applicant was ordered to limit that claim to the creek bank. In another case, the Real Property Application was made for the new Torrens Title to extend *only to the bank* of the creek. In this case, RPA 31194 (1929) and RPA 35657 (1944) converted two parcels of land up to the bank. The adjoining strip of land, comprising half the bed of Shrimpton's Creek, remained in Old System Title with the applicant of the RPA being the land owner. As part of a recent redevelopment of this site, a redefinition plan DP 1247443 (2018) was created, which claimed ownership of the two remnant parcels up to the centreline of the creek (Figure 33), with a new RPA raised for the Old System land of the bed.

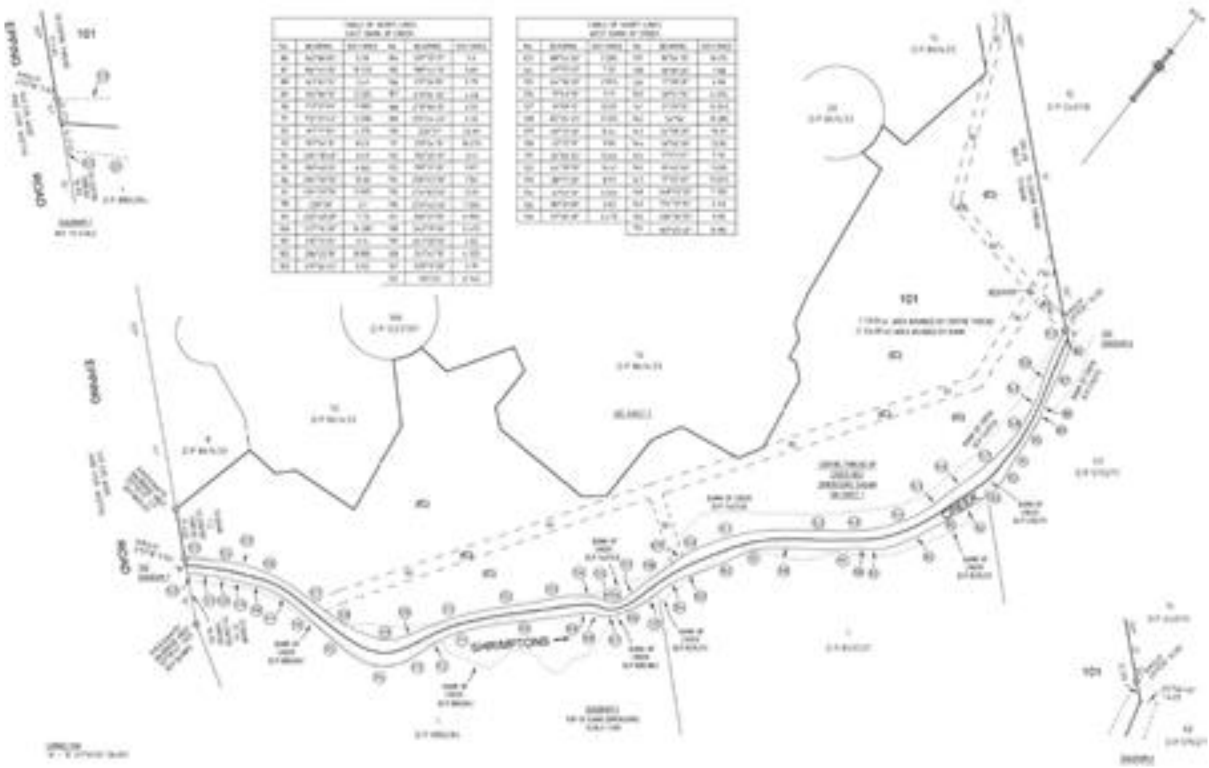


Figure 33: Redefinition plan DP 1247443 (2018).

2.10 Who Owns the Fallen Tree?

In the aftermath of a storm event in 2019 (Figure 34), a tree that was undermined by flooding water fell across the rear of a property, which abutted Shrimpton's Creek, and caused significant damage to two fences.

Figure 34: Shrimpton's Creek in full flow.

The property owner approached City of Ryde requesting that the Council rectify the damage. The first question to be resolved was who owns the land where the tree was once rooted. At this location, City of Ryde owns to the middle thread of the creek. The tree was *sited* on the opposite half of the creek to Council, which happens to be Lot 8 where the Part IVA conversion excluded the bed (see section 2.5). The tree was originally rooted in the Old System part of Lot 8 and not in the Torrens Titled part of Lot 8. In either case, City of Ryde was not the owner of the bed. Council offered a small payment to assist the land owners with restoration of the damaged fences.

3 CONCLUDING REMARKS

There is always a story behind a story. Many times, that secondary story is more captivating, but gets lost beneath the main story. The questions researched and answered in this paper were all raised from the detailed investigation into the ownership of the bed of Shrimpton's Creek. Further stories are bound to appear in the future, when the information on ownership is put into use as new works and developments occur along the length of Shrimpton's Creek.

REFERENCES

de Belin F. (2019) Status of a stream: Who owns the creek? *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 231-250.

Songberg G. (2016) Riparian cadastral boundaries: A step toward reform, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 74-86.

Songberg G. (2019) Cadastral integrity loss from riparian boundaries, *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 182-208.

Thompson K. (2019) Are our coastal waterways tidal? *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 209-230.

Riparian Boundary Definition: Legislation vs. Practice

Geoff Songberg
Crown Lands (Retired)
geoffsongberg@gmail.com

ABSTRACT

Riparian boundary determinations are theoretically governed by common or case law and the legislation which contains the definitions for those boundaries. Surveyors are required to comply with the law or legislation and conduct their survey accordingly. If the surveyor does not comply, then the survey is, theoretically, not accepted by the titling authority. However, do surveyors and the authorities have clarity of vision to know whether or not the legislation has been complied with? Or, as many practitioners across a wide range of disciplines have discovered, is that vision clouded because legislation and theory do not equate to practice but instead are two different things? Is this the case for riparian boundary determinations? Are the theory, legislation and definitions different from the practice, i.e. what surveyors actually define? This paper compares the law combined with the legislation to the practice of surveyors and related practitioners to see if the two are the same or not.

KEYWORDS: *Riparian boundary, definitions, legislation, survey practice*.

1 INTRODUCTION

Surveyors have been contemplating the where and how of complying with the definition of riparian boundaries for more than 160 years. Now in 2020, it would be expected that the insight gained over the years would result in clarity of vision over the legislative and legal requirements for the definition of riparian boundaries. One would hope such clarity would provide the surveyor with a bright foresight into future practices. But what would be the case if in hindsight the vision of riparian boundary definition was cloudy, and the practice being conducted was not in accordance with the law or legislation? What then would the future hold? Will the practices of surveyors in defining riparian boundaries continue as is, or not? Will the law or legislation be the same? Will legislation merge with practice or will they remain separate?

It is not easy to split the difference between riparian boundary law and legislation. Often the two coexist and sometimes overlap in duplicate. Common law or law of precedence from court cases is in part the law of the land. So too is legislation the law of the land. To make things easier, law and legislation can and will be interchangeable in this paper, but only as far as ease of dialogue.

Riparian boundaries are split into two main categories, tidal and non-tidal, though it is not always easy to distinguish between the two as some surveyors have experienced. Riparian zones of the sometimes tidal regime often have their category confused. Neither the legislation nor the definitions themselves help if there are any grey areas, and it is left to the surveyor to further ponder the circumstances of what is on the ground, or rather the division between the ground and the riparian entity. One might have simply said the division between the ground and the water but that too is not always the case. This paper compares the law combined with the legislation to the practice of surveyors and related practitioners to determine if the two are the same or not.

2 RIPARIAN BOUNDARY LEGISLATION

Legislation governing the delineation of riparian boundaries is not spelt out in simple terms. It can be quite convoluted with some things left to interpolation. Practitioners dealing with riparian boundaries are conversant with the theory that the boundary of land fronting tidal water is the mean high water mark (MHWM) and for non-tidal waters the boundary is the bank. Or that is the case for the most part, but it is not necessarily always the case. Some tidal boundaries can be the low water mark and some non-tidal boundaries can be the centreline of the stream.

Today, in 2020, the legislative definition of the MHWM can be found in the Surveying and Spatial Information Regulation 2017, part 1, section 5, definitions (NSW Legislation, 2017). There is no legislation or definition for the low water mark. The legislation does not specifically say that the boundary of tidal waters shall be the mean high water mark. It is left to the law of precedence, common law, that the bed of tidal waters, within limits of the Kingdom, is vested in the Crown and that that boundary is now referred to as the mean high water mark. In some earlier surveys, the boundary of land fronting tidal waters was not always described as the mean high water but simply high water or similar derivatives or sometimes not labelled. The Regulation clarifies the situation in clause 51, stating that in previous survey plans or other description of land, any reference to a boundary abutting or fronting tidal waters or just high water should be read as mean high water mark. The legislation is silent if there is no previous definition. So, if the surveyor is tasked to create a parcel of land fronting tidal water that has never before been delineated or described as fronting tidal water, then it is left to interpolation of the legislation to determine that the boundary should be the mean high water mark.

The Surveying and Spatial Information Regulation 2017 does not specify that the non-tidal boundary of the land should be the bank as in some cases it may not be. The boundary could be the centreline of the stream or even something else. The Regulation in clause 51 does however state that in previous survey plans or other description of land, any reference to a boundary that is the bank of a lake or stream or described as a boundary that abuts a lake or stream is to be taken to be the limit of the bed of the lake or stream. The Regulation does give a definition of the bed in part 2, division 5, boundaries formed by tidal and non-tidal waters and other natural boundaries, section 44, definitions. For a first-time definition of land against a non-tidal stream, the legislation does not specify what or where the boundary is to be located. That is left to the deliberation of the surveyor.

The riparian boundary of non-tidal streams is further complicated by the Crown Lands Act in its varied versions, now the Crown Lands Management Act 2016. The Act in section 13.3 gives a definition of the bank that is then related to the limit of the bed. This is not reproduced in the Surveying and Spatial Information Regulation 2017. The Crown Lands Act however only relates to land alienated, sold, by the Crown. It does not relate to land internally subdivided against non-tidal streams from out of a much larger holding. The non-tidal boundary then could be anything that is intended by the subdivider. A further complication is the reservation of the beds of non-tidal streams from land alienated by the Crown after 11

May 1923 in the eastern and central divisions of NSW or after 31 May 1935 in the western division of NSW.

To add further complexity for non-tidal streams, there is the *ad medium filum aquae* rule emanating from common law. The ownership of the land, despite indicating that the boundary is the bank, could be to the centre thread of the stream, especially if the land was part of a grant or sale from the Crown before the dates of reservation of the beds of stream.

If this is not enough complexity, the riparian boundary could be set at an offset from either the mean high water or the bank, having a reserve or road in between. The position of the land boundary is then dictated by the position of either the mean high water mark or the bank at the time of creation. More often this boundary is termed the landward boundary of either the reserve or road, but overall it is still governed by the definitions of riparian boundaries.

3 MEAN HIGH WATER MARK

According to the Surveying and Spatial Information Regulation 2017, "Mean High-Water Mark means the line of mean high tide between the ordinary high-water spring and ordinary high-water neap tides."

This legislative definition was brought to the surveying industry in 1854 (166 years ago) with the English court case, *Attorney General v. Chambers.* This first definition did not include the reference to ordinary. It was not until 1907 in another court case, *Tracey Elliot v. Morley (Earl),* where the ordinary part was added (Blume, 1995). Perhaps someone did not like the idea that some tides are higher than others and did not want the mean high water mark being located too far up the shoreline. The then theory did not equate to what was deemed should have been practiced, so changes were sought. It did not do much for the theory and practice merging, but only created further debate and possibly an even wider separation. What the court case did do was limit the ownership of the Crown within tidal waters to the line of mean high water against the foreshore. That may appear to make things simpler, but not in all cases.

If the surveyor is to delineate land against tidal water, then the entity that is to be defined is determined by the wording of the definition. That entity is the line of mean high tide between two other tidal events. If the meaning is taken literally, and there is nothing to suggest otherwise, then that line is a surface of water which is the mean of high tides between the neap and the spring tide events (Figure 1). Surveyors attempt to actually obtain a value of the mean high water surface, but that is only a means to an end as it is not the entity that they are defining on the ground. That entity is the line that the mean high water surface makes against the foreshore (Songberg, 2016).

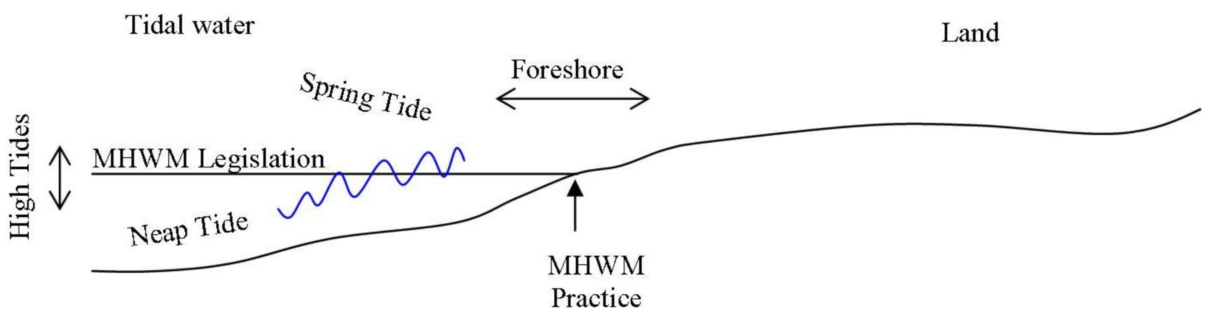


Figure 1: MHWM legislation vs. MHWM practice.

The legislation does not give a definition to the line along the foreshore, but every surveyor knows that that is what is intended so they extrapolate the legislated definition and in practice survey the foreshore line. At the same time, they call the surveyed shoreline the mean high water mark (see Figure 1). Here then is the first point at which the legislation and the practice differ.

3.1 Period of Observation

The legislated definition for the MHWM, or really the MHW surface, gives two measures for the time interval of observation, the neap and spring tides. Those events occur around the time of the full and new moons (spring tides) and the 1st and 3rd quarters of the moon (neap tides). The period between the new or full moons and either quarter is approximately 7 days. The length of time required for observations as required by the legislation is thus 7 days (Songberg, 2015, 2016). The 7-day cycle is reinforced by the explanations of the judges in the *Attorney General v. Chambers* court case: "In our opinion, the average of these median tides in each quarter of a lunar revolution during the year gives the limit" (Blume, 1995). Further strength to the 7-day period comes from the reference "for three days it is exceeded and for three days it is left short and for one day it is reached" (Blume, 1995). Do surveyors use this method of determining a value of mean high water? Such a practice is very unlikely and probably has never been undertaken. Here then is the next variance between legislation and practice.

The legislation governing riparian boundaries does not give direction as to how a surveyor should perform a mean high water mark determination. It is either left to the surveyor to ponder or seek guidance from another source. One source is Surveyor General's Direction No. 6 (Water as a Boundary). This document does not actually tell the surveyor how to perform a MHWM definition but instead tells the surveyor, rightly or wrongly, what is wanted. For methods to determine a MHWM, the surveyor is referred to part 6 section 22 of the Manual of the New South Wales Integrated Survey Grid (Department of Lands, 1976). So, do these methods coincide with the wording of the legislation?

According to the ISG manual, the time period required for a MHWM observation is 12 months for an accurate result, but it also states that an observation of a full lunation period of 29 days is also acceptable. This then is at odds with the time period ascertained from the legislation. Why the difference? This probably stems from the definition of MHWM used in the manual. The manual's definition is "the mean of all high tides (including both spring and neap tides) taken over a long period". This is not the legislation definition. If surveyors follow this definition, then they are not complying with the legislation. This is then another case of legislation and practice not being the same.

Combining 4 sets of legislation observation requirements results in the shorter version of the ISG manual period of observation. Adding more legislation observation periods, the practitioner will arrive at a 12-month period. Doing this thus translates the definition of MHWM from the legislation to the ISG manual. The definitions are not the same and the results will not be the same. The results under the ISG manual definition will not be of greater accuracy as claimed but simply different (Songberg, 2015, 2016).

The ISG manual also specifically includes both the spring and neap tides in the observation. The legislation definition does not. The legislation is worded such that only high tides between the neap and spring tides should be used. Thus, the neap and spring tides should be excluded (Songberg, 2015). Once again, the legislation is at odds with the practice.

3.2 Levelling from a Benchmark

The ISG manual outlines that the position of MHWM can be fixed by levelling from an Australian Height Datum (AHD) benchmark, provided that the tidal gradient is known and that there is a nearby tide gauge related to AHD. At the time of the manual's publication, only a few long-term tide gauges were related to AHD. Today, tidal gradients along the coast and inland along connecting tidal streams have been determined by Manly Hydraulics Laboratory (MHL) through a network of tide gauges. One of their publications is MHL2053 (OEH Tidal Planes Analysis: 1990-2010 Harmonic Analysis (Couriel et al., 2012). Many surveyors undertaking a MHWM definition have referred to this document to obtain the value of MHW, and despite now being 10 years out of date and no longer applicable (Songberg, 2015, 2016), it is still being used. The values for MHW, and other tidal plane entities, are related to the AHD network throughout the country, so it is relatively easy to mark the appropriate AHD level of MHW along the shoreline. This practice usually gives a more consistent, but not necessarily more accurate, value of MHW than values that could be obtained from local short-term observations (Songberg, 2005, 2015, 2016).

Despite the widely accepted use of AHD values of MHW determined by MHL through either the tidal plane analysis or other means, the use thereof does not equate with the legislative requirements for a MHWM determination. The values of MHW in the tidal plane analysis have not been determined from the mean of high tides between the neap and spring. Instead, a complex modelling program (Foreman tidal height analysis and prediction) is used (Couriel et al., 2012), which incorporates much more tidal data than just the high tides as required by the legislation. Therefore, technically, legislation and practice are once again two different things.

3.3 Range Ratio

The range ratio method of determining a value for MHW at some point within an estuary is, in simplicity, just a means of transferring the value of MHW from a known point such as a tide gauge to the unknown point. This method does not require any need to know the AHD value of MHW. The method utilises a single day's observation of consecutive high and low tides, comparing them to the tide gauge's recording of the same tides and the relationship of those values to the MHW.

Because the method is just a transfer mechanism, it in itself does not need to satisfy the requirements of the legislation. It is the method by which the reference gauge determines the value of MHW that determines whether or not the MHWM definition is compliant with the legislation. If the gauge utilised only the heights of the high tides between the spring and neap tides, then the method would be compliant with the legislation. The value of MHWM at the gauge would need to be obtained for the same time period as the survey. If not, then because of the changing values of MHWM from one period to the next the value of MHWM used would not be compliant for that survey (Songberg, 2015, 2016). Today however, surveyors rely on the values from permanent tide gauges spread throughout the tidal estuaries. The value of MHW determined from those gauges does not comply with the strict wording of the legislation. Thus, seeing that the surveyor only carried out a 1-day observation of a high and low tide and that the tide gauge utilised more than the 7 days observation of high tides, this method does not agree with the requirements of the legislation. Again, legislation and practice are two different things.

3.4 Other Methods

Where survey sites are a considerable distance from both tide gauges and AHD levelled control marks, surveyors have used other methods to determine the location of the MHWM. One method that has been used is to cast an eye over the foreshore and through either experience, or just guesswork, visually determine the MHWM. This method may be accurate where the foreshore is very steep, if not near vertical, but it does not comply with the Regulation. Where the foreshore is quite flat, the method may be extremely erroneous. In either case, there has been no observation of the high tides, thus practice and legislation differ, in this case considerably.

Other methods, such as biological assessments, may have also been used, e.g. the top of the oysters surrounding a wharf pile, the limit of the mangrove cobbler pegs or their tops. These or other indicators may provide a natural indication of MHW, but that does not change the fact that it is something different to the requirements of the legislation. If utilised, then legislation and practice again are divergent.

3.5 The Sometimes Tidal

It is the practice in NSW that water is considered tidal along rivers, streams or inlets to the tidal limit. Many of those tidal limits have been recorded rightly or wrongly on parish maps. These notations are not the only record of tidal limits. The Department of Lands (date unknown) compiled tidal limits into a single document (Tidal Limits of Watercourses in New South Wales) from a combination of map and file information. Manly Hydraulics Laboratory also produced their own document, MHL1286 (Survey of Tidal Limits and Mangrove Limits in NSW Estuaries 1996 to 2005).

Some of the tidal limit records were from observations that the estuary was tidal at that time and so surveys were conducted accordingly. However, further observations indicated that the estuary was not always open to the sea and so should have been classed as an Intermittently Closed and Open Lake or Lagoon (ICOLL). Where the surveyor has made the error of judgement conducting a MHWM survey, there is the issue of continued validity (Thompson, 2019). Where the next surveyor continues with the MHWM presumption, it starts to create a separation between the legislation and practice as the survey should have been conducted as a bank survey.

The tidal limits, assuming that the inlet is not an ICOLL, have been based on observations of the highest tides. In other words, the tidal limit is the furthest reach of the tide along an estuary. The legislative boundary of tidal waters is the MHWM. The tidal limit is created by tides higher than the mean high water. The two measures are not the same vertically and consequently will have differing reaches up the estuary (Songberg, 2016). There is part of every estuary that is considered as tidal, but in reality should not be, as all parts of the estuary above the mean high water line, in a cadastral sense, are not tidal. In this instance, the practice definitely does not meet with the legislative requirements for a tidal boundary.

4 THE BANK

Another long-term contemplation of surveyors and riparian boundary practitioners is the bank. A definition of the bank first appears in NSW legislation in 1931 with the Crown Lands (Amendment) Act 1931, which amended the Crown Lands Consolidation Act 1913 by adding section 235A. One of the references to the wording given in the Act was from an 1897 English court case *Thames Conservators v. Smeed 2 G.B.* At 123 years, the contemplations of the non-tidal boundary have been going on nearly as long as those for the tidal boundary. Prior to the 1931 amendment, prior contemplations within the Crown Lands acts only mentioned an abuttal as the boundary of land where the land has frontage to a stream, tidal or non-tidal, sea coast or road. The new section made it clear that the boundary along non-tidal streams was to be the bank. And by then, at least for the eastern and central divisions of the State, presumptive middle thread tidal did not apply thanks to reservation 56146. The western division would follow suit four years later.

However, the definition of the bank is not straight forward. The definition also covers both non-tidal streams and lakes. The Crown Lands Management Act 2016 states:

> Bank means the limit of the bed of a lake or river.
> Bed means the whole of the soil of a lake or river including that portion
> (a) which is alternately covered and left bare with an increase or diminution in the supply of water, and
> (b) which is adequate to contain the lake or river at its average or mean stage without reference to extraordinary freshets in time of flood or to extreme drought.
> Lake includes a permanent or temporary lagoon or similar collection of water not contained in an artificial work.
> River includes any stream of water, whether perennial or intermittent, flowing in a natural channel, and any affluent, confluent, branch or other stream into or from which the river flows.

The Surveying and Spatial Information Regulation 2017 in clause 44 does not entirely duplicate this definition but tries a slightly different wording. It also excludes a definition for the bank.

> Bed in relation to a lake or stream, includes any portion of the lake or stream
> (a) that is alternatively covered and left bare with an increase or diminution in the supply of water, and
> (b) that is adequate to contain the lake or stream at its average or mean stage without reference to extraordinary freshets in time of flood or to extreme drought.
> Lake includes a permanent or temporary lagoon or similar collection of water not contained in an artificial work but does not include tidal waters.
> Stream includes any non-tidal waters that are not a lake.

Further on in the Regulation, in clause 51 it is stipulated that a reference to the bank in any previous plan is to be taken as a reference to the limit of the bed of the lake or stream. What the intent was for this particular wording is unknown, but what it effectively does is remove the bank as a boundary feature for non-tidal waters. Instead, if the wording is to be taken literally, then the boundary identifier is the limit of the bed.

There is also the nature of the stream that differs between the legislations. In the Crown Lands Act the stream must be natural. That is not the case in the Surveying and Spatial Information Regulation as it includes any non-tidal waters not a lake. Under this wording, a constructed channel would be classed as a stream.

4.1 Surveying the Bank

Because of the differences in the two legislations, if a survey is being conducted on a non-tidal waterway and if the surveyor identifies the boundary feature as the bank, then there will be a disparity with the Surveying and Spatial Information Regulation. However, if the survey is on behalf of the Crown, the surveyor will be required to identify the boundary feature as being the bank. This would make the survey compliant with the Crown Lands Act but not the Surveying and Spatial Information Regulation. So here is the next instance of legislation and practice being different.

When it comes to surveying the bank, things really start to get interesting. Figure 2 shows an image of just one of the varying types of stream banks that will confront a surveyor. Despite any differences in features the ‘how to’ of defining the bank will remain the same. It is the ‘how to’ contemplation that has eluded surveyors over the same time as the bank has been used as a boundary feature of land.

Figure 2: Where along the edge of the river is the bank?

The surveyor’s contemplation of exactly where at the edge of the stream the bank should be located varies with each survey. Figure 2 identifies four differing bank opinions: (A) the edge of the water, (B) somewhere in between the water’s edge and the toe of the high bank, (C) the toe of the high bank, and (D) the top of the high bank. Although all of these choices have been used over time, it is likely that none of these options is correct. All the choices used have been determined by an instantaneous observation. There have been no measurements undertaken for the determination of the height of the mean stage. Essentially, the determinations have been a guess (Songberg, 2002, 2012, 2016).

Position A is the edge of the usual or low-flow channel within the bed, which is not adequate to cater for the average stage or flow. B, a change of vegetation type moving back from the water, is an entirely unknown quantity. C, be it the back of the shingle bed or the toe of the high bank, if it is a measure of the mean stage, could be the cadastral entity the bank and was often used, but without measurement is just another guess. D has been used from time to time, being the limit of viable agricultural land. It is also the geological bank, but that does not make it the bank for cadastral purposes (Songberg, 2002, 2012). In any of these choices, and most have been used at one time or another, the surveyor is not complying with the requirements of the legislation, so the practice and the legislation do not equate.

In order to undertake a survey of the bank in accordance with the legislation, it would require the surveyor to know the capacity required over the river bed to contain the average or mean stage. That information is not obtainable on any short-term survey. It takes observations of all river stages over decades to determine the quantum required. That is a task not likely to be undertaken by a surveyor. With considerable data analysis, the required information can be ascertained from long-term stream gauges (Songberg, 2002, 2012). Unfortunately, those gauges are few and far between and may not be able to be related up and down a river. Many streams do not have a gauge. Subsequently, it is virtually impossible for a surveyor to comply with the terms of the legislation.

As previously stated, the bank definition only applies to non-tidal boundaries of land alienated from the Crown. It does not apply to riparian boundaries of subdivided land within the bounds of the original Crown delineation. An example of this is land subdivided onto non-tidal streams within the former Port Stephens Estate of the Australian Agricultural Company. In this part of the State, boundary identifiers along streams vary considerably.

4.2 Other Identifiers

One of the more common non-tidal stream boundary identifiers is the centreline. It is of course related to both banks, and the Surveying and Spatial Information Regulation has this covered. Both banks must be surveyed and shown. However, like the bank survey, unless there is a measure of stream average or mean stage determined, the position subsequently determined for the centreline is a pure guess. It is also likely to be incorrect. As with the bank, there is a non-agreement between practice and legislation.

Another identifier known to exist is the extreme margin of the river. This feature is likely to be synonymous with the top of the high bank and the geological bank. Unlike the cadastral bank, this feature is more easily identified. In Figure 2, the extreme margin would be position D. Although the Crown Lands Acts provide for a definition of the bank, there is nothing saying that the bank must be used. Other features, such as the extreme margin or high bank, show up from time to time. Even though the feature would be acceptable under the Crown Lands Acts, it does not conform to the wording of the Surveying and Spatial Information Regulation 2017. As the land abuts a non-tidal stream, the Regulation at clause 51(d) states that a reference to or description of a boundary that abuts a lake or stream is to be taken as a reference to the limit of the bed. That limit is set at the average or mean stage capacity of the stream, not the extreme capacity. The extreme stage and cadastral bank stage of a stream flow are two distinctly different measures (Songberg, 2002, 2012, 2016). To change the titled boundary from the extreme margin to the cadastral bank would require a purchase of land, all be it within the geological confines of the stream. The wording of the Surveying and Spatial Information Regulation 2017 will not change this. Thus, once again legislation and practice are two different things.

5 APPROVAL OF RIPARIAN BOUNDARIES

Legislation provides surveyors with more than just definitions for riparian boundaries. There is also a series of approvals that need to be complied with before the surveyor's definition can be accepted. These are spelt out in the Surveying and Spatial Information Regulation 2017 from clause 45 on through to 50.

In tidal boundaries, whether it be a first-time determination or a subsequent determination, the surveyor needs to gain approval of the Minister administering the Crown Lands Act, in its varying designations. That is assuming the land below mean high water is Crown land. This may have been the case in early common law, but nowadays it may not be the case. If the land does not belong to the Crown, then approval of the otherwise owner needs to be obtained. Approval, however, cannot be given for an increase in land if the circumstances come under the criteria of section 55N of the Coastal Protection Act. In the coastal zone, if the additional land would cause restriction to public access along the foreshore or the increase is not naturally and indefinitely sustainable, approval cannot be given.

In a non-tidal stream or lake, if the survey contains a first-time determination of the riparian boundary, no approval is required for the determination, but the plan lodging authority will still need to approve the surveyor's work.

In a subsequent determination over a non-tidal boundary, if there is no change from the previous position, then no approval (other than plan examination) is required, but the surveyor must note on the plan that the determination is the same as the previous. If, however, there is a change, the surveyor must lodge a report to the Registrar General setting out why the change should be accepted. In other words, approval must be obtained from the Registrar General to a changed non-tidal riparian boundary.

For the first-time survey of the landward reserve or road boundary, approval from the Minister administering the Crown Lands Act must be obtained. This is irrespective of whether or not the land is tidal, non-tidal, or who the "below water" land belongs to. The reserve or road will fall under the administration of the Crown and approval is required. There is no approval required from the Minister for subsequent determinations. It is a requirement of the surveyor to determine the position of the boundary as it was originally located.

If a surveyor is conducting a survey over Crown Land, generally on behalf of the Crown, in addition to any other approvals, an appropriately delegated Crown Lands officer is also required to sign off on the survey.

Essentially, all riparian boundaries need some form of approval, whether it be from a Parliamentary Minister, land owner, or just the examination requirements of obtaining approval of plan registration. Without that approval, the boundary does not get accepted. The surveyor has no choice but to comply fully with the legislation. Thus, here is where legislation and practice do coincide.

5.1 Boundary by Agreement

Although the surveyor may have obtained approval, or agreement of the various authorities and/or land owner to the position of the riparian boundary and complied with the legislation in doing so, it is another matter when it comes to the determination itself. As has been discovered, when it comes to surveyors undertaking exactly what the legislated boundary definitions requires, in practice it is another matter. In surveying riparian boundaries legislation and practice do not agree. The boundary surveyed is not that as required by the legislation, but although it may resemble the requirements of the legislation, it is instead something else. As agreement of this boundary line location has been arrived at between the surveyor, authority and/or land owner, the boundary thus becomes a boundary by agreement.

6 CONCLUDING REMARKS

It has not been too difficult to show that when it comes to riparian boundary definition, the theory or legislation and practice are two different things. How legislation and practice diverged is unclear. It may have resulted from poor or inadequate legislation. It could also be a result of the legislation being impossible to comply with in a practical sense. It could also be a result of how surveying practices have evolved over time. What may be a practical solution acceptable to the whole industry may not, as we have seen, be the solution required by the legislation. It is, however, quite evident that definitions, legislation and survey practices are not rigorously valid.

What the result does mean is that riparian boundaries by virtue of the evolved non-compliant practices have evolved into boundaries by agreement. The implication of this is that these boundaries have actually moved away from being a strict riparian boundary. The boundary can be located wherever the agreement places it, even though later investigations show that that agreed location has been made in error. If the legislative requirements had been adhered to, the true location would be different (Songberg, 2004, 2007, 2012, 2019). Although the later investigations can show the earlier determination was wrong, the boundary remains, an error in place. This ad-hoc determination of riparians, contrary to what should have been, can result in a divergence of boundaries along the riparian zone, destabilising the cadastre (Songberg, 2019), even to a point where the river disappears from the cadastre and parcels of land from either side overlap (Songberg, 2004).

If this conclusion is examined against all riparian boundaries within the State, then there is a high probability that those boundaries are in effect not true riparian boundaries as none will comply with the legislation. If this were the case, the next outcome would be that the doctrine of accretion and erosion does not apply.

In order to equate legislation and practice so as to get back to riparian boundaries and not boundaries by agreement, do things need to change? The answer to that can only be yes (Songberg, 2016). But what should change? Should it be the legislation, or should it be the survey practice, or should it be both? The answer to that could be quite difficult and revolutionary.

REFERENCES

Blume P. (1995) Mean high water mark revisited, *Proceedings of Association of Public Authority Surveyors Conference (APAS1995)*, Port Macquarie, Australia, 5-7 April, 24pp.

Couriel E., Alley K. and Modra B. (2012) OEH NSW tidal planes analysis: 1990-2010 harmonic analysis, Report MHL2053, Public Works Manly Hydraulics Laboratory, http://new.mhl.nsw.gov.au/services/publications/oehreport (accessed May 2020).

Department of Lands (1976) Manual of the New South Wales Integrated Survey Grid, NSW Department of Lands, Sydney, 166pp.

NSW Legislation (2017) Surveying and Spatial Information Regulation 2017, https://www.legislation.nsw.gov.au/#/view/regulation/2017/486 (accessed May 2020).

Songberg G. (2002) Spatio-temporal anomalies in cadastral boundaries, *Proceedings of Association of Public Authority Surveyors Conference (APAS2002)*, Sutton, Australia, 5-8 March, 45-67.

Songberg G. (2004) River? What river. A status investigation of the Macleay River Frederickton to Smithtown, *Proceedings of Association of Public Authority Surveyors Conference (APAS2004)*, The Entrance, Australia, 24-25 March, 70-90.

Songberg G. (2005) Accurate mean high water mark determination – Fact or fiction? *Proceedings of Association of Public Authority Surveyors Conference (APAS2005)*, Batemans Bay, Australia, 16-17 March, 49-65.

Songberg G. (2007) Surveying in a time warp, *Proceedings of Association of Public Authority Surveyors Conference (APAS2007)*, Canberra, Australia, 27-29 March, 57-65.

Songberg G. (2012) The Bank: A mathematical determination, *Proceedings of Association of Public Authority Surveyors Conference (APAS2012)*, Wollongong, Australia, 19-20 March, 178-194.

Songberg G. (2015) Mean High Water Mark: Is the mean the answer? *Proceedings of Association of Public Authority Surveyors Conference (APAS2015)*, Coffs Harbour, Australia, 16-18 March, 110-131.

Songberg G. (2016) Riparian boundaries: A step towards reform, *Proceedings of Association of Public Authority Surveyors Conference (APAS2016)*, Leura, Australia, 4-6 April, 74-86.

Songberg G. (2019) Cadastral integrity loss from riparian boundaries, *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 182-208.

Thompson K. (2019) Are our coastal waterways tidal? *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 209-230.

Martin's Creek: Small Flow, Big Issue

Fred de Belin
City of Ryde
fdebelin@ryde.nsw.gov.au

ABSTRACT

Martin's Creek is a short watercourse flowing through North Ryde into the Lane Cove River. In 1881-82, as part of the Crown's "Grants Under the Field of Mars Common Resumption Act 1874", surveys were carried out by Mr Surveyor Charles Robert Scrivener, who created portion boundaries along Martin's Creek. The area of investigation includes Portions 231-236, which were all the subject of Torrens Title Crown Grants in 1885-86. This paper delves into some of the interesting and fascinating questions raised from pawing through the chain of titles and subsequent subdivisional Deposited Plans. It describes in detail some of the anomalies and strange happenings uncovered during the research and tries to answer such poignant questions as: Does the description on title override what is shown on the plan of survey? Does the diagram on title supersede the plan of survey? Is land in a remnant of a Certificate of Title able to be claimed by Possessory Title action? Is consolidation of parcels across a creek enough to claim title of the bed of the creek? Who has the right to claim ad medium filum aquae?

KEYWORDS: *Middle thread, natural boundary, grant boundary, title diagram.*

1 INTRODUCTION

Martin's Creek is a short and narrow watercourse (Figure 1), which flows through North Ryde and joins other creeks to flow into the Lane Cove River. In 1881-82, as part of the Crown's "Grants Under the Field of Mars Common Resumption Act 1874", surveys were carried out by Lands Department Staff Surveyor Charles Robert Scrivener, who created portion boundaries along Martin's Creek.

Figure 1: Martin's Creek, looking upstream.

The area of investigation includes Portions 231-236, which were all subject to Torrens Title Crown Grants in 1885 and 1886 (Figure 2). Investigation of these first portions and subsequent transactions of the land produces an abundant array of anomalies and strange happenings when it comes to such straightforward processes as (see also de Belin, 2019):

- Does the Description on Title override what is shown on the plan of survey?
- Does the Diagram on Title supersede the plan of survey?
- Is land in a remnant of a Certificate of Title able to be claimed by Possessory Title action?
- Is consolidation of parcels across a creek enough to claim title over the bed of the creek?
- Who has the right to claim *ad medium filum aquae*?

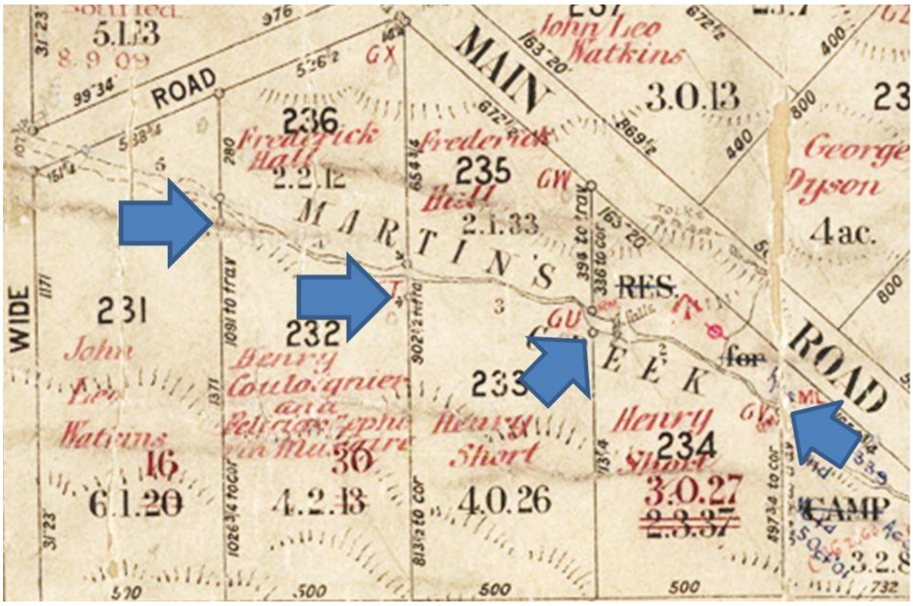


Figure 2: Detail from Crown Grant Plan 386.2030 (1881-82), showing corner marking.

Mr Staff Surveyor Scrivener placed several broad arrow rock marks on what he noted as corners and creek-traverse stations. Connecting lines between these sets of marks have been added by the author in Figure 3.

Figure 3: Plan 386.2030 (1881-82) with right lines joining corner marks (yellow) and creek traverse (blue).

The yellow lines connect between corner marks, at one point even crossing the creek. Each side line between adjoining portions displays three dimensions: "*to corner*", "*to traverse*" and a *remainder*. Except in one place only, the corner is not marked on the creek bank. Rear boundary lines are not drawn on the portion plan. The creek banks are shown broken across Portion 231 and part of Portion 232 but solid elsewhere (the remaining portions). Across Portions 235 and 236, and Portions 232 to 234, the creek banks are the only solid lines drawn. At least one broad arrow corner rock mark is still evident, between Portion 232 and Portion 233 (Figure 4).

Figure 4: Original broad arrow rock mark found (450 mm deep) at base of white painted steel post.

A creek traverse is shown (blue in Figure 3) and also marked. A straight line rear boundary is suggested on the plan, and marked, but not drawn. Present occupations follow this right line (Figure 5). Are the portion areas corroborated by right line or natural creek line? Areas are shown to the nearest 1 perch, which equates to 25 m^2. Calculation of the area of each portion, with boundary being taken as the natural creek bank, revealed almost exact correlation with the areas as notated, or corrected, on the portion plan.

Figure 5: Views along Martin's Creek at the rear of Portion 233.

2 THE PORTIONS IN DETAIL

2.1 Portion 231

26 September 1885 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 777 Folio 221 … to John Leo Watkins (Figure 6).

"*Commencing on the North Eastern side of a road one chain wide at the Western corner of Portion 232 of four acres two roods thirty perches and bounded thence on the South West by that road dividing it from portion 230 of six acres thirty four perches bearing North fifty eight degrees thirty seven minutes West five chains on the North West by a line bearing North thirty one degrees twenty three minutes East eleven chains seventy one links on the North by a road one chain wide dividing it from part of a measured portion of five acres one rood thirteen perches bearing South eighty degrees twenty six minutes East five chains thirty eight links and three fourths of a link and on the South East by the North Western boundary of portion 236 of two acres two roods twelve perches a line **crossing Martin's Creek** and the North Western boundary of portion 232 aforesaid in all bearing South thirty one degrees twenty three minutes West thirteen chains seventy one links to the point of commencement*."

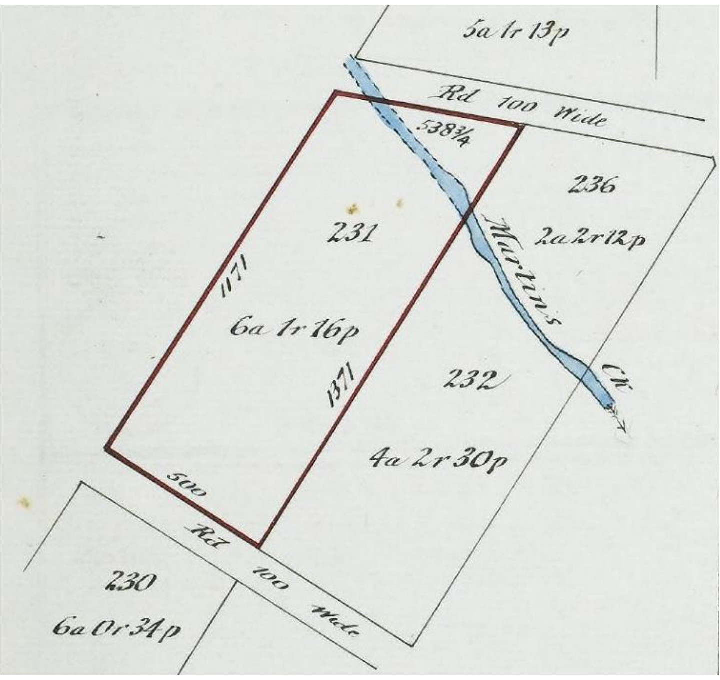


Figure 6: Crown Grant Title Diagram for Portion 231.

It should be noted that the whole of the creek bed is contained within Portion 231. Subsequently there followed a series of transfers of ownership (see Appendix), from 1885 up until 1926. The registered proprietor at this point was Ernest George Marwood, who is important to this investigation (see section 4), when subdivision of the grant portions first occurred (in 1941).

2.2 Portion 232

13 March 1886 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 783 Folio 31 … to Henry Joseph Couloignier & Felecian Zephirim Muraire (Figure 7).

"*Commencing on the* ***right bank*** *of Martin's Creek at the northern corner of Portion 233 of four acres twenty six perches and bounded thence on the South East by the North Western boundary of that Portion bearing South thirty one degrees twenty three minutes West eight chains thirteen links and half a link on the South West by a road one chain wide dividing it from Portion 229 of six acres two roods sixteen perches bearing North fifty eight degrees thirty seven minutes West five chains on the North West by part of the South Eastern boundary of Portion 231 of six acres one rood sixteen perches bearing North thirty one degrees twenty three minutes East ten chains twenty six links and three fourths of a link* ***to Martin's Creek*** *and on the South East* ***by that creek*** *downwards to the point of commencement*."

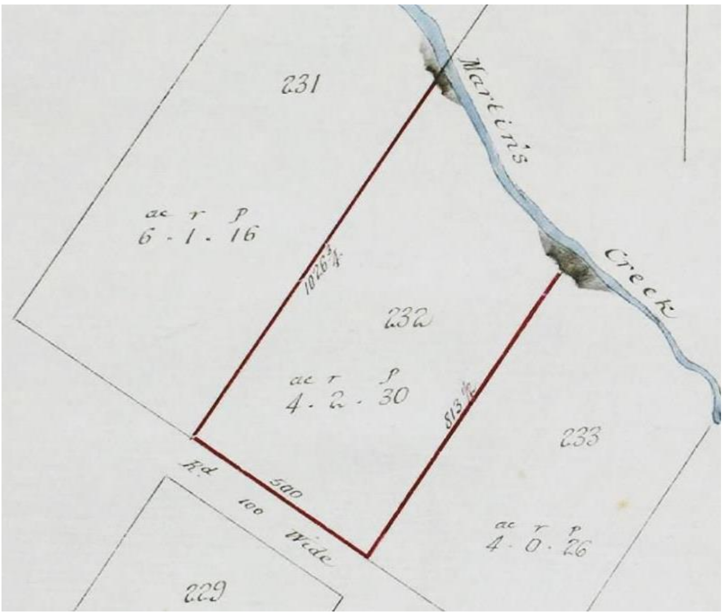


Figure 7: Crown Grant Title Diagram for Portion 232.

It should be noted that there is no red edging along the creek. Dimensions are identical to Crown plan 386.2030, which did not reach to the creek. Does this indicate a high bank perhaps? The boundary appears to be drawn as a bank in the Crown Grant diagram. Subsequently there followed a series of transfers of ownership (see Appendix), from 1885 up until 1926. The registered proprietor at this point was Ernest George Marwood.

2.3 Portion 233

28 January 1886 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 777 Folio 160 … to Henry Short (Figure 8).

"*Commencing on the* ***right bank*** *of Martin's Creek at the Eastern corner of Portion 232 of four acres two roods thirty perches and bounded thence on the North West by the South Eastern boundary of that Portion bearing South thirty one degrees twenty three minutes West eight chains thirteen links and half a link on the South West by a road one chain wide dividing it from Portion 228 of six acres one rood two perches bearing South fifty eight degrees thirty seven minutes East five chains on the South East by the North Western boundary of Portion 234 of three acres twenty seven perches bearing North thirty one degrees twenty three minutes East seven chains thirteen links and one fourth of a link* ***to Martin's Creek*** *and on the North East* ***by that creek*** *upwards to the point of commencement*."

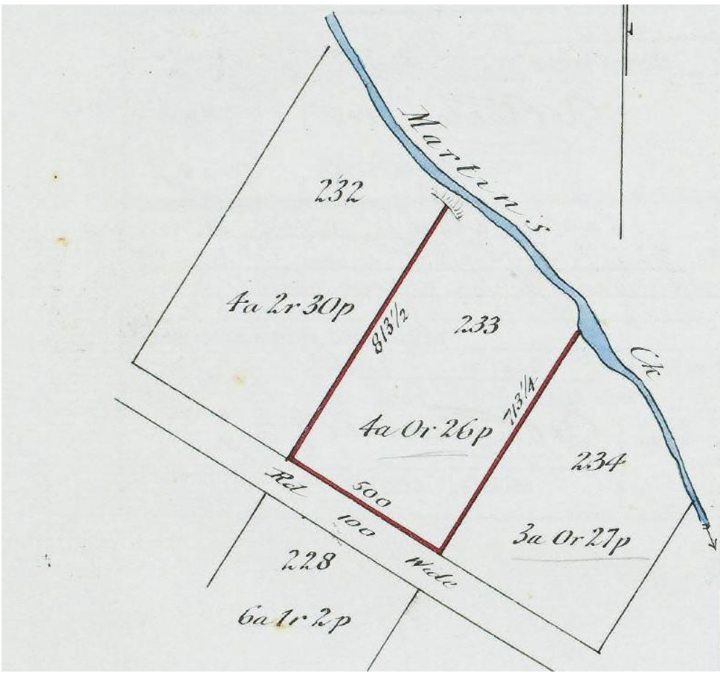


Figure 8: Crown Grant Title Diagram for Portion 233.

It should be noted that there is no red edging along the creek. Dimensions shown are identical to Crown plan 386.2030, which also did not reach to the creek. Does this indicate a high bank? It appears to be drawn as a bank in the Crown Grant diagram. Subsequently there followed a series of transfers of ownership (see Appendix), from 1886 up until 1932. The registered proprietor at this point was Edward Coleman.

2.4 Portion 234

28 January 1886 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 777 Folio 161 … to Henry Short (Figure 9).

"*Commencing on the **right bank** of Martin's Creek at the Eastern corner of Portion 233 of four acres twenty six perches and bounded thence on the North West by the South Eastern boundary of that Portion bearing South thirty one degrees twenty three minutes West seven chains thirteen links and one fourth of a link on the South West by a road one chain wide dividing it partly from Portion 227 of four acres thirty two perches bearing South fifty eight degrees thirty seven minutes East five chains on the South East by a North Western boundary of a measured portion of three acres two roods eight perches bearing North thirty one degrees twenty three minutes East four chains ninety seven links and three fourths of a link **to Martin's Creek** and on the North East **by that creek** upwards to the point of commencement*."

It should be noted that there is no red edging along the creek. Dimensions are identical to Crown plan 386.2030, which did not reach to the creek. Subsequently there followed a series of transfers of ownership (see Appendix), from 1886 up until 1932. The registered proprietor at this point was Edward Coleman.

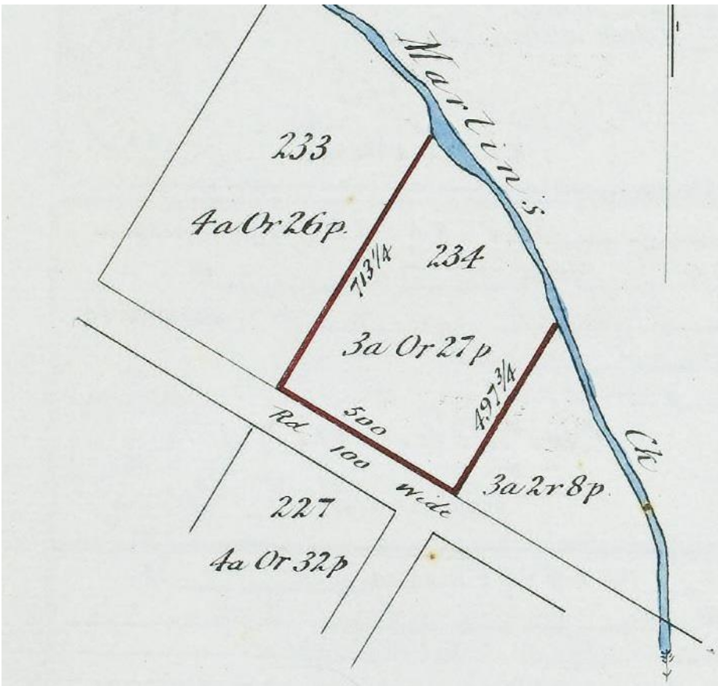


Figure 9: Crown Grant Title Diagram for Portion 234.

2.5 Portion 235

28 January 1886 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 777 Folio 110 … to Frederick Hall (Figure 10).

"*Commencing on the **left bank** of Martin's Creek at Southern corner of Portion 236 of two acres two roods twelve perches and bounded thence on the North West by the South Eastern boundary of that portion bearing North thirty one degrees twenty three minutes East six chains fifty four links and three fourths of a link on the North East by the road one chain fifty links wide from Pittwater to Gladesville dividing it from part of portion 237 of three acres thirteen perches bearing South sixteen degrees forty minutes East six chains seventy two links and half a link on the South East by a North Western boundary of a measured portion of three acres two roods eight perches bearing South thirty one degrees twenty three minutes West three chains thirty six links **to Martin's Creek** and on the South West **by that creek** upwards to the point of commencement*."

It should be noted that there is no red edging along the creek. Dimensions are identical to Crown plan 386.2030, which did not reach to the creek. Subsequently there followed a series of transfers of ownership (see Appendix), from 1885 up until 1926. The registered proprietor at this point was Ernest George Marwood.

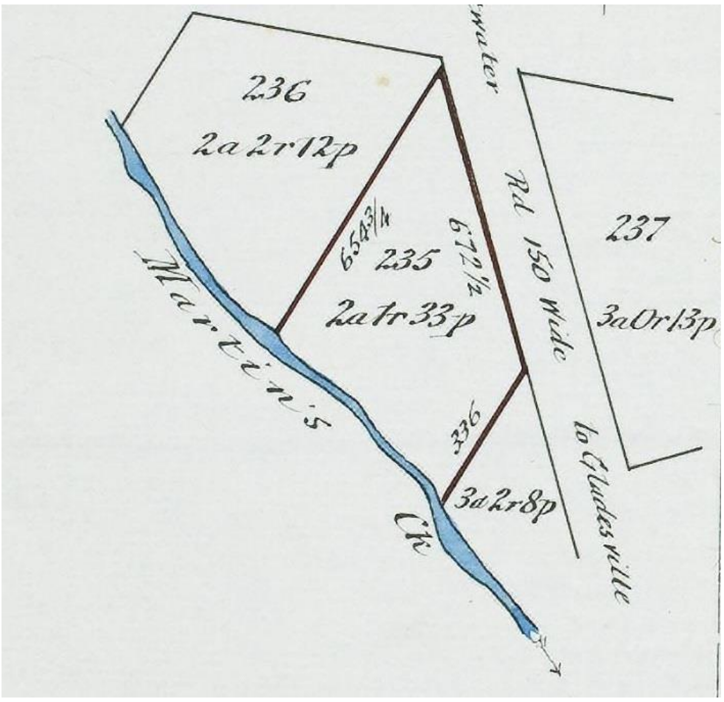


Figure 10: Crown Grant Title Diagram for Portion 235.

2.6 Portion 236

21 August 1886 … Crown Grant under Field of Mars Resumption Act 1874.
Volume 777 Folio 111 … to Frederick Hall (Figure 11).

"*Commencing on the **left bank** of Martin's Creek at a point where the South Eastern boundary of Portion 231 of six acres one rood sixteen perches intersects that bank and bounded thence on the North West by part of that boundary bearing North thirty one degrees twenty three minutes East two chains eighty links on the North by a road one chain wide dividing it from part of a measured portion of five acres one roods thirteen perches bearing South eighty degrees twenty six minutes East five chains twenty six links and half a link on the North East by the road one chain fifty links wide from Pittwater to Gladesville dividing it from part of portion 237 of three acres thirteen perches bearing South sixteen degrees forty minutes East fourteen links and one fourth of a link on the South East by the North Western boundary of portion 235 of five acres one rood and thirty three perches bearing South thirty one degrees twenty three minutes West six chains fifty four links and three fourths of a link **to the aforesaid Creek** and on the South West **by that creek** upwards to the point of commencement*."

It should be noted that there is no red edging along the creek boundary. Dimensions are identical to Crown plan 386.2030, which did not reach to the creek. Subsequently there followed a series of transfers of ownership (see Appendix), from 1885 up until 1926. The registered proprietor at this point was Ernest George Marwood.

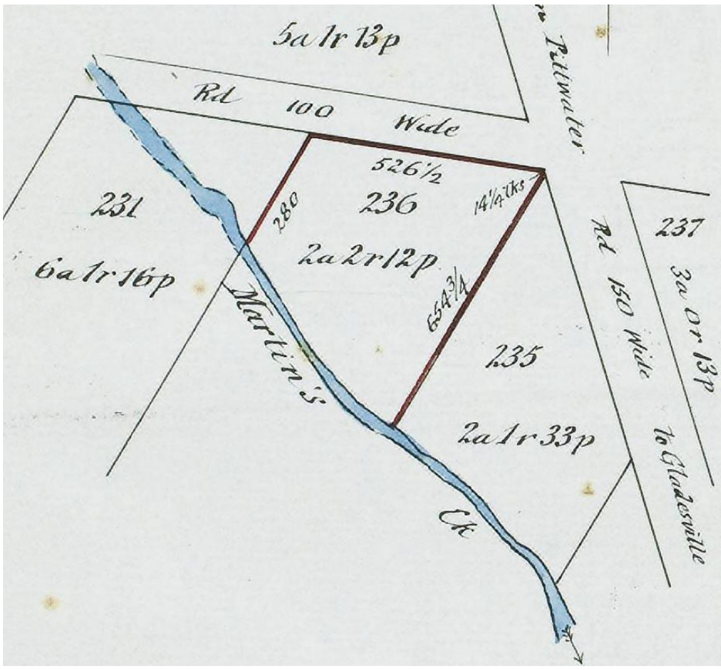


Figure 11: Crown Grant Title Diagram for Portion 236.

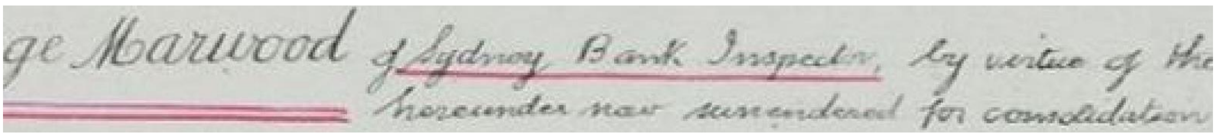
3 TITLES AND TRANSFERS

Table 1 shows the chain of title to Ernest George Marwood as registered proprietor of four of these portions (also see Appendix).

Table 1: Chain of title up to Ernest George Marwood in 1926.

231	232	235	236
26 Sep 1885	13 Mar 1886	28 Jan 1886	21 Aug 1886
John Leo Watkins	Couloignier & Muraire	Frederick Hall	Frederick Hall
Vol 777 Fol 221	Vol 783 Fol 31	Vol 777 Fol 110	Vol 777 Fol 221
26 Mar 1892	13 Oct 1892	2 Apr 1886	2 Apr 1886
Couloignier & Muraire, then through various transfers until James Gilmour, who transferred to Ernest George Marwood	Rennetel, Murlay & Muraire, then through various transfers until James Gilmour, who transferred to Ernest George Marwood	Couloignier & Muraire, then through various transfers until James Gilmour, who transferred to Ernest George Marwood	Couloignier & Muraire, then through various transfers until James Gilmour, who transferred to Ernest George Marwood
16 Dec 1926	16 Dec 1926	16 Dec 1926	16 Dec 1926

In December 1942, Ernest George Marwood had one Certificate of Title after a consolidation of Portions 231, 235 and 236 (Figures 12 & 13) and a separate Certificate of Title for Portion 232 (Figure 14). It is worth noting the unintentional pun of Ernest George Marwood being a *bank* inspector (Figure 12).


ge Marwood of Sydney Bank Inspector, by virtue of the
hereunder now surrendered for consolidation

"…*by virtue of the Crown Grants specified in the schedule hereunder now surrendered for consolidation*…"

Figure 12: Extract from Volume 5356 Folio 78 (10 December 1942).

It should be noted that the title diagrams (Figures 13-15) are fully edged in red and indicate that the creek bank is the natural boundary. The title diagrams as shown in Volume 5356 Folio 78 (Figure 13) and Volume 4550 Folio 210 (Figure 15) display both banks of Martin's Creek, with edging clearly to the bank, while the title diagram as shown in Volume 5329 Folio 56 (Figure 14) draws the creek as a single line, yet clearly indicates that the right bank of the creek is the natural boundary.

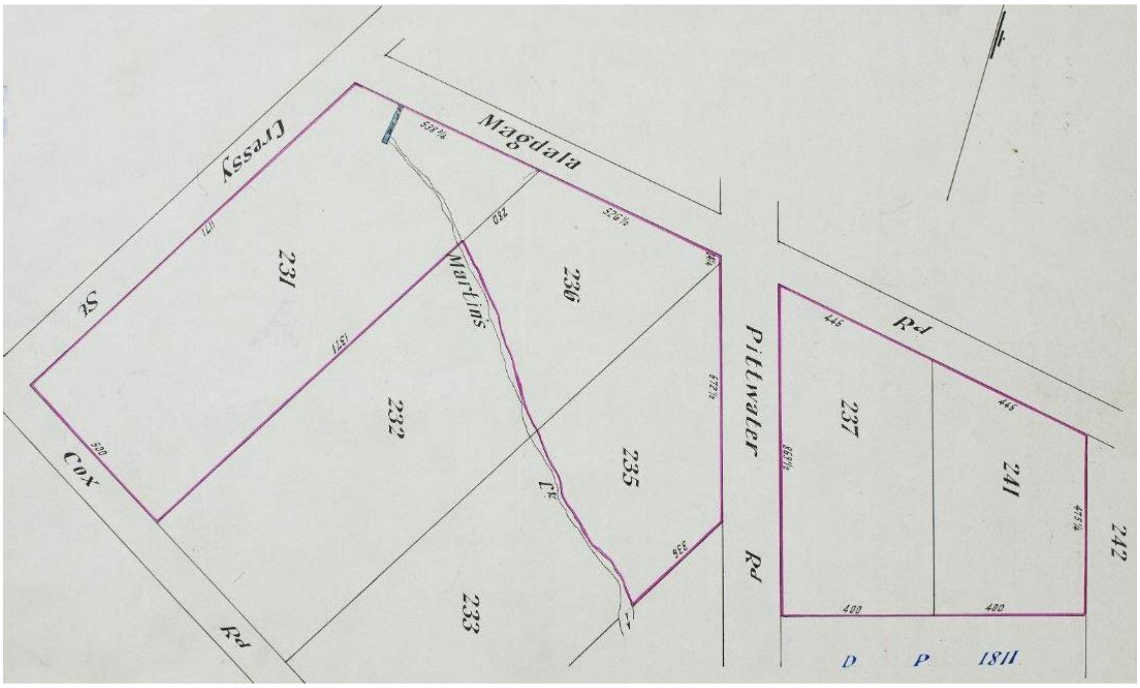


Figure 13: Title Diagram for Ernest George Marwood's land in 1942 (Volume 5356 Folio 78).

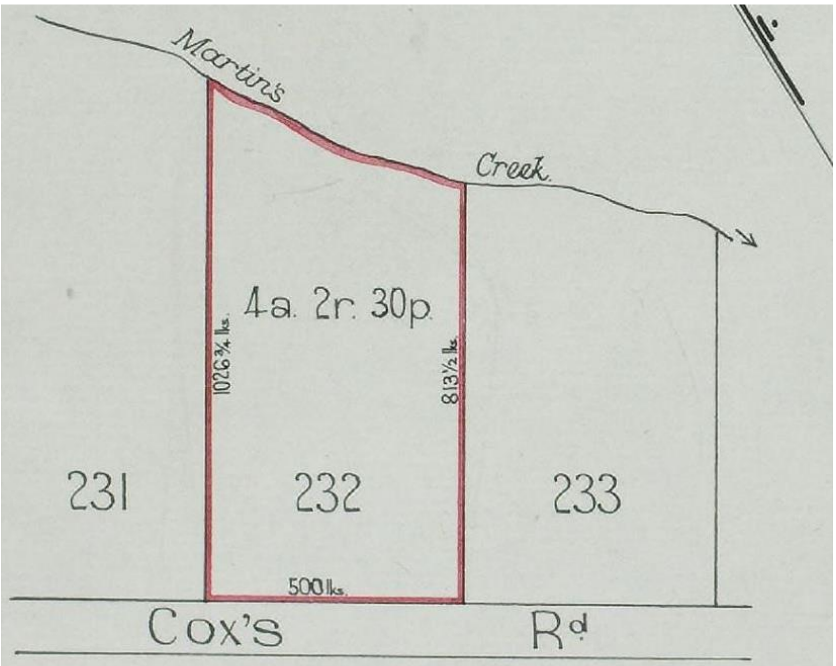


Figure 14: Title Diagram for Ernest George Marwood's land in 1942 (Volume 5329 Folio 56).

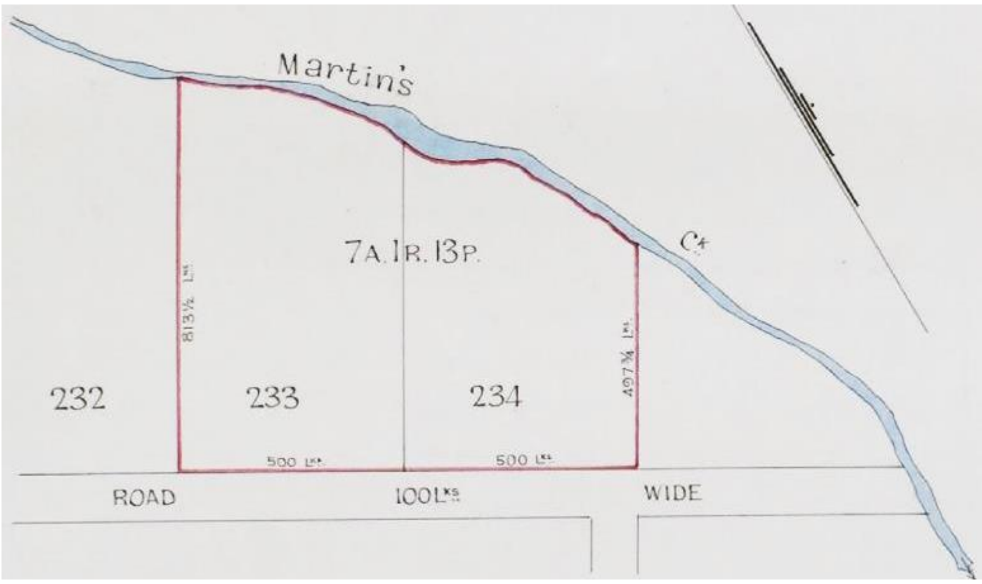


Figure 15: Title Diagram for Edward Coleman's land in 1932 (Volume 4550 Folio 210).

4 WHERE IS THE BOUNDARY?

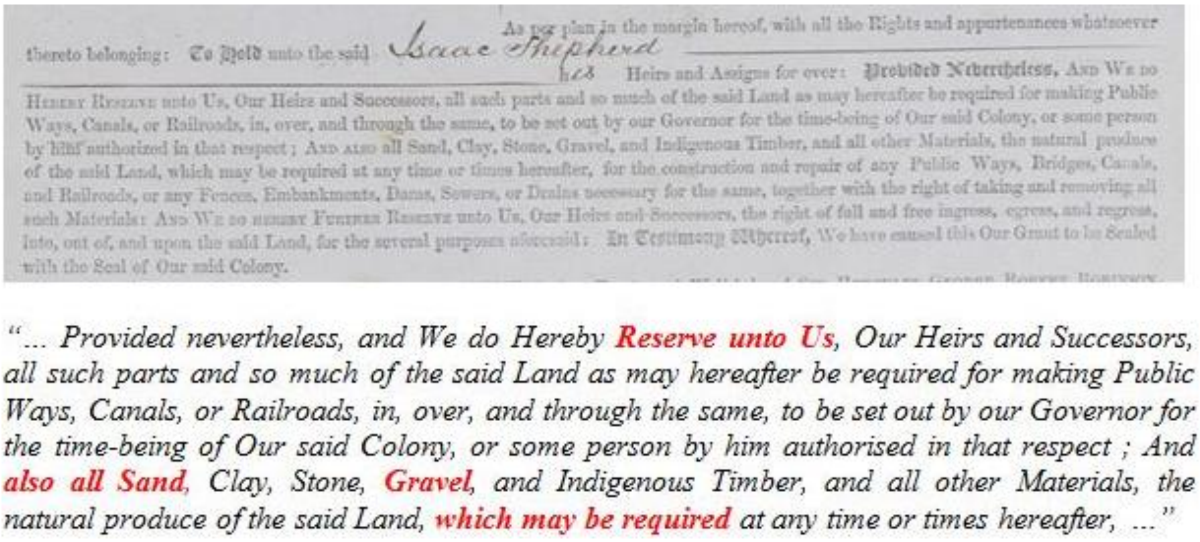
With respect to non-tidal streams, why is a boundary *ad medium filum aqua*e such an issue? There was a time through the 1830s when the Old System Crown Grant (Figure 16) included a *reservation* unto the Crown *of the right* to take and remove *all gravel* upon the land. By the 1870s, the Torrens Title Crown Grant (Figure 17) included a *reservation* unto the Crown of *all sand and gravel* upon the said land. Sand and gravel are predominately found in the bed of a watercourse, so some doubt arose as to whether the Crown Grant was to the bank of a stream or included part of the bed of the stream, i.e. up to the centreline of a stream, when the granted land abutted a natural watercourse. If the Crown is *reserving the right* to take sand and gravel, then presumably the Crown does not own the bed of the creek after the time of grant.

Sixteen Shillings and eight pence

and every part thereof and all arrears of the same, due at the time of Our said entry, or which shall accrue due during the time of Our possession by virtue thereof, together with all Costs and Charges attending the non-payment of said Quit-Rent, and Our said entry thereupon, these Presents notwithstanding; AND ALSO SAVING AND RESERVING unto Us, Our Heirs, and Successors, all such parts and so much of the said land as may hereafter be required for a Public Way or Public Ways, in, over, and through the same, to be set out by the Governor for the time being of Our said Territory, or some Person lawfully authorised in that respect, together with all Lands within One Hundred Feet of High Water Mark on the Sea Coast, and on every Creek, Harbour, andInlet; AND ALSO all Mines of Gold, of Silver, and of Coals, with full and free liberty and power to search for, dig, and take away the same; AND ALSO SAVING AND RESERVING unto Us, Our Heirs and Successors, the right of taking and removing all Stone and Gravel, all Indigenous Timber, and all other Materials, the produce of the same Land, which may be required at any time for the construction and repair of Ways and Bridges, for Naval Purposes, and for Public Works, together with right of ingress, egress, and regress, on the Land, for all the purposes aforesaid.

"... AND ALSO SAVING AND PRESERVING unto Us, Our Heirs and Successors, all such parts and so much of the said Land as may hereafter be required for a Public Way or Public ways, in, over, and through the same, to be set out by our Governor for the time-being of Our said Territory, or some Person lawfully authorised in that respect, together with all Lands within One Hundred Feet of High Water Mark on the Sea Coast, and on every Creek, Harbour, and Inlet ; AND ALSO all Mines of Gold, of Silver, and of Coals, with full and free liberty and power to search for, dig, and take away the same; AND ALSO SAVING AND RESERVING unto Us, Our Heirs and Successors, ***the right*** *of taking and removing* ***all*** *Stone and* ***Gravel****, all Indigenous Timber, and all other Materials, the produce of the same Land,* ***which may be required*** *at any time for ..."*

Figure 16: Example of the Crown Grant reservation from 1831.



As per plan in the margin hereof, with all the Rights and appurtenances whatsoever thereto belonging: To Hold unto the said Isaac Shepherd his Heirs and Assigns for ever: Provided Nevertheless, And We do Hereby Reserve unto Us, Our Heirs and Successors, all such parts and so much of the said Land as may hereafter be required for making Public Ways, Canals, or Railroads, in, over, and through the same, to be set out by our Governor for the time-being of Our said Colony, or some person by him authorized in that respect; And also all Sand, Clay, Stone, Gravel, and Indigenous Timber, and all other Materials, the natural produce of the said Land, which may be required at any time or times hereafter, for the construction and repair of any Public Ways, Bridges, Canals, and Railroads, or any Fences, Embankments, Dams, Sewers, or Drains necessary for the same, together with the right of taking and removing all such Materials: And We do hereby Further Reserve unto Us, Our Heirs and Successors, the right of full and free ingress, egress, and regress, into, out of, and upon the said Land, for the several purposes aforesaid: In Testimony Whereof, We have caused this Our Grant to be Sealed with the Seal of Our said Colony.

*"… Provided nevertheless, and We do Hereby **Reserve unto Us**, Our Heirs and Successors, all such parts and so much of the said Land as may hereafter be required for making Public Ways, Canals, or Railroads, in, over, and through the same, to be set out by our Governor for the time-being of Our said Colony, or some person by him authorised in that respect ; And **also all Sand**, Clay, Stone, **Gravel**, and Indigenous Timber, and all other Materials, the natural produce of the said Land, **which may be required** at any time or times hereafter, …"*

Figure 17: Example of the Crown Grant reservation from 1870.

So, does the metes and bounds description in the Crown Grant override the plan? Yes. Does the Title Diagram in the Crown Grant override the plan? Yes, in so much that it represents the metes and bounds description and indicates that the rear boundary is a natural boundary being the bank of the creek.

It should be noted that the "*Bank of creek by CT*" notation on DP 19636 (1941) has been crossed through prior to plan registration (Figure 18). The bearings and dimensions on these straight lines are identical to the lines joining between marks in C.R. Scrivener's 1881 portions survey (as drawn by the author in Figure 3). Also of interest in DP 19636 is that it contains numbered lots with one lot described by the letter B.

Figure 18: Detail from DP 19636 (1941), showing rear boundary lines.

DP 19636 found the "*original corner on rock*" marks. At this time, Ernest George Marwood was the owner of the land on either side of Martin's Creek, albeit in two Certificates of Title. The surveyor who was responsible for DP 19636 obviously thought that Scrivener's straight lines should be adopted for the rear boundary lines of Lot 36 and Lot B (Figure 19).

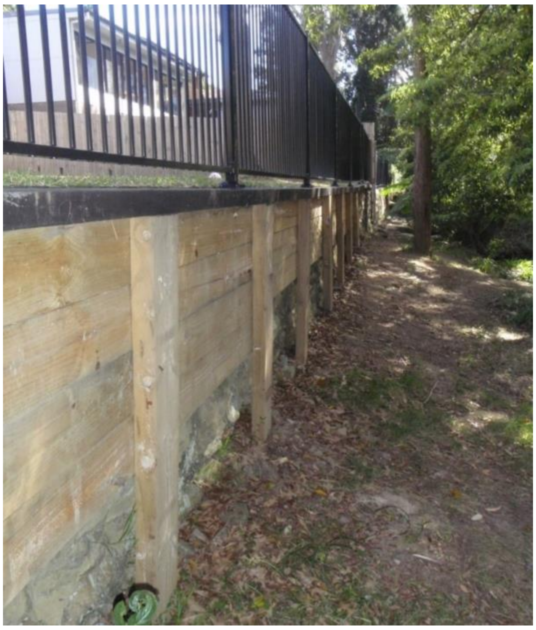


Figure 19: Rear boundary of DP 222878 (1964), formerly Lot B in DP 19636 (Portion 232).

5 THE REMNANT PARCELS

The Registrar General must have agreed and issued titles for Lot 36 and Lot B in DP 19636. However, remnant parcels remained between the straight line boundary and the creek bank (Figure 20).

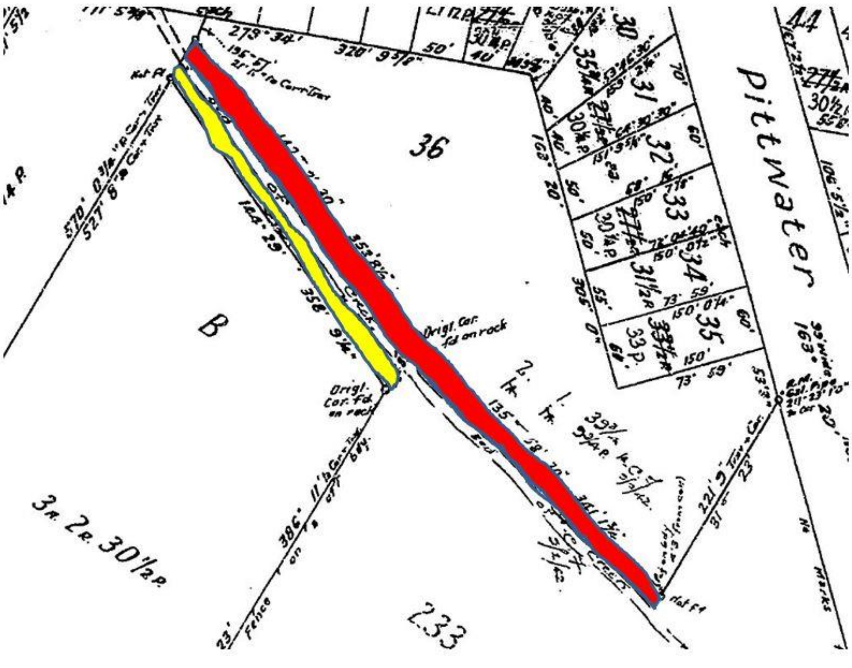


Figure 20: Detail from DP 19636 (1941), showing remnant parcels from Certificates of Title.

Lot 29 in DP 203206 (1960) and Lot 29 in DP 30900 (1959) were remnants after the subdivision of Portions 233 and 234. Both Lots 29 were dedicated as drainage reserves and are now owned by City of Ryde (Figure 21).

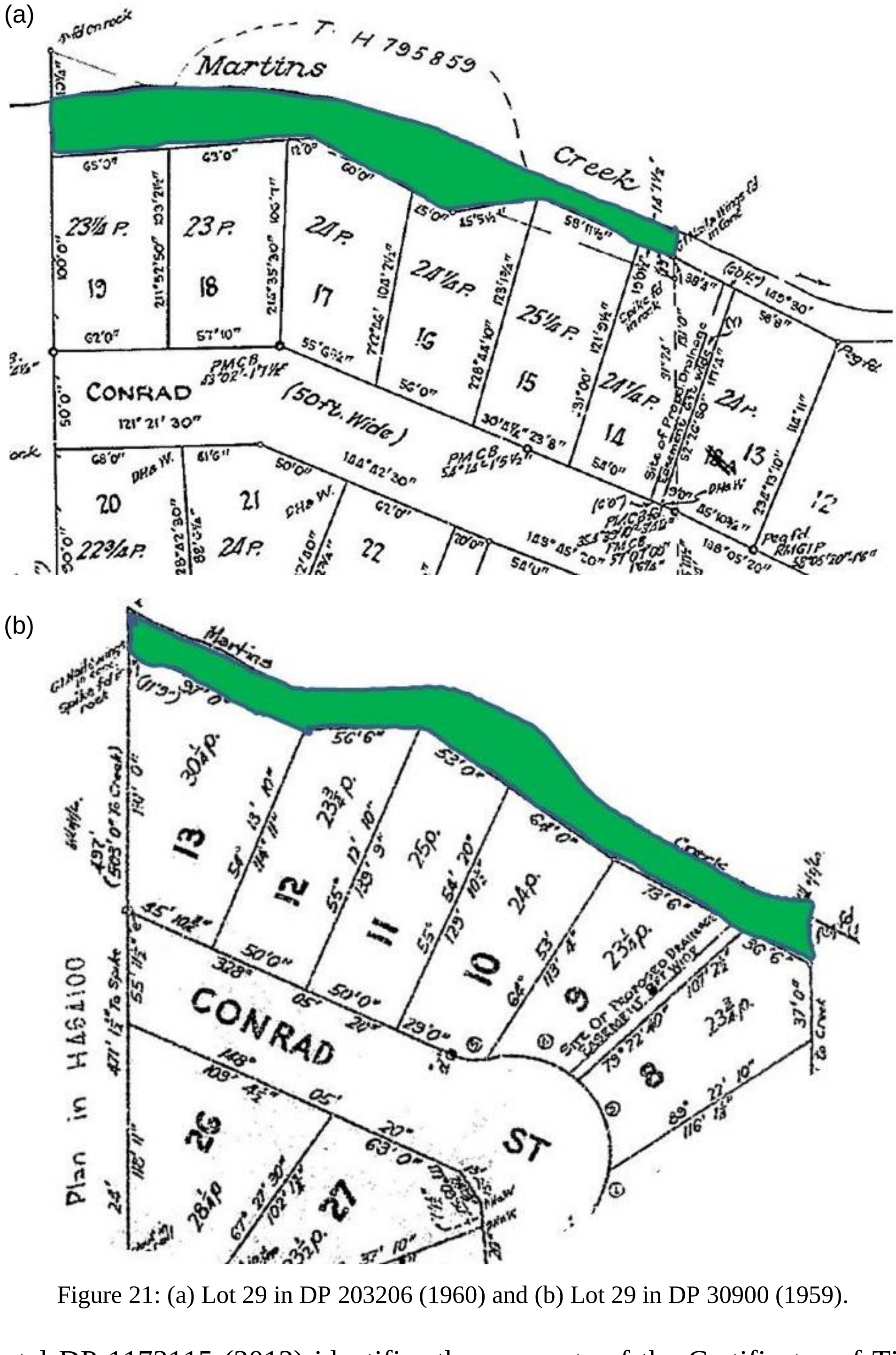


Figure 21: (a) Lot 29 in DP 203206 (1960) and (b) Lot 29 in DP 30900 (1959).

Departmental DP 1173115 (2012) identifies the remnants of the Certificates of Title, which were subdivided by DP 19636 (Figure 22), and creates three new titles with Ernest George Marwood nominated as the registered proprietor. DP 1173115 shows that the bed of the creek is not included on any of these titles.

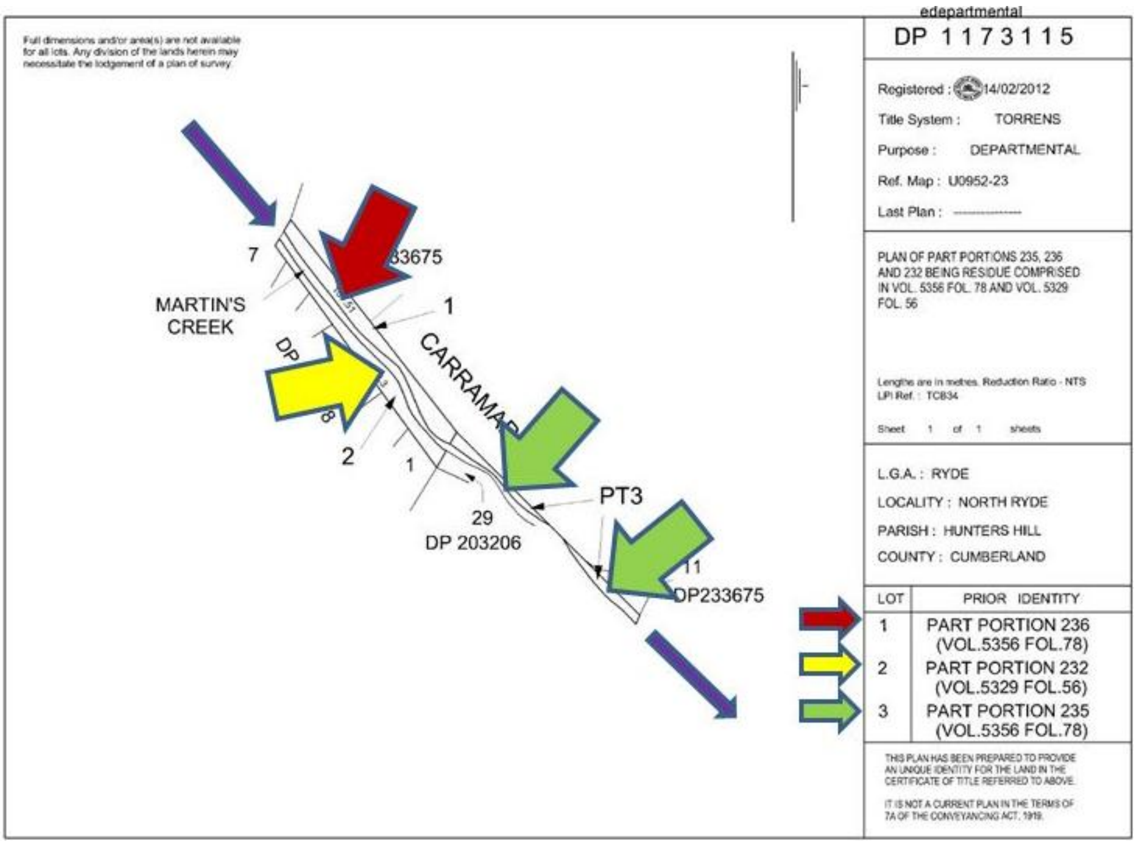


Figure 22: Departmental DP 1173115 (2012) identifies the remnants and creates three new titles.

DP 1125003 (2008) was prepared for title identification only (Figure 23). It should be noted that the natural boundary of Lot 7002 is clearly drawn containing the bed of Martin’s Creek and abutting the opposite bank, which is Lot 29 in DP 30900 (1959) and Lot 29 in DP 203206 (1960).

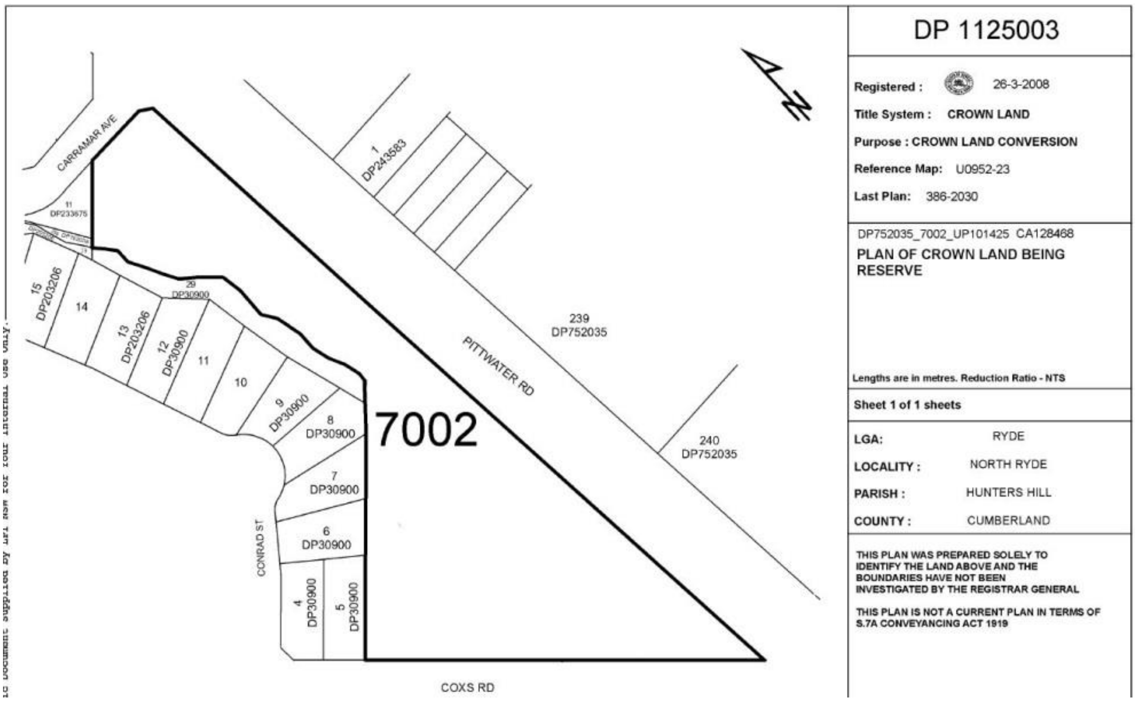


Figure 23: Lot 7002 in DP 1125003 (2008) being Martin Reserve.

6 COUNCIL CLEANS UP

At present, Martin Reserve only comprises Lot 7002 in DP 1125003 (Reserve) together with Lot 11 in DP 233675 (Public Reserve) and the Lots 29, which are City of Ryde drainage reserves. Council would like to include the remnant parcels along Martin's Creek (Figure 24).

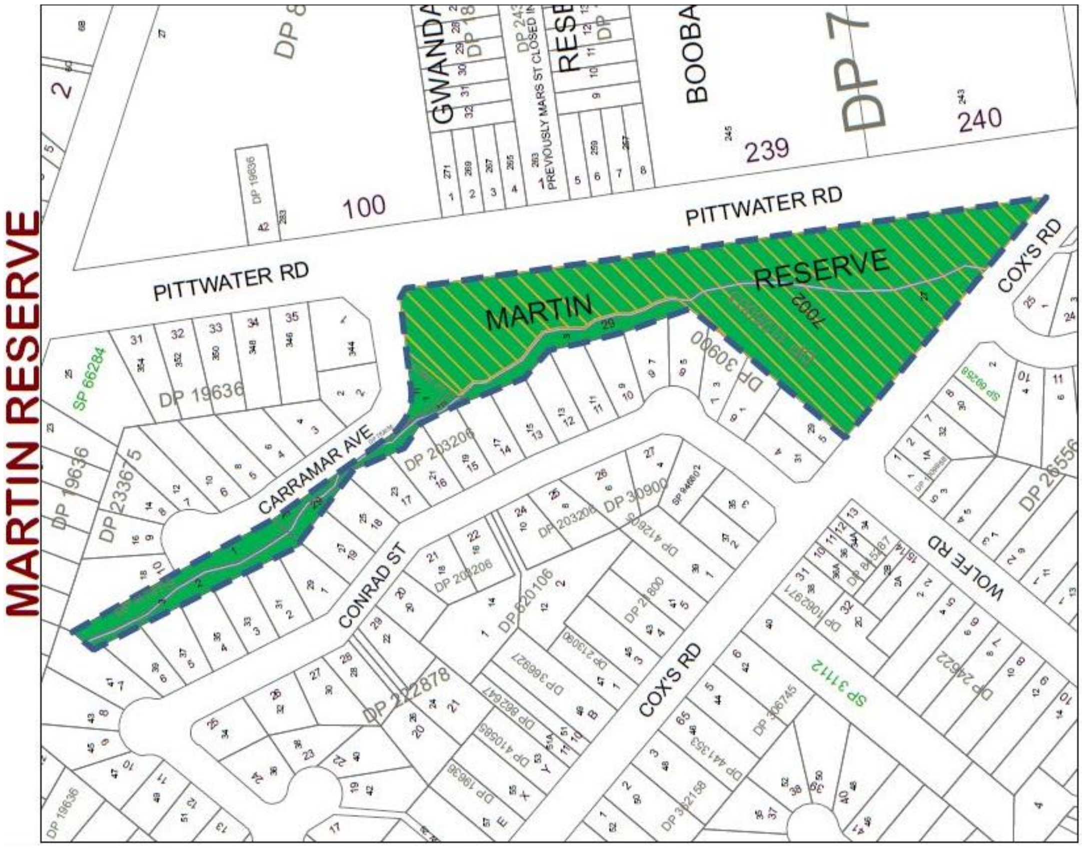


Figure 24: Martin Reserve as Council would like to see it in its masterplan.

This is supported by Council being the presumed owner of the creek bed and responsible for the maintenance of the watercourse, and first point of call for local residents with respect to the removal of dangerous and threatening trees.

7 CONCLUDING REMARKS

This paper has shown that a Possessory Title claim can now be made by City of Ryde for the land remnant in the Certificates of Title once owned by Ernest George Marwood, land which has since been identified and recreated by DP 1173115 in 2012. These narrow strips of Torrens Titled land lie between the straight line 'boundary' and the natural boundary being the bank of Martin's Creek. Land from the bank of the Martin's Creek to the centreline of the creek (which forms part of the bed of Martin's Creek) can likewise be subject to a claim via Possessory Title by City of Ryde for the first Crown Grants remnant land, which carried a presumption *ad medium filum aquae*.

What would have happened if the land in the two Certificates of Title, which included Portions 231, 232, 235 and 236, had been consolidated across the creek by Ernest George Marwood? Most likely a residue after subdivision would have included the bed of the creek.

Either way, the titles to the land that Council seeks, with reference to Martin Reserve, have been identified and City of Ryde can now decide on any future course of action.

REFERENCES

de Belin F. (2019) Status of a stream: Who owns the creek? *Proceedings of Association of Public Authority Surveyors Conference (APAS2019)*, Pokolbin, Australia, 1-3 April, 231-250.

APPENDIX

Chains of Title: Progressing from the Crown Grants to Certificates of Title for Ernest George Marwood

Portion 231

29 March 1886 … Transfer 105901
to Henry Joseph Couloignier & Felician Zephirim Muraire
13 October 1892 … Transfer 206720
to Peter Le Rennetel & Charles Murlay & Zephirim Muraire
25 June 1908 … Transfer 508965
to Andre Jean Marion & Placide Huault & Francois Laurent
9 November 1925 … Transfer B 354279
to Francois Laurent & John Rausch & Eugene Courtais
20 July 1926 … Transfer B 428036
to James Gilmour
16 December 1926 … Transfer B 468550
to **Ernest George Marwood**

5 December 1941 … Transfer and Grant D 94778 of Drainage Easement 10 feet wide
to **Ryde Council**, within Portion 231 and connecting Magdala Road to Martin's Creek

Portion 232

13 October 1892 … Transfer 206720
to Peter Le Rennetel & Charles Murlay & Zephirim Muraire
25 June 1908 … Transfer 508965
to Andre Jean Marion & Placide Huault & Francois Laurent
22 March 1925 … Transfer B 218469
to Jean Baptiste Chevreuil & Francois Laurent & Eugene Courtais
9 November 1925 … Transfer B 354279
to Francois Laurent & John Rausch & Eugene Courtais
20 July 1926 … Transfer B 428036
to James Gilmour
16 December 1926 … Transfer B 468550
to **Ernest George Marwood**

New Certificate of Title Vol 5329 Fol 56:
23 June 1942 … Order No. D 129002
to **Ernest George Marwood**

Vol 6515 Fol 192
23 July 1951 … Transfer F 590168 of Lot B in subdivision DP 19636
to Thomas James Brownhill

New Certificate of Title 2/1173115 (2012) for residue
to **Ernest George Marwood**

Portion 233

17 May 1887 … Transfer 121604
to John Archdale Palmer
27 July 1898 … Transfer 280363
to Mary Louisa Palmer
18 September 1919 … Transfer 510036
to John Henry Turbil

Portion 233 & 234

Travelling together as one parcel / tenants in common.

CT Vol 3902 Fol 216
26 August 1926 … Transfer B 394798
to Edward Coleman

CT Vol 3902 Fol 217
26 August 1926 … Transfer B 394798
to Donald William Finlay

Back into one title.

CT Vol 4550 Fol 210
4 November 1932 … Transfer C 146256
to Edward Coleman

Then into separated portions again.

Portion 233

CT Vol 5823 Fol 47
6 May 1948 … Transfer D 780771
to Wallace Gerald Thomas Sampson and Cecily Joyce Sampson

CT Vol 6035 Fol 128
6 October 1949 … Order No. D 982948 of Lot 1 in subdivision DP 21800 (1949)
to Wallace Gerald Thomas Sampson and Cecily Joyce Sampson

CT Vol 6240 Fol 65
18 December 1950 … Transfer F 313603 of Lot A in subdivision DP 366927 (1949)
to Desmond Alfred Shaw and Rene Dorothy Shaw

CT Vol 8055 Fol 133
5 December 1960 … Transfer H 464100 of Lot D in subdivision DP 416661 (1959)
to Contemporary Timber Homes Pty Ltd

who subsequently subdivided the land by DP 203206 (1960), which created Lot 29 as Drainage Reserve.

CT Vol 9096 Fol 19
8 May1961 … Transfer H 795859 of Lot 29
to **The Council of the Municipality of Ryde**

being Certificate of Title 29/203206 in the current format.

Portion 234

CT Vol 5823 Fol 48
6 May 1948 … Transfer D 780771
to George James Warr

CT Vol 7864 Fol 133
9 March 1960 … Transfer H 207759 of Lot X in subdivision DP 412605 (1959)
to Contemporary Timber Homes Pty Ltd

who subsequently subdivided the land by DP 30900 (1959), which created Lot 29 as Drainage Reserve.

CT Vol 7983 Fol 81
7 September 1960 … Order No. H 561495
to Contemporary Timber Homes Pty Ltd

CT Vol 8055 Fol 75
5 December 1960 … Transfer H 521256 of Lot 29
to **The Council of the Municipality of Ryde**

being Certificate of Title 29/30900 in the current format.

Portion 235

2 April 1886 … Transfer 106057
to Henry Joseph Couloignier and Felecian Zephirim Muraire
13 October 1892 … Transfer 206920
to Peter Le Rennetel & Charles Murlay & Zephirim Muraire
25 June 1908 … Transfer 508965
to Andre Jean Marion & Placide Huault & Francois Laurent
22 March 1925 … Transfer B 218469
to Jean Baptiste Chevreuil & Francois Laurent & Eugene Courtais
9 November 1925 … Transfer B 354279
to Francois Laurent & John Rausch & Eugene Courtais
20 July 1926 … Transfer B 428036
to James Gilmour

16 December 1926 … Transfer B 468550
to **Ernest George Marwood**

CT Vol 5356 Fol 78
10 December 1942 … Order No. D 168949

New Certificate of Title Auto Consol 5356-78 (2012) for residue Lot 3 in DP 1173115
to **Ernest George Marwood**

Portion 236

2 April 1886 … Transfer 106057
to Henry Joseph Couloignier and Felecian Zephirim Muraire
13 October 1892 … Transfer 206920
to Peter Le Rennetel & Charles Murlay & Zephirim Muraire
25 June 1908 … Transfer 508965
to Andre Jean Marion & Placide Huault & Francois Laurent
22 March 1925 … Transfer B 218469
to Jean Baptiste Chevreuil & Francois Laurent & Eugene Courtais
9 November 1925 … Transfer B 354279
to Francois Laurent & John Rausch & Eugene Courtais
20 July 1926 … Transfer, B 428036
to James Gilmour
16 December 1926 … Transfer B 468550
to **Ernest George Marwood**

CT Vol 5356 Fol 78
10 December 1942 … Order No. D 168949

New Certificate of Title Auto Consol 5356-78 (2012) for residue Lot 1 in DP 1173115
to **Ernest George Marwood**

Is there a Future for the Survey Peg?

Michael Spiteri
Public Works Advisory
NSW Department of Planning, Industry and Environment
michael.spiteri@finance.nsw.gov.au

ABSTRACT

Survey marks are a big part of a surveyor's life. From having to find old survey marks placed and buried years ago to connecting to the state geodetic network and marking new property boundaries, survey marks make up so much of the tasks carried out by a cadastral surveyor. The requirements for survey marking have evolved from early surveying in this country, brought over by the First Fleet and then subsequently changed by various Surveyor Generals over the years as technology and techniques changed. This evolution has come to the point as detailed in the current Surveying and Spatial Information Regulation 2017, which was only recently made. The standards for marking have typically been based on cost and efficiency, and what was easily available on hand. The wooden boundary peg is a prime example of this, typically formed from local timber available on site and fashioned by hand to meet the standards at the time and to suit the conditions being faced. Due to changes to the nature of our work, particularly cadastral work being more urbanised, and the increased need for efficiency, easy transportation, mass production and reduction of survey team size, the wooden survey peg has had to evolve. Furthermore, there was the need for standardising across surveys to assist other occupations and the public to understand which peg actually marked their boundary corners. Our current requirements for pegs are 350 mm long with a top of 75 mm by 35 mm for urban surveys and 450 mm long with a top of 75 mm by 75 mm for rural surveys, made of sound, durable hardwood or white cypress pine or polycarbonate. However, are this type and the other boundary and reference marks we currently use sustainable into the future? This paper investigates our current marking requirements, considering their deficiencies and strengths, compares current standards to our past and to other jurisdictions within Australia and overseas, and formulates some ideas for the profession to consider as we head into the future.

KEYWORDS: *Cadastral, survey marks, survey peg, boundary mark, reference mark.*

1 INTRODUCTION

The survey profession has a long and distinguished history, which provides the foundation for our current practices, standards and techniques, but what will the future hold? The world is not static, and society views and expectations are continually evolving as new technology and ideas are introduced. Even in the last 20 to 30 years, we have seen the introduction of an array of new technology that has developed into now common everyday tools. Technology such as Global Navigation Satellite Systems (GNSS), laser scanners, drones, smart phones and improving computer power has enabled us to collect large amounts of data in a quicker time, thereby having a large impact on the way surveys are carried out. One constant during this time has been survey marking, but this too is under pressure from our changing world. Will the practices we use today still be here in the future? Can we learn anything from our past or from comparing our current practices to other jurisdictions?

This paper investigates how the marking standards developed in NSW and compares these with current marking standards of other jurisdictions across Australia and New Zealand as well as overseas. It then looks into the future and discusses changes that could be made to our current marking standard to meet the pressures of our changing world, with the main aim to spark discussion within the surveying profession regarding the role of surveying marking and surveyors into the future.

2 REVIEW OF PAST MARKING STANDARDS IN NSW

The foundations of our current marking standards are based on the original marking standards brought to NSW by each of the early Surveyor Generals. The main focus for early marking was to quickly map the new colony and mark out the early land grants. As such, marks were mainly pegs fashioned from wood, which was obtained on site, and nearby trees being blazed and marked, with the main aim to quickly mark land grants and ensuring that boundary extents were identifiable to the land owners in the area. Due to the constraints on equipment available, the type of country in which measurements were being made, and the urgent nature for surveys to be completed, marking overrode measurement. This is still one of the overriding principles in our current marking standards, even though our measurement accuracy is so much greater.

It was also figured out early in the development of NSW that standardisation of marking was required to provide consistency between surveys and ensure land owners and the general public could identify official marking of boundaries. This saw the introduction and development of the first survey directions, which subsequently became the basis of our current Surveying and Spatial Information Regulation 2017 (NSW Legislation, 2017). The first known written direction to surveyors was a circular to surveyors issued in 1836 during the term of Surveyor General Mitchell. From this initial direction, over the years, there has been the introduction of new types of survey marks and marking standards with the issuing of each new direction or regulation. Table 1 lists the major milestones in the development of marking standards in NSW, as detailed in Marshall (2002).

Table 1: Major milestones in development of marking standards in NSW (Marshall, 2002).

Date	**Milestone**
1 January 1836	First recorded directions - Surveyor General Mitchell to all surveyors.
10 April 1848	Specification for corner marking.
9 July 1853	Blazed lines, numbered reference trees and lockspitting.
11 August 1855	Report from the Commissioners appointed to inquire into the Surveyor General’s Department.
9 May 1864	Line marking and trenches 20 links in length. Town sections to be lockspitted 6 links long and allotments 4 links only. Road surveys - marking of mile trees. Adoption of standard needle. Reference to corner schedule introduced on plans. Rock on boundary line to be marked with a pick line - portion corners with broad arrow. Forerunner of permanent marking in town surveys introduced. Posts to be mounded.
30 January 1872	The use of circumferentor is prohibited. Maximum offsets to natural features introduced. Road marking formalised - 3” square peg introduced - mile posts 4’ 6” long and not less than 12” in diameter. Trenching standardised to 10 links in length in both town and country. Plain country remains at 20 links.

	Corner marking of portions where no trees exists - pegs to be 30” long and driven 18” into the ground (survey post). Expressions of bearing to be related to North and South only.
1 May 1882	A “dot”, the forerunner of the drill hole is introduced. Intervisible line marks of a permanent nature invoked - pegs 3” by 2” by 18” long. In plain country and in absence of trees - peg to be mounded by earth 6’ in diameter and 2’ high. Steel ribands in use - 66’ long only. True bearing to be determined by stellar or solar observations. Bearings to be observed to trigonometrical stations. Fence posts, marked with a broad arrow over the letter R.
September 1884	Introduction of limits of error allowable in closes. Mode of marking standard length - chain standardisation.
July 1886	Alignment stakes in lieu of trenching. Permanent marking introduced, e.g. bottle, gas-pipe, iron bolt, vertically below survey post at corner, 3’ 6” below ground surface - homestead leases only. Fence posts marked with the broad arrow over the letters RD. Reserve roads to be marked on both sides. Lineal closures introduced into regulations. Bearings of reference to corners to read 0 to 360. The 5-chain steel riband introduced to the regulations.
20 February 1895	Special marking of surveys for recovering of azimuth and the standard of measure of a survey.
24 January 1901	Survey stakes to be 4” by 4” by 24” long. Alignment and direction stakes to be 18” long and 3” by 2”. Reference and corner posts to be 3’ 6” long, 6” square or 8” in diameter. All corner and/or reference trees to be blazed on four sides. Lines of stones acceptable in lieu of lockspits. Drilled hole at a corner on rock introduced. Line pegs at 10-chain intervals - reference stations each 80 chains. A concentric circle on plans to indicate a special mark. Gunter’s chain ceases to be standard equipment. Instructions for alignment of streets introduced - consequent to Municipalities Act, No. 23 AD 1897. Omissions of fractional quantities on plans.
2 December 1914	Reference trees to be within 200 links of corners. Widths of lanes in towns amended to 20’ wide and not less than 31 links.
1 January 1915	Issuing of Instructions to Surveyors by the Registrar General’s Department - the first instructions specifically for surveyors undertaking surveys of real property land.
June 1920	Survey marking under the Local Government Act 1919 introduced in Ordinance 32.
12 May 1933	Commencement of the Survey Practice Regulations 1933. These regulations applied to both Crown surveys and real property surveys.
1 October 1963	Portion corner pegs become 3” square and 21” long in lieu of 4” square. Lockspits become 4’ long in lieu of 10 links. Reference trees beyond 150 links of the corner necessitates placement of additional marking pursuant to Survey Practice Regulations 1933 - reference trees up to 300 links. Crown survey bound by Survey Practice Regulations 1933 as well as the special requirements of the Department of Lands. Age of fencing defined. Dimension of alignment pins prescribed for the first time.
1 January 1981	Lockspits 1 m long.
1 September 1990	Commencement of the Survey Practice Regulation 1990. Requirements for the connection of surveys to the survey control network.
1 October 1994	Minor amendments to the Survey Practice Regulation 1990 - refinement of requirements for connections to the survey control network and use of the Integrated Survey Grid for orientation.
1 September 1996	Commencement of the Surveyors (Practice) Regulation 1996.
1 September 1998	Commencement of the Survey Co-ordination Regulation 1998. Minor amendments made to clarify certain clauses. Use of Type 3 State Survey Marks discontinued.

In addition to Marshall's (2002) list, Table 2 lists other regulations for survey marking that have been introduced since 1998.

Table 2: Changes in survey regulations since 1998.

Date	Milestone
1 September 2001	Commencement of Surveyors (Practice) Regulation 2001, which replaced the Surveyors (Practice) Regulation 1996. Introduction of use of Map Grid of Australia for orientation. Allowance for cadastral surveys using Global Positioning System (GPS) included. Surveyor to indicate type of survey - urban or rural.
25 June 2003	Repeal of Surveyors Act 1929, Survey Co-ordination Act 1949, Survey Co-ordination Regulation 1998, Survey Marks Act 1902 and Survey (Geocentric Datum of Australia) Act 1999. Surveyors (Practice) Regulation 2001 renamed Surveying Regulation 2001 and incorporates the majority of the provisions included in the repealed legislation. Mining surveying and registration incorporated into Surveying Regulation 2001. Approved boundary marks, permanent marks, and conventional symbols and signs added as schedules of the Surveying Regulation 2001. Introduction of non-corrodible rod or spike as approved boundary mark. Introduction of galvanised iron star picket, non-corrodible nail in timber and PVC pipe as approved reference marks.
1 September 2006	Commencement of Surveying Regulation 2006, which replaced the Surveying Regulation 2001. Use of GPS extended to other Global Navigation Satellite System (GNSS) equipment and measurements derived by this type of equipment are to be noted on plan of surveys. The showing of natural boundaries on plans changed from traverse/offsets/ radiations to table of short lines directly along natural boundary. Introduction of polycarbonate pegs, non-corrodible nail in concrete/rock, star picket and boundary mark tokens as approved boundary marks.
14 December 2009	Surveying Regulation 2006 renamed to the Surveying and Spatial Information Regulation 2006.
1 September 2012	Commencement of Surveying and Spatial Information Regulation 2012, which replaced the Surveying and Spatial Information Regulation 2006. Schedule detailing street addresses for each property surveyed to be included on plan of survey. For partially surveyed or compiled surveys, the type of terrain needs to be indicated on plan. Introduction of Permanent Survey Mark Type 11 (Tier 2 CORS Pillar), Permanent Survey Mark Type 12 (Tier 3 CORS Pillar - Freestanding), and Permanent Survey Mark Type 14 (Tier 3 CORS Pillar - Wall mounted). Introduction of non-corrodible nail and wing in tree, non-corrodible nail in concrete, and PVC star picket introduced as approved reference marks.
18 December 2015	Introduction of new State Survey Mark Type 15.
1 September 2017	Commencement of Surveying and Spatial Information Regulation 2017, which replaced the Surveying and Spatial Information Regulation 2012.

Upon review of the marking standards, some common themes appear amongst the various standards. These include:

- The need to mark boundaries so that they are readily and unambiguously discernible on the ground.
- Consistency between surveys, in particular shape and size of marks and standard of measurement.
- The need to place or connect to permanent marks to allow future surveyors to re-establish boundaries.

- Flexibility of types of marks available to cater for all types of terrain and specific situations, e.g. drill hole & wing in concrete, PVC pipe in swampy areas.
- Continual evolution of marking to cater for availability of material suitable for marking, the introduction of new types of marks that may be suitable for marking, new and different techniques of installation, changes in terrain (particularly the increase of hard surfaces such as concrete and bitumen), and the cost of marking.

The one common mark over all the standards is the wooden peg. It has come in many sizes but remains the most common boundary mark for most surveys. The wooden peg does have its disadvantages of being susceptible to fire, pests, disease, movement and removal, but in most cases, it is easy to manufacture, easy to install and the material is easy to source. The use of wood into the future may be affected by cost and availability of hardwood, particularly with the continued trend of replacing hardwood forests with quicker growing softwood forests. Another aspect that may need to be considered is the sustainability of this particular material. Deforestation and the release of carbon into the atmosphere may also affect the availability of wood into the future.

However, the wooden peg cannot be used in all situations, e.g. rock and concrete, and is not permanent in nature due to its disadvantages. As such, a number of alternative marks have been developed to cater for situations where wooden pegs cannot be placed and to provide more permanency to the marks to enable surveyors to re-establish the boundaries in the future. Our environment is also becoming more highly urbanised, which means an increase of hard surfaces such as concrete and bitumen, unsuitable for the wooden peg. Flexibly in types of boundary marks will therefore become important due to the various surfaces that may be encountered while marking out boundaries.

Initially trees were marked and lockspits placed, but these also had the same disadvantages as the wooden peg. This saw the introduction of special marks such as rock marks, gas-iron pipes, bottles and iron bolts. In urban areas, efforts were put into permanently marking street alignments with marks such as alignment posts, stones or pins. Later with the introduction of the Local Government Act, street alignments were marked with concrete blocks at set offsets from the street alignment. This made re-establishing the street alignment a less onerous task for surveyors and authorities. The disadvantages were subsequent conflicts with the installing of utilities in the street and the reconstruction of kerbs with many marks destroyed. One main reason would be the lack of resources placed into the maintenance and replacement of alignment marks, with other works such as road construction and utility installation having far more importance in the eyes of government and the public, even though the survey marks were used to assist in the construction of roads and utilities. Set offsets were changed from 3 feet 6 inches (3’ 6”) to 1 foot 6 inches (1’ 6”) to counter this, but without success, so subsequently surveyors were allowed to place reference marks at any distance less than 30 m from a boundary corner, in such a place which the surveyor felt would not be destroyed by subsequent road and utility construction.

The destruction of survey marks would be an ongoing battle for the profession with various changes to the marking standards implemented to counter the destruction. Changes such as placing more marks, making marks more visible and authoritative looking, connecting surveys to current geodetic datum, and deferment of the placement of survey marks. These have all initially assisted in the protection of survey marks, but due to a lack of diligence from the profession to support these initiatives fully and a lack of ignorance from Council, utility providers and the public, survey marks continue to be destroyed. Ignorance does not only include the lack of understanding of how important survey marks are for re-establishing boundaries but also the lack of understanding of the effort and cost involved in establishing the marks in the first instance, their maintenance and re-establishment if destroyed. There is also a lack of understanding of the extra costs in re-establishing boundaries when survey marks are destroyed, which in most cases are passed onto consumers via higher survey fees, even though competition within the profession lowers the effects of the full cost of establishing property boundaries.

3 CURRENT MARKING STANDARDS IN NSW

The current marking standard in NSW is the Surveying and Spatial Information Regulation 2017 (NSW Legislation, 2017). This legislation came into force on 1 September 2017, repealing the previous marking standard, being the Surveying and Spatial Information Regulation 2012. A summary of the marking standards contained in the Surveying and Spatial Information Regulation 2017 is contained in Table 3.

Table 3: Current marking standards in the Surveying and Spatial Information Regulation 2017.

Subject	**Details**
Datum and orientation of surveys	Surveys must be connected to Map Grid of Australia 94 (MGA94) if established permanent marks are within 300 m of land surveyed for urban surveys and within 1,000 m of land surveyed for rural surveys at the time of writing this paper. In other cases, rural surveys still need to be connected to MGA94 by connecting to established permanent marks within 5,000 m or by approved GNSS methods. For urban surveys where established permanent marks are not within 300 m, surveys can either be connected to MGA94 by connecting to established permanent marks within 1,500 m or by approved GNSS methods or establish datum and orientation from marks shown on a plan filed or recorded with the Registrar General. It is noted that from 1 January 2020, surveys are required to connect to the new Map Grid of Australia 2020 (MGA2020) datum.
Boundary marking	All corners of the land surveyed and the lines of the land surveyed need to be marked with an approved boundary mark. The only exception are natural boundaries such as mean high water and banks of streams. Where a boundary mark cannot be placed at a boundary corner, an approved reference mark must be placed unless the corner is within the material of a structure. Unless a peg is placed, details of the mark placed are to be noted on plan or obstructed corner to be shown if corner is within the material of a structure.
Approved boundary marks	**Peg** of sound durable hardwood or white cypress pine pointed for about two-thirds of its length or polycarbonate pegs as approved. Pegs for rural surveys to be at least 450 mm long and at least 75 mm by 75 mm nominal section at the top end. Pegs for urban surveys to be at least 350 mm long and at least 75 mm by 35 mm nominal section at the top end. Peg to be placed upright in the ground, pointing downwards and top not more than 80 mm above ground level. **Drill hole** of at least 5 mm in diameter and at least 10 mm deep drilled into rock, concrete or substantial structure and if practicable a chiselled wing cut and directed to the mark. **Non-corrodible nail** at least 65 mm long driven completely into fixed timber and if practicable a chiselled wing cut and directed to the mark. **Solid metal spike** at least 300 mm long and external diameter of at least 20 mm placed vertically and driven flush to the surface. Only to be used if placement of a peg is not practicable. **Galvanised iron pipe** at least 300 mm long with an internal diameter of at least 20 mm and a rim wall thickness of at least 3 mm placed vertically and driven flush to the surface. Only to be used if placement of a peg is not practicable. **Star picket** at least 450 mm long placed vertically and at least flush with the surface of the ground.

	Non-corrodible token at least 32 mm in diameter and 1.5 mm thick with “Boundary Mark” permanently stamped, engraved or etched on the upper surface, secured using a non-corrodible nail, spike, rivet or screw. **Non-corrodible nail** at least 50 mm long and 6 mm in diameter placed in a drill hole of a minimum of 5 mm diameter into rock, concrete or substantial structure and if practicable a chiselled wing cut and directed to the mark or a boundary mark token secured. **Broad arrow** comprising three chiselled wings at least 80 mm long, 20 mm wide and 10 mm deep at the base, pointed at one end, cut in rock, concrete, substantial structure or fixed timber. Only used for surveys carried out by Surveyor General or public authority. **Steel fence post**, excluding a star picket, which is durable and installed in a permanent and stable base. **Marks approved** by the Surveyor General from time to time.
Additional requirements for marking of unfenced rural survey boundaries	Line marks to be placed on boundary line at intervals of at least 200 m if not visible between line marks and at least 500 m if visible between line marks. Lockspits to be placed in the direction of the boundary from each corner, angle or line mark. Lockspits are to be a trench or line of packed stones not less than 1 m long, 200 mm wide, 150 mm deep and commencing 300 mm from each boundary mark. If type of soil renders trenches ineffective, direction stakes at least 50 mm wide by 30 mm thick by 450 mm long may be placed in the direction of the boundary lines 4 m distant from the corner. Unless environmental considerations dictate otherwise, boundary must be reasonably cleared and any tree with a trunk diameter greater than 100 mm and within 500 mm of the boundary must be blazed or if situated on the boundary, double blazed.
Placement of reference marks	For urban surveys when abutting a road, a reference mark is to be placed at each extremity of the land surveyed, including the junction or intersection of roads and at intervals of not more than 100 m along a road frontage that has intervening side boundaries. If an urban survey does not abut a road, at least two reference marks in suitable locations to be placed in relation to the land surveyed. For rural surveys, reference marks must be placed at the extremity of the land surveyed, road intersections, at intervals of not greater than 1,000 m along roads and not greater than 500 m along banks of streams, and not greater than 2,400 m for other boundaries. Each parcel should have two reference marks in positions suitable for redefinition.
Approved reference marks	**Permanent Survey Marks** as described in Schedule 4 of the Surveying and Spatial Information Regulation 2017, i.e. marks in ground in cover box, brass plaques in concrete/kerb, trigonometrical stations, and CORS stations. **Drill hole** at least 5 mm in diameter and at least 10 mm deep drilled into rock, concrete or substantial structure with chiselled wing cut and directed to the mark. **Chiselled wing** at least 80 mm long, 20 mm wide and 10 mm deep at the base, pointed at one end, cut in substantial structure, fixed timber or the sound wood of a suitable tree where point of the chiselled wing being the reference point and chiselled wing to face towards the relevant corner. **Broad arrow** comprising three chiselled wings at least 80 mm long, 20 mm wide and 10 mm deep at the base, pointed at one end, cut in rock, concrete, substantial structure, fixed timber or the sound wood of a suitable tree. Only used for surveys by Surveyor General or public authority. **Metal spike** at least 300 mm long with an external diameter of at least 20 mm placed vertically and at least 80 mm below ground surface. **Galvanised iron pipe** at least 300 mm long, an internal diameter of at least 20 mm and a rim wall thickness of at least 2.6 mm, placed vertically and at least 80 mm below ground surface. **Specific point** on a permanent and substantial structure and if practicable a chiselled wing must be cut and directed to the mark. If the corner referenced abuts a road an additional reference mark must be placed. **Galvanised star picket** at least 450 mm long placed vertically and at least 80 mm below the surface of the ground.

	Non-corrodible nail at least 65 mm long driven completely into fixed timber or driven into the sound wood of suitable tree, and if practicable a chiselled wing cut and directed to the nail. **PVC star picket** at least 600 mm in length made of material with a thickness of at least 3 mm, placed vertically and at least 80 mm below ground surface in soil, swampy or marsh areas. **Reinforced concrete block** in form of a truncated pyramid 400 mm long, 150 mm square at the lower end and 100 mm square at the upper end. A non-corrodible nail or plug at least 80 mm long to be inserted at least 75 mm into top. Concrete block to be placed vertically and at least 80 mm below ground surface. **Non-corrodible token** at least 32 mm in diameter and 1.5 mm thick with “Reference Mark” permanently stamped, engraved or etched on the upper surface, secured with a non-corrodible nail, spike, rivet or screw. **Non-corrodible nail** at least 50 mm long and 6 mm in diameter placed in a hole of 5 mm in diameter drilled into rock, concrete or substantial structure with a chiselled wing cut and directed to the mark or a reference mark token secured.
Connecting and placement of permanent marks	Surveys to be connected to a minimum of two permanent marks, either existing or placed. Further permanent marks need to be connected if survey involves more than 10 parcels or if survey redefines the frontage of a formed road or creates a new road greater than 1,000 m for an urban survey and 200 m for a rural survey. New permanent marks to be placed to a position suitable for orientation of survey and redefinition of the survey (particularly in regards GNSS methods), be located in a position unlikely to be disturbed, situated at road junctions, road intersections, road angles or crest of hills so as to be visible from other permanent marks without obstruction and suitable for inclusion in the State Control Survey. Sketch plans to be prepared for all new permanent marks. Heights for new permanent marks to be determined if survey has been connected to existing permanent marks which have appropriate height accuracy.
Approved permanent marks	Type 1 State Survey Mark (brass plague), Type 2 State Survey Mark (brass plague), Type 4 Permanent Mark Urban Type (stainless steel pin with cover box), Type 6 Permanent Mark Non-Urban Type (star picket with cover box), Type 7 Permanent Mark (feno spike with cover box), Type 8 Permanent Mark DWR “C-Type” (steel rod and pipe with cover box), Type 9 Trigonometric Station (concrete pillar), Type 10 Trigonometric Station (rooftop pillar), Type 11 Tier 2 CORS Pillar (concrete pillar), Type 12 Tier 3 CORS Pillar (freestanding), Type 13 Tier 3 CORS Pillar (wall mounted, no eaves), Type 14 Tier 3 CORS Pillar (wall mounted, with eaves), Type 15 State Survey Mark (stainless steel pin and disc), Type 16 State Survey Mark (domed brass plague).

Changes introduced into the Surveying and Spatial Information Regulation 2017 include:

- The requirement for all rural surveys to be connected to Map Grid of Australia 94 (MGA94) via established permanent marks or approved GNSS methods.
- The requirement for urban surveys to be connected to MGA94 slightly tightened to encourage the majority of urban surveys to be connected to MGA94 by connection to established permanent marks or approved GNSS methods.
- New schedules for the noting of coordinates of all permanent marks connected or placed as part of the survey, GNSS validation to ensure the survey has been correctly connected to MGA94, height schedule and height difference schedule of all permanent marks connected or placed if a new permanent mark has been placed and connected to permanent marks with accurate heights.

The strengths and deficiencies can be summarised as:

- Strong focus on connecting the cadastre to the current geodetic datum (MGA94, now MGA2020).
- Good flexibility in the types of marks that can be used.

- Strong emphasis on standardisation, accuracy of measurement and permanent marking of surveys.
- Too many marks or just enough?
- Rural surveys – do we still need to lockspit and blaze trees?
- Are we giving more incentive to surveyors to use newer types of marks or are we allowing them to just continue with the same techniques?
- Do any marks need to be phased out?
- Profession centric – are we considering the needs of the public?

4 MARKING STANDARDS IN OTHER JURISDICTIONS

4.1 Australian Capital Territory

The current marking standard in the Australian Capital Territory are the Surveyors (Surveyor-General) Practice Directions 2013 (No 1) (ACT Legislation, 2013). A summary of the marking standards contained in the Surveyors (Surveyor-General) Practice Directions 2013 (No 1) is contained in Table 4.

Table 4: Current marking standards in the Australian Capital Territory.

Subject	**Details**
Datum and orientation of surveys	The bearing used for the orientation of the survey shall: a) where possible and practical, be calculated from co-ordinate values of established survey control marks. Such coordinates shall be obtained from the ACT Government Survey Control Mark Register within 3 months before the completion of the survey and be accurate to Class C Order or better. The bearing adopted must be verified by angular connection, and (if practicable) distance connection, to at least one other established survey control mark; or b) be taken from a registered or approved survey plan either directly or by calculations from stated dimensions. Whenever possible the defining marks adopted shall be contained within a single registered or approved survey; or c) be obtained from GNSS observations; or d) be obtained from astronomical observations.
Boundary marking	For urban surveys, whenever possible, each corner must be firmly marked with a peg or mark as prescribed in the Directions. Where it is not possible or practical to mark a corner, an approved reference mark must be placed. In addition to the corners, all unfenced boundary lines shall be marked distinctly and durably with pegs or marks prescribed in the Directions placed at intervals of not more than 200 m, and the position shown on the plan. Marking of urban surveys shall not be completed until land servicing has reached a stage where all CRMs, reference marks and corner marking will be durable and stable. For rural surveys, all boundary lines which form or are to form the boundaries between parcels shall be marked distinctly and durably with a peg or mark prescribed by the Directions together with lockspits cut in the direction of each unfenced boundary from each corner and angle; and on unfenced boundaries with pegs or marks and lockspits as prescribed in the Directions placed at intervals of not more than 200 m where one peg or mark cannot be seen from the next, or 500 m where one peg or mark can be seen from the next, and the position shown on the plan. Where it is not possible or practical to mark a corner, an approved reference mark must be placed.
Approved boundary marks	Where any line or corner of any portion of a survey is required to be marked in accordance with the Directions, the points shall be firmly marked with a **peg**; **drill hole in rock, concrete, or similar material**; **a chisel mark or nail in fixed timber**; or **otherwise suitably marked**. For rural surveys, or surveys of blocks of 5,000 m^2 or more, all pegs shall be of sound durable wood at least 350 mm long and not less

	than 75 mm by 75 mm section at the top end. For urban surveys of blocks less than 5,000 m^2, pegs shall be of sound durable wood at least 250 mm long and not less than 75 mm by 35 mm section at the top end. All pegs are to be pointed for approximately two-thirds of their length and be bevelled at the top. All pegs are to be placed upright, so that the top is not more than 75 mm above the ground level for rural surveys and 40 mm above ground level for urban surveys. **Lockspits** shall consist of trenches at least 1 m long, 200 mm wide at the surface and 150 mm deep dug in the direction of the boundary lines and commencing 300 mm from each corner or angle or may consist of packed stones of similar dimensions. Where any corner, angle or other point is marked other than with a peg, where practicable wings shall be cut in solid rock, concrete or fixed timber, 75 mm long, 20 mm wide and 10 mm deep commencing 50 mm from the corner or where the surface renders it desirable lines may be painted at least 300 mm long and 20 mm wide. Where practicable, a corner or angle may be marked using a **boundary mark token** securely attached to timber, post, fence or other surface using a non-corrodible nail, spike, rivet or screw. The boundary mark token shall be at least 32 mm diameter and 1.5 mm thick, with "Boundary Mark" permanently stamped or etched on the upper surface.
Placement of reference marks	For urban surveys, when abutting a road, a reference mark is to be placed at each extremity of the land surveyed, including the junction or intersection of roads, and for streets where reference marks or CRMs have not been placed or have been disturbed reference marks are to be placed at intervals of not more than 150 m throughout the length of the frontage of the land surveyed. If an urban survey does not abut a road, two reference marks are to be placed suitable for orientation. For rural surveys, where the land surveyed is not being subdivided, at least two reference marks suitable for redefinition of the survey must be placed. Where land surveyed is being subdivided at least two reference marks must be placed in respect of each parcel. For road frontages, reference marks shall be placed at each extremity, and at intervals of not more than 1,000 m intervals. For boundaries, other than road frontages and exceeding 2,400 m, additional reference marks at intervals not more than 1,500 m must be placed.
Approved reference marks	**Reinforced concrete block** in form of a truncated pyramid 375 mm long, 150 mm square at the lower end and 100 mm square at the upper end with a galvanised nail or other suitable non-corrodible metal plug not less than 75 mm fixed therein. **Galvanised iron pipe** at least 300 mm long and internal diameter not less than 10 mm with a rim wall thickness of not less than 3 mm. **Solid non-corrodible metal spike** at least 300 mm long and having an external diameter of at least 20 mm. **Galvanised iron spike** at least 100 mm long driven into fixed timber with a wing 75 mm long cut into the timber and directed to the galvanised iron spike. **Drill hole cut into a kerb or other substantial structure** at least 5 mm in diameter and 10 mm deep with a wing at least 75 mm long, 20 mm wide and 10 mm deep at the base, and the point directed thereto. **Drill hole into bedrock** at least 10 mm in diameter and 25 mm deep with a wing 75 mm long and directed thereto where such bedrock exists within 300 mm of the natural surface of the ground. **Chisel mark** cut into the sound wood of a suitable tree. **Mark of durable character** or a **specific point** on a permanent or substantial structure.
Connecting and placement of CRMs	Existing CRMs within 200 m of an urban survey are to be connected to the survey by closed traverse. CRMs of the type of a plaque in concrete block or steel rod are to be placed at a ratio of at least 1 such CRM per one 100 parcels of land. CRMs of type of a plaque in concrete kerb shall be installed along roads at intervals of not more than 150 m throughout the length of the land surveyed and should have a clear line of sight to adjacent CRMs. Where a CRM is installed in such a position that it has, or the surveyor may have reason to consider that it may have in the future, clear line of sight only to one other CRM, then the surveyor shall place nearby a reference mark and shall connect the CRM to it by closed traverse.
Approved CRMs	Non-corrodible metal plaque set in a concrete kerb. Non-corrodible metal plaque set in the top of a concrete block in the form of a truncated pyramid at least 500 mm long, 450 mm square at the lower end and 300

	mm square at the upper end with a minimum volume of concrete of at least 0.07 m^3. Such mark shall be placed such that its highest point is flush with or below the surface of the ground. Deep driven stainless-steel rod.

As the Australian Capital Territory (ACT) is surround by NSW, it is not surprising that their marking standards are quite similar to NSW. Cross sectional sizes of pegs are the same as NSW but slightly smaller in length and must be of sound durable wood. Other types of boundary and reference marks are quite similar to NSW albeit with less options but do allow some flexibility by allowing other similar marks of the same durability and stability. The ACT standards also have a strong focus on the connection to and placement of Coordinated Reference Marks (CRMs) which are very similar to the network of Permanent Parks (PMs) and State Survey Marks (SSMs) in NSW. Their requirements require a closed network of CRMs to be installed in new roads at regular intervals of 150 m and clear line of sight between CRMs. As the name suggests, these marks are also coordinated and provide a strong basis for future surveys in the area.

4.2 New Zealand

The current marking standard in New Zealand are the Rules for Cadastral Survey 2010 (NZ Legislation, 2010). A summary of the marking standards contained in the Rules for Cadastral Survey 2010 is contained in Table 5.

Table 5: Current marking standards in New Zealand.

Subject	**Details**
Datum and orientation of surveys	Every bearing in a cadastral survey that defines or marks a new primary parcel boundary point must be oriented in terms of an official geodetic projection applicable to the area unless the survey does not make a new field measurement or if the survey is a boundary reinstatement survey.
Boundary marking	The following boundary points must be marked, where practicable: a) each new boundary point on a new primary parcel, unless: i. it is a boundary point that is only between new parcels that are all intended to remain in Crown ownership, or ii. it is on a survey under the jurisdiction of the Maori Land Court, or iii. it is a boundary point that is only between parcels that are required to be, or as a result of the survey will be required to be, held in common ownership, or iv. it is on a boundary where parcels on each side of that boundary are required to be, or as a result of the survey will be required to be, subject to reciprocal rights of way, or v. it is unlikely that it will need to be physically located in the foreseeable future because of the terrain, ground cover, or protected vegetation, or vi. the boundary point is readily identifiable by occupation along the boundary; b) each boundary point on an existing boundary of a new primary parcel, that is required to be defined by survey, unless: i. a reliable mark is already in place, or ii. it is part of a parcel where the title is to remain limited as to parcels and the boundary point is not in common with a new parcel where the limitation is not going to remain; and c) each primary parcel boundary point that results from an existing irregular class A boundary that is being converted to one or more right-line boundaries.
Approved boundary marks	A new boundary mark must be: a) a wooden **peg**, chamfered at the top, with a minimum width of 45 mm and at least 3,000 mm^2 in cross-section, or b) a **post**, or c) any other type of peg that is clearly labelled as a boundary mark, or

	d) if the above marks are impractical, **any other type of mark** which must, if practical, be clearly labelled as a boundary mark. A new boundary mark must be: a) soundly anchored in place, and b) readily visible, where practical.
Placement of witness marks	The following points on a cadastral survey must be witnessed: a) every boundary point on a primary parcel boundary that is being defined by survey, b) every new boundary point on a parcel where the purpose of the parcel is for a lease and the boundary is not a permanent structure boundary, c) every new or old boundary mark on the boundary of a parcel under survey, and d) every new stratum boundary point. A cadastral survey must have at least one witness mark within the applicable horizontal distances specified in the Rules (Class A – 150 m, Class B – 500 m, Class C – 1,000 m, Class D – n/a) for each of the boundary points specified above. In the case of an extensive rural boundary point, the class B distance may be increased to 1,000 m if the survey is connected by vectors to one or more cadastral survey network marks. A survey that requires a witness mark under the Rules must include a minimum of three witness marks if all boundaries are class A, or a minimum of four witness marks if any boundaries are class B or C. A boundary reinstatement survey must include a minimum of one witness mark.
Approved witness marks	An adopted mark cannot serve as a witness mark. A witness mark must be in a different position to the boundary point it is witnessing and be made of sufficiently durable material, set in sufficiently stable material, and located in a suitable position, so that it can be reasonably expected to survive and remain useable for at least 10 years.
Connecting and placement of permanent marks	Every cadastral survey that is required to have a witness mark by the Rules must include a minimum of two permanent reference marks (PRMs). A boundary reinstatement survey is not required to include a PRM. At least two PRMs required by the Rules must be within the applicable horizontal distance specified in the Rules of a least one boundary point that is required to be witnessed (Class A – 300 m, Class B – 500 m, Class C – 1,000 m, Class D – n/a). In case of an extensive rural boundary point, the class B distance may be increased to 1,000 m if the survey is connected by vectors to one or more cadastral survey network marks. A PRM that complies with the distance requirements specified in the Rules may be used as a witness mark. Two PRMs must also have reduced levels if any of the witness marks are required to have reduced levels.
Approved permanent marks	An adopted mark cannot serve as a PRM. A PRM must be in a different position to a new boundary point, and be made of sufficiently durable material, set in sufficiently stable material, and located in a suitable position, so that it can be reasonably expected to survive and remain useable for at least 50 years.

The types of marks included in the New Zealand marking standards are very flexible, with the choice of mark for each particular situation left to the surveyor's professional judgement. The main aim is that any boundary mark must be identifiable as a boundary mark, stable and visible, that witness (reference) marks should be durable, stable and located in positions which are unlikely to be disturbed for at least 10 years, and permanent reference marks be durable, stable and located in positions which are unlikely to be disturbed for at least 50 years. The default option for corner pegs are wooden pegs smaller in cross section than NSW at 45 mm square. Once again there is a strong focus to connect surveys to existing coordinated geodetic marks and the placement of such marks, with connection distances similar to NSW.

4.3 Northern Territory

The current marking standard in the Northern Territory is the Licensed Surveyors Act 1983 (NT Legislation, 1983) and the various Survey Practice Directions such as the Survey Practice Directions 2014 – Surveys outside of coordinated survey areas (NT Surveyors Board, 2014). A summary of the marking standards contained in the Licensed Surveyors Act 1983 and various Survey Practice Directions is contained in Table 6.

Table 6: Current marking standards in the Northern Territory.

Subject	**Details**
Datum and orientation of surveys	A survey within a coordinated survey area is to be in accordance with an approved methodology to delimit land boundaries by geodetic coordinates or with another system of delimitation. For uncoordinated areas, a datum line consisting of at least 3 reasonably spaced original marks or groups of marks is adopted for each survey. The survey must ensure that sufficient work is carried out to confirm that the marks are in their original positions or that they can be related to their original positions.
Boundary marking	For uncoordinated areas: A surveyor must ensure that, in an urban area, each angle, bend or corner of a section, portion or unit not defined or referenced by a structural element, is – 1) if the area of the section, portion, lot or unit is not more than 1 ha – marked by a peg; 2) if the area of the section, portion, lot or unit is not more than 10 ha – marked by a peg or a steel peg; 3) if the area of the section, portion, lot or unit is more than 10 ha – marked by a steel peg. For urban areas, a surveyor must ensure immediate pegs are placed on all boundary lines which are not defined or referenced by structural elements in intervals of not more than 100 m. A surveyor must ensure that, in rural areas, each angle, bend or corner of a section, portion, lot or unit not defined or referenced by a structural element, is – 1) if the area of the section, portion, lot or unit is not more than 10 ha – marked by a peg or steel peg; or 2) if the area of the section, portion, lot or unit is more than 10 ha – marked by a steel peg and a finder. For rural areas, a surveyor must ensure immediate pegs are placed on all boundaries which are not defined or referenced by structural elements in intervals of approximately 400 m and not more than 500 m. For boundary lines greater than 3,000 m, a steel peg and finder are to be placed at near intervals of 2,000 m. If a boundary mark is not visible from the next adjoining boundary mark on a boundary line, a finder is to be placed on the boundary line of not less than 20 m from each bend, corner or intermediate mark so as to indicate the direction of the boundary line. A surveyor must ensure that a boundary described as a parallel of latitude is marked in a series of chords not more than 10,000 m long.
Approved boundary marks	A surveyor must ensure that a survey mark is constructed of concrete, steel or hardwood or another material that will resist destruction by fire, decay and termites. **Peg**, being a white-painted, flat-topped mark not less than 50 mm square and 350 mm in length, driven at least 250 mm into the ground. **Steel peg**, being a white-painted, steel star dropper not less than 600 mm in length driven at least 450 mm into the ground. **Another mark that is approved by the Board from time to time**. If the above marks are impracticable or unsuitable in a particular case, a surveyor may place or adopt marks of equivalent durability and stability. A surveyor must mark a survey mark with the lot, portion, section or unit number of the parcel being surveyed and adjoining parcels by stamping the numbers onto a metal tag of not less than 1 mm thickness and attaching the tag securely to the survey mark.

	At each peg a finder that is a fence spacer not less than 900 mm long or a white painted, 25 mm square wooden stake not less than 900 mm long is driven firmly into the ground.
Placement of reference marks	For urban areas: 1) A surveyor must ensure that one or more reference marks are placed at sufficient points on street boundaries to ensure that groups of reference marks are not more than 200 m apart. 2) If an urban lot is more than 1 ha in area, a surveyor must ensure that sufficient reference marks are placed on each boundary of the lot (other than the road boundaries) to ensure that the reference marks are not more than 200 m apart. For rural areas: 1) Two reference marks are placed at all bends in roads and at sufficient other points on road boundaries to ensure that reference marks are not more than 500 m apart. 2) On boundaries (other than road boundaries) of parcels containing an area of 10 ha or less – two reference marks are placed at sufficient corners and bends to ensure that reference marks are not more than 500 m apart. 3) On boundaries (other than road boundaries) of parcels containing and area of more than 10 ha and for every isolated lot irrespective of area – two reference marks are placed at every bend and corner. 4) On long line surveys in isolated areas – two reference marks are placed at or near 2,000 m intervals and at each bend or corner and each intersection with another boundary.
Approved reference marks	**Spike**, being a steel or iron spike not less than 8 mm in diameter and 200 mm long, driven flush into a paved surface, if practicable, or driven not less than 100 mm below and unpaved surface. **Nail**, being a broad-headed nail driven or set into concrete or another durable medium, but not placed in the natural surface of the ground. **Concrete block**, being a plaque, spike, or steel peg, set in concrete, whether poured in situ or precast, which may be placed flush with or below the ground, depending on the nature of the surface. **Drill hole**, being a hole not less than 5 mm in diameter and 10 mm deep, drilling into a kerb or other substantial concrete structure and with wing(s) not less than 50 mm long cut on the side of the hole to indicate its position. **Another mark approved by the Board from time to time**. If the marks above are impracticable or unsuitable in a particular case, a surveyor may place or adopt marks of equivalent durability and stability.
Connecting and placement of permanent marks	In urban areas, coordinated reference marks (CRMs) are placed at intervals of not more than 200 m and at road intersections or at a density or at a location prescribed by the Surveyor-General. In rural areas, CRMs are placed at intervals of not more than 1,000 m and at road intersections or at a density or at a location prescribed by the Surveyor-General. A surveyor is to ensure that a locality and warning plate, which indicates that a CRM is in the vicinity, is to be affixed to a substantial structure and placed adjacent to the CRM. A surveyor must ensure that the CRM is suitably located for GNSS observation, adjacent to land or unit boundaries, and in a location that is safe for survey observations. At each CRM measurements to two recovery marks are to be made. Recovery marks are to be within 20 m of the CRM and placed at locations where the likelihood of disturbance or destruction is kept to a minimum. Recovery marks are to consist of either a new or existing spike, a new or existing drill hole, or another mark approved by the Surveyor-General from time to time.
Approved permanent marks	A CRM is in the form of a) a brass plaque, stamped with the unique CRM number that is i. centrally set in situ on the surface of a concrete block that is precast or in situ and that has a concrete frustum that consist of • a truncated pyramid or cone of 200 mm diameter at the top, 300 mm diameter at the base and 450 mm deep set in stable ground; • a cylindrical shape of 200 mm diameter and 700 mm deep in unstable ground.

	ii. securely affixed to an existing, stable concrete structure. b) an existing concrete block, post or a drill hole with wings in a substantial concrete structure that is able to be stamped or have affixed to it an identification tag marked with the unique CRM number. c) Another mark approved by the Surveyor-General from time to time.

The Northern Territory marking standards note the susceptibility of survey marks to fire, decay and termites and as such give the surveyor the option of placing marks made from other material such as concrete and steel in addition to hardwood. Boundary marks come in two forms, one being the familiar peg but with a 50 mm square top and the other the steel dropper. The standards also require the installation of a "finder", i.e. a star dropper placed in close proximity to a boundary mark and painted the colour white. In addition to placing boundary marks, the Northern Territory marking standard requires the surveyor to indicate lot numbers by affixing a metal tag. Options for reference marks are limited but very similar to reference marks as used in NSW. The Northern Territory also has a strong focus on the connection and placement of stable marks for coordination and future re-establishment of boundaries, with connection distances being very similar to NSW.

4.4 Queensland

The current marking standard in Queensland are the Cadastral Survey Requirements Version 7.1 dated September 2016 (QLD Dept Natural Resources and Mines, 2016). A summary of the marking standards contained in the Cadastral Survey Requirements Version 7.1 is contained in Table 7.

Table 7: Current marking standards in Queensland.

Subject	Details
Datum and orientation of surveys	A cadastral surveyor must connect all field surveys that create 10 or more lots, and are to be lodged for registration, to the State control survey. Connection to the State control survey can be way of: • A continuously operating reference station (CORS) network included in the datum control survey, or • Connection to two existing coordinated permanent survey marks in the datum control survey each of which has a horizontal positional uncertainty of <30 mm. The quality of the connection to the State control survey must be able to provide a horizontal positional uncertainty of <50 mm on any mark for which coordinates are determined. Surveys that create less than 10 lots do not have to connect to the State control survey, but may still connect to existing or new permanent survey marks that are of good geometry spanning the survey. Where a survey is connected to the State control survey, MGA bearings must be used to an accuracy of 20 seconds of arc, by derivation from points in the State control survey (such as coordinated permanent survey marks or coordinated CORS) or from astronomical observations. Where a survey is not connected to the State control survey, MGA bearings are still preferred, but the survey may be on one of the following meridians: • County Arbitrary Meridian. • The meridian of the original survey. • The meridian of an adjoining survey.
Boundary marking	Recognisable survey marks must be placed at each new corner unless it is physically impractical to do so. A clear description of cadastral survey marks placed, including reference marks, must be shown on the plan, and where applicable in the survey records. A surveyor must mark all existing corners on the subject land that are reinstated in the course of a survey, unless an original mark or suitable occupation exists at the

<table>
<tr><td></td><td>corner. However, there are instances where revisiting these corners to mark them may be impractical, such as when traversing to an existing mark, many corners away. In such cases, as a minimum requirement, when a new boundary intersects and existing boundary, both terminal points of that existing boundary must be marked unless one of the following applies:
• The terminal points are not fully reinstated.
• Other marks are used for reinstatement along the boundary (e.g. original line pegs).
• The survey is a secondary interest action only.
• The survey is an identification survey where a client requires certain corners marked only.
Unless fencing is to proceed immediately, subject to environmental considerations, trees standing nearest to the line may be blazed with a horseshoe-shaped mark cut into the heart-wood on opposite sides of the tree in such positions that the marks face along the survey line.
Tree through which the boundary lines passes should be double blazed on opposite sides so that the marks face along the boundary line.
Where corner marks are not intervisible, sufficient marks should be placed on line between the corners so that the boundary is readily and unambiguously discernible on the ground.</td></tr>
<tr><td>Approved boundary marks</td><td>A cadastral survey mark that identifies a boundary must be a peg capable of resisting destruction, corrosion or decay that is at least 350 mm in length, is coloured white and has a square top with a minimum cross section of 50 mm for a sufficient distance from the top to provide for branding. If a surveyor considers that it is impracticable or unsuitable to use a mark of this type, the surveyor may place a survey mark of equivalent durability and stability, and as far as practicable, of a similar character so that they are recognisable as cadastral boundary marks.
For rural surveys, alternate marks such as a survey post, galvanised iron pipe or star picket may be placed at corners where circumstances so dictate, provided such marks are identifiable as survey marks.
Lot numbers should be marked on corner pegs.
For rural surveys, where a fence post is used as a corner, it should be branded with a broad arrow and the lot number except where a reference tree is taken.</td></tr>
<tr><td>Placement of reference marks</td><td>A cadastral surveyor must ensure sufficient reference marks exist on a cadastral survey to facilitate future reinstatement of a cadastral survey.
A cadastral surveyor must record the location of permanent improvements (e.g. buildings, retaining walls) on the land that will assist in the future reinstatement of boundaries.</td></tr>
<tr><td>Approved reference marks</td><td>A cadastral reference mark may be any of:
• A suitably marked tree or fence post.
• A durable mark on a building or other immovable object.
• A pin made of durable material that is at least 300 mm in length and 15 mm in diameter.
• A permanent survey mark.
• Any other mark of equivalent durability and stability.</td></tr>
<tr><td>Approved permanent marks</td><td>In order for a survey mark to be accepted as a permanent survey mark, it must conform to the following criteria:
• The mark must be made of a durable material, preferably metal.
• When installed, the mark must be permanent and stable (i.e. have the expectation of longevity). Marks located in shallow structures, such as kerbing or footpaths, do not satisfy this specification.
• It must be capable of being readily identifiable as a survey mark.
• It must be able to be identified with a unique survey control number (as per the Survey Control Register number) either on the mark itself or attached to the mark (e.g. on concrete collar).
• The mark must be recorded in the State’s Survey Control Register.
• It should be capable of occupation, preferably in a location suitable for measurement by GNSS.</td></tr>
</table>

The default boundary mark in the Queensland marking standards is a peg 350 mm long with a square top of 50 mm and painted. Other marks can be used with the main requisite that the mark placed is identifiable as a cadastral boundary mark and that the mark is of similar durability and stability. The requirements for the placement of reference marks is left to the surveyor's judgement but must be sufficient to facilitate future reinstatement. The standards do require surveys to be connected to the state control mark network but there is no mention in regards the placement of new survey control marks as it is in NSW. State control marks are though an approved reference mark.

4.5 South Australia

The current marking standard in South Australia are the Survey Regulations 2007 (SA Legislation, 2007), the Surveyor-General's Directions February 2019 (SA Dept Planning, Transport and Infrastructure, 2019a), and the Cadastral Survey Guidelines February 2019 Version 3.0 (SA Dept Planning, Transport and Infrastructure, 2019b). A summary of the marking standards contained in the South Australia's regulations, directions and guidelines is contained in Table 8.

Table 8: Current marking standards in South Australia.

Subject	**Details**
Datum and orientation of surveys	In carrying out a cadastral survey of land within the coordinated cadastre, a surveyor must accept the Map Grid of Australia coordinates describing the boundaries of the land, as recorded in the plan of the area filed in the Land Titles Registration Office. In carrying out a cadastral survey of land within a designated survey area, a surveyor must comply with the following additional requirements: a) The survey must connect to at least three permanent survey marks or two permanent survey marks and one state survey mark for which the Map Grid of Australia coordinates are known; b) The survey must be adjusted to the scale and orientation dictated by the coordinates of the permanent and state survey marks to which the survey is connected; c) If the survey does not agree with the coordinates of the permanent or state survey marks to which the survey is connected within the standards of accuracy required by the Surveyor-General, the matter must be reported to the Surveyor-General and any directions of the Surveyor-General in relation to the matter followed.
Boundary marking	Every new boundary point defined on a cadastral survey must be marked. It is not necessary to mark existing boundaries. Where it is not practicable to peg the actual boundary corner, a position offset to the boundary corner is to be pegged using a reference mark. Where a survey peg marking a boundary is not visible from an adjacent peg, survey pegs shall be placed along the new boundary so that from any survey peg on the boundary the adjacent survey pegs are visible. New boundaries need not be pegged if their improvements are within 1 m of the boundary, and the relationship between the boundary and the improvement is shown on the plan. If the survey is for a division of land into more than 5 allotments or lot, the allotment or lot numbers must be placed, in a permanent and durable manner, on the top or face of each survey peg.
Approved boundary marks	**Peg** of a durable nature, composed of wood, metal, plastic or other material approved for the purpose by the Surveyor-General, measuring at least 300 mm in length and 50 mm square at the top and coloured white. **Metal spike** of at least 300 mm in length to which is mounted a metal or plastic top of durable material, at least 50 mm square and coloured white. **Star dropper** of at least 300 mm in length and coloured white. If not practicable to drive the above marks due to fencing, walls or permanent covering of the boundary, the following reference marks may be used as alternatives:

	• Galvanised iron nail driven into the fence and painted white. • Masonry nail or screw secured into the wall or pavement and painted white. • Deck spike at least 100 mm in length and 8 mm in diameter driven into bitumen and painted white.
Placement of reference marks	No requirement for reference marks.
Connecting and placement of permanent marks	Surveys must connect to at least three Permanent Survey Marks (PSMs) or two PSMs and one State Survey Mark (SSM) in urban areas, or three SSMs in rural areas, existing or new. If any two or more of the marks are within a 100 m radius of each other in urban areas, or within a 500 m radius of each other in rural areas, they shall count as only one mark for the purposes of this requirement. PSMs and SSMs within the survey are required at 200 m spacing from other PSMs and SSMs in urban areas and 2,000 m spacing in rural areas. In all areas, PSMs and SSMs shall be placed in safe locations where they are least likely to be disturbed. Below ground marks shall be set at least 200 mm below ground level to allow encasement in urban areas and to reduce the risk of being disturbed in rural areas. Below ground PSMs or SSMs shall be protected by a cast iron cover suitably supported by a 195 mm diameter PVC pipe: • When placed in urban areas. • On re-establishment of the pavement after existing PSMs or SSMs are found in place below pavements. PSMs and SSMs shall be witnessed by a steel dropper with a witness plate attached: • When placed in rural areas. • If existing PSMs and SSMs connected in rural areas are not already witnessed by a dropper, or the witness dropper and/or its plate are in state of disrepair such that they are no longer serve their purpose. • If not practicable to protect below ground PSMs and SSMs placed in urbans areas with a cast iron cover. • When placed below ground in divisions of land in urban areas of more than 5 allotments or lots (as well as the cover required above). Witness droppers shall be placed to best protect the PSM/SSM, and to be in safe locations. In urban areas, witness droppers shall be encased in a PVC sleeve; a rolled witness plate shall be fixed to the PVC sleeve. The witness plates to be used on steel droppers or PVC sleeves shall be those provided by the Surveyor-General, with the relevant details of the PSMs location marked on the witness plate in a permanent manner.
Approved permanent marks	Permanent Survey marks are: • A below ground permanent survey mark being a brass plaque inscribed survey mark or a steel rod measuring at least 300 mm in length and 10 mm in diameter set in a concrete block measuring at least 150 mm square at the top, 250 mm square at the base and 300 mm in depth. • An above ground permanent survey mark being a brass plaque inscribed survey mark or a metal rod set in concrete pillar firmly secured in the ground. • Stainless steel pins, at least 50 mm long and 5 mm in diameter, with inscribed washer suitable for permanent installation in concrete. State Survey Marks are: • Brass plaque inscribed survey mark set in a concrete block measuring at least 150 mm square on the top, 250 mm square at the base and 300 mm in depth. • Beacon being a wooden or metal tripod or quadripod fixed to the ground, or a stone cairn supporting a wooden, metal or plastic vane or cap, constructed for survey observations. • Any other mark approved by the Surveyor-General as a State Survey Mark permanently placed on land for use in surveying.

The South Australian marking standard is based upon new boundary corners being marked and a very strong coordinated survey control network. There are no requirements for reference marks within the South Australian standard and the marking of reinstated corners is only optional. The default boundary mark is a peg 300 mm in length and top of 50 mm square, but the surveyor does have flexibility when the circumstances do not allow a peg to be installed.

4.6 Tasmania

The current marking standard in Tasmania are the Survey Directions, Tasmania (Land Tasmania, 2018). A summary of the marking standards contained in the Survey Directions, Tasmania is contained in Table 9.

Table 9: Current marking standards in Tasmania.

Subject	**Details**
Datum and orientation of surveys	The horizontal datum for bearing and coordinates to be adopted for all surveys of a type listed in the Directions must be GDA94. All bearing and coordinate values must be expressed in terms of MGA94. The MGA94 coordinates for a survey must be determined specifically for that survey and: a) in the case where a previously established survey mark is used as the origin of the MGA94 coordinates, it must be a permanent mark held in SURCOM, or b) in the case where a CORS network is used as the origin of the MGA94 coordinates, it must be derived from a CORS network whose stations have Regulation 13 certified coordinates, or c) in the case where a single CORS base station is used as the origin of the MGA94 coordinates, it must be a station with Regulation 13 certified coordinates, or d) in the case where an AUSPOS solution is used as the origin of the MGA94 coordinates, the AUSPOS report must indicate that a reliable solution has been achieved.
Boundary marking	A boundary mark must be placed at every corner of surveyed boundaries. In rural areas, a corner boundary mark must be secured with a pile of stones, where these are available. Where a physical impediment exists at a corner preventing the placement of a boundary mark at the corner, a boundary line mark must be placed along one or more boundaries terminating at that corner, as near as practicable to the corner and the survey notes must report its position and description and the reason for not marking the actual corner. The line of a boundary between corners, if not sufficiently defined by a fence, hedge, wall, natural feature, or some other similar feature, must be defined and made clearly evident by the placement of boundary marks. For the purpose of line marking of boundaries in rural areas, the line of a boundary may be considered to be clearly evident where a fence, hedge, wall or other similar feature falls within 0.5 m of the boundary as defined. A boundary in bushland, if not able to be made clearly evident by placement of boundary line marks alone, shall in addition be made clearly evident by a) clearing; or b) flagging with pink tape or discrete painting with pink paint, in accordance with the Forest Practices Code in force at the time; or c) placement of stakes. A boundary in bushland may be made evident by the marking of trees and logs in preference to or addition to clearing, flagging, painting or placement of stakes only where a) the owners on both sides of a boundary require it to be so marked; and b) the action is not contrary to any environmental statutory requirement or limitation.
Approved boundary marks	**Wooden peg** at least 75 mm square in cross section extending at least 100 mm from the top and is to have a length of not less than 400 mm. **Metal peg** in the form of a steel star bar at least 450 mm long. **Plastic peg** at least 50 mm square in cross section at its top with a length of not less than 350 mm for urban surveys and at least 75 mm square in cross section at its top with a length of not less than 400 mm for surveys in all other areas.

Placement of reference marks	A survey must be connected to at least three reference marks. The minimum number of reference marks connected to shall be one mark per 500 m of external perimeter of the area under survey, subject to a minimum of 3 marks for surveys of 3 lots or less, 5 marks for surveys of 4 to 9 lots, and 7 marks for surveys of 10 or more lots. Subject to availability, a clearly identifiable corner of, or mark on, a permanent building or an immovable object must be located as a reference mark in preference to other types. Where reference marks are placed during a survey, they must be situated so as to provide for an even distribution throughout the survey, with a maximum likelihood of preservation and ease of accessibility and future discovery. A reference mark must be situated within 10 m of the corner being referenced unless this would compromise its future preservation, in which case it must be placed as close to the corner as physically practicable consistent with its future preservation.
Approved reference marks	Any durable, clearly described mark on a building or on an immovable object. Iron spike, bar or pipe of not less than 12 mm in diameter and 300 mm in length driven flush with a paved surface or 50 mm below an unpaved surface. Tree marked in accordance with the Directions.
Connecting and placement of permanent marks	A survey must be connected to all permanent marks within 100 m of any part of the lots under survey that are reasonably accessible and discoverable, which may be substituted for the location or placement of other prescribed reference marks.
Approved permanent marks	Permanent marks comprise any mark adopted as a permanent mark under section 14 of the Survey Co-ordination Act 1944.

The default boundary mark within the Tasmanian marking standard is a wooden peg with a square top of 75 mm and 400 mm in length. The standard does allow for metal and plastic pegs and allows for smaller pegs of 50 mm square in urban areas. Reference mark types are fairly limited to trees, iron spikes, iron bars, iron pipes and marks on a building or an immovable object. There is no requirement to place permanent marks in the marking standard, but all surveys are required to be connected to MGA94 and all permanent marks within 100 m of the survey need to be connected to.

4.7 Victoria

The current marking standard in Victoria are the Surveying (Cadastral Surveys) Regulations 2015 (VIC Legislation, 2018) and the Cadastral Surveys Practice Directives July 2018 (VIC Dept Environment, Land, Water and Planning, 2018). A summary of the marking standards in Victoria is contained in Table 10.

Table 10: Current marking standards in Victoria.

Subject	**Details**
Datum and orientation of surveys	A licensed surveyor making a cadastral survey must • adopt and verify a datum in accordance with a previous cadastral survey or plan; • if an abstract of field notes is to be lodged with the Surveyor-General or the Registrar of Titles, bring the bearing datum on to the Map Grid of Australia 2020 (MGA 2020) as is reasonable in the circumstances.
Boundary marking	A licensed surveyor making a cadastral survey must ensure that boundaries • are marked with pegs together with any additional markings that are necessary to assist in locating the pegs and the direction of boundaries; or • if pegs are not practical, are marked with other suitable marks approved by the Surveyor-General. A licensed surveyor must ensure that line identification and marking is implemented in a manner so that the defined boundary can be readily identified. Intermediate 'line' pegs are also required at distances no greater than 200 m apart on boundaries of significant length and/or when the ends of the boundaries are not inter-visible.

	If it is impractical or inappropriate to place marks at the corners themselves, another form of marking the boundaries in the vicinity of the corners, such as offset marks, is to be implemented. Options for providing identification of boundaries and their direction include trenching, staking, stamping numbers on pegs (front and rear), or by using a combination of these methods. In rural environments, and where appropriate in urban areas, the preferred method of indicating a boundary direction is by trenching, rock-filled trenches, or laying rock mounds.
Approved boundary marks	**Peg**, not less than 50 mm square and not less than 300 mm long, made of sound seasoned timber or other durable material, and set with the top not more than 20 mm above the ground.
Placement of reference marks	No requirement for reference marks.

Connecting and placement of permanent marks	A licensed surveyor making a cadastral survey must connect the cadastral survey to permanent marks and primary cadastral marks in accordance with the following principles:
	• For up to and including 10 allotments or lots at ground level, to at least three permanent marks or primary cadastral marks in the immediate vicinity of the subject land.
	• If there are more than 10 allotments or lots at ground level, further permanent marks or primary cadastral marks must be placed within the subdivision so that the distance between these marks is not greater than
	  o 100 m, or
	  o an alternate distance approved by the Surveyor-General.
	• If more than four marks are required to be placed for more than 10 allotments or lots, then one in every five marks placed must be a permanent mark.
	• If the design or layout is unusual, place additional permanent or primary cadastral marks within the subdivision as is reasonable in the circumstances.

Approved permanent marks	A permanent mark must be in the form as described in the Survey Co-ordination Regulations 2014 or other survey monuments as adopted or authorised by the Surveyor-General. Current forms of marks in the Regulations are:
	• Approved metal plaque installed in situ in top of block of 30 Mpa concrete with a base of not less than 300 mm diameter, top of 120 mm diameter, and length of at least 600 mm.
	• Approved metal plaque installed in top of pre-cast 30 Mpa concrete block with a base 300 mm square, a top 120 mm square, length 600 mm, and contains 500 mm long 6 mm diameter mild steel rod reinforcement.
	• 3,000 mm corrosive rod in sleeve with cast iron cover and concrete collar.
	• 1.8 m, 25 mm diameter mild steel rod coasted with bitumen with approved metal plaque welded to top of rod and installed in 100 mm diameter hole with bottom 500 mm in concrete, backfilled with crush rock, and concrete collar.
	A Primary Cadastral Mark (PCM) is a survey mark of a permanent nature. To qualify as a PCM, a survey mark must be all of the following:
	• Made of a durable material.
	• Permanent and stable in construction.
	• Placed so that it can be readily found and accessed.
	• Placed such it does not present a hazard to the public.
	When establishing PCMs, surveyors should endeavour to place them in locations where they are not likely to be damaged or destroyed such as in concrete kerbs and other places away from pedestrian or vehicular traffic. Surveyors should endeavour to establish PCMs in GNSS friendly locations, where possible.
	Marks suitable for nomination as PCMs include:
	• For hard artificial surfaces (e.g. concrete, brick and stone):
	  o aluminium rivets
	  o hardened survey nails
	  o expanding metal dowels with a collar
	  o drill holes at least 10 mm deep with wings

	○ etches (or chisel cuts) that are prominent and well-defined with wings at least 50 mm in length and not less than 3 mm deep Survey marks placed in bitumen or asphalt are not considered suitable as PCMs. • For natural surfaces: ○ Steel star posts or other survey marks of metal construction (e.g. rods or pipes) at least 600 mm in length. Such marks should be placed with the top not less than 50 mm beneath the surface. For all PCMs connected to and established in a cadastral survey, surveyors must: • Preserve the PCM numbers already assigned to existing PCMs connect to. • Assign numbers to all new PCMs from the series of numbers pre-allocated to them by the Surveyor-General. • Show the connections to the PCMs on the abstract of field records or RE Plan. • Include the PCM numbers on the survey documents (abstract of field records, RE Plan and licensed surveyor's report) associated with the survey.

The Victorian marking standard has adopted MGA2020 for the majority of their cadastral surveys. Similar to South Australia, Victoria has adopted a 50 mm square peg as the default boundary mark, has no reference mark requirements, and is heavily focused upon a network of survey control marks for future re-establishment of property boundaries.

4.8 Western Australia

The current marking standard in Western Australia are the Licensed Surveyors (General Surveying Practice) Regulations 1961 (WA Legislation, 1961a) and the Licensed Surveyors (Transfer of Land Act 1893) Regulations 1961 (WA Legislation, 1961b). A summary of the marking standards in Western Australia is contained in Table 11.

Table 11: Current marking standards in Western Australia.

Subject	**Details**
Datum and orientation of surveys	Each survey must be connected to a previous survey. Authorised surveys are to be connected on a map grid approved by the Board.
Boundary marking	The corners and angles of a boundary or land parcel must be marked. The numbers of all relevant land parcels are to be indicated on boundary marks. On all permanent boundaries that exceed 250 m in length, a mark consisting of an iron spike at least 10 mm in diameter and 400 mm long driven flush is to be placed on the boundary line at intervals not exceeding 250 m such that from each mark at least one other mark is visible forward and backward. Alternative intermediate marks can be used if iron spikes are not reasonably available or conditions are unsuitable for their use, and that alternative marks used are of equivalent durability and stability. If the length of any boundary exceeds 2 km, numbered reference kilometre posts shall be placed in the boundary. If there are no improvements indicating the direction of a boundary, the direction must be clearly indicated by trenches, stakes, stone pointers or other appropriate marks on the ground.
Approved boundary marks	Area over 4 ha: • **Hardwood post**, pointed at the top, 100 mm square, at least 600 mm long; or • **Concrete post**, 60 mm square, at least 450 mm long; or • **Steel post or peg**, 60 mm square, at least 900 mm long; or • **Mark made from polypropylene**, 75 mm square, at least 450 mm long. Area 4,000 m^2 to 4 ha: • **Peg**, 75 mm square at least 350 mm long; or • Concrete post 60 mm square, at least 450 mm long; or • Steel peg, 75 mm square, at least 600 mm long.

<table>
<tr><td></td><td>Area under 4,000 m^2:
• Peg, 50 mm square, at least 350 mm long; or
• Concrete post, 50 mm square, at least 400 mm long.
Posts and pegs are to be made from jarrah, jam (wood) wandoo, steel, concrete or polypropylene.
Where the above marks are inappropriate, an alternative mark can be used if it is of equivalent durability and stability, is identifiable as a cadastral mark, and sufficiently resembles a standard mark so as to be identifiable as such by the public.
Where practicable, all exposed portions of posts and pegs shall be coloured white or if they are hardwood pegs 75 mm square may be coloured red.
All concrete posts are to be topped by a secure non-corrosive metal plate.</td></tr>
<tr><td>Placement of reference marks</td><td>Two reference marks must be placed:
a) At each angle of the boundary if it is the boundary of a land parcel that is greater than 4 ha.
b) At key points along the boundary if it is the boundary of a land parcel that is equal or less than 4 ha.
c) At each corner and angle of the boundary if it is another boundary.
A single reference mark (without trenching) must be placed at each instrument point that is not otherwise permanently marked.
The objective of the placement of a reference mark is to ensure its long term stability and accessibility.
At any truncated corner of the street, right-of-way, pedestrian access way, drainage reserve or railway:
a) The intersection of two adjoining alignments must be marked with a single reference mark; and
b) Two other reference marks must be placed in positions so as to minimise the chance of disturbance and to enable the re-establishment of both alignments.
If a corner or angle of the street, right-of-way, pedestrian access way, drainage reserve or railway is not intervisible with an adjoining corner or angle, the intermediate instrument point (being the point from which both corners or angles are visible) must be marked by a single reference mark (without trenching).</td></tr>
<tr><td>Approved reference marks</td><td>Iron spike at least 10 mm in diameter and 400 mm long, driven flush into a paved surface or sunk, where practicable, at least 250 mm below an unpaved surface.
Where such marks are not reasonably available or conditions are unsuitable for their use, alternative marks of other materials of equivalent durability and stability may be used.
Marks with a head or lip such as bridge nails or dog spikes should not be placed in situations where they are to be excavated for use.</td></tr>
<tr><td>Connecting and placement of permanent marks</td><td>On every authorised survey (including repegs and survey stratas) in town and suburban lands, if the re-establishment or new line passes within 100 m of a standard survey mark (SSM), that SSM must be connected to the authorised survey unless the SSM has in the past been directly connected to a cadastral alignment to which this authorised survey is directly connected. If more than one SSM is passed both or all must be connected. For rural lands, the proximity to an SSM is extended to 2 km (or 10 km if GPS is being used). Although desirable, it is not necessary to provide an azimuth connection, but surveyors are encouraged to consider the use of a remote reference object (RO), and to connect to any SSM that is conveniently visible even if it is outside the stated proximity.
Every subdivision (which is not within a special survey area) within the following specifications must be connected to the geodetic network, unless that subdivision is connected to a cadastral alignment that has previously been directly connected to the network:
• Of more than 10 lots, within 800 m of an SSM
• Of more than 10 km of new boundary, within 5 km of an SSM.
• Surveyed by GPS if within 10 km of an SSM.
The horizontal stability of the SSM(s) must be validated from reference marks.</td></tr>
<tr><td>Approved permanent marks</td><td>Approved brass plaque set in pre-cast concrete block with square base of 180 mm and square top of 115 mm and length of 500 mm. Concrete block is installed in 400 mm deep in-situ concrete and pre-cast concrete hatch cover and lid with at least 150 mm clearance between lid of cover and top of brass plaque.</td></tr>
</table>

	For remote areas, approved brass plaque set in concrete 300 mm diameter and 200 mm deep connected to a star iron picket or galvanised pipe driven into the ground so that top of brass plaque is 50 mm above ground level. Brass plaque to be connected to star picket or pipe by tie wire and concrete is to encase this connection. A minimum of three reference marks shall be placed around the SSM preferably at 120º separation at least 200 mm below the natural surface and approximately 3 to 5 m away from the SSM.

The Western Australian marking standard is based around the size of the land being surveyed determining the type and size of mark to be placed. Boundary marks range in top size from 50 mm to 75 mm depending upon the circumstance and are quite long compared to other jurisdictions to allow boundary marks to be marked with lot numbers and other identifying features. Connection to existing survey control network is required in the marking standard but does not include a requirement of placing additional survey control marks.

4.9 Canada and USA

Canada and the USA are two other jurisdictions that are based on a commonwealth of states, provinces and territories with the basis of their legal and land title systems being common law. The development of these two countries has seen the land divided into lots based on a rectangular grid system and the development of marking standards based upon similar principles as Australia, where boundary marks need to be visible and recognisable as boundary marks by the public as well as be stable and durable. Their marking standards have also evolved over the years based upon materials available, differing techniques and changes in public perception. Currently the preferred mark is a mark consisting of steel or concrete, placed so it is stable and visible. The mark also requires having some sort of identification either being a plastic or steel cap or metal plate. This identification includes details identifying who has placed the mark and their authority, being their registration number, and details of the corner marked being the lot and section numbers. Their standards are very similar to NSW and other jurisdictions in Australia where boundary lines as well as corners need to be clearly identified by placing extra marks on line at a certain interval, the placement of reference marks to enable re-establishment of property boundaries, and the connection of boundaries to a geodetic datum.

5 COMMON ASPECTS OF SURVEY MARKING

When comparing marking standards across various jurisdictions, a number of common aspects appear. These include:

1) Recognition by the general public – survey marks and particularly boundary marks need to be recognised and accepted as being boundary marks. A number of jurisdictions note this particular need within their marking standards and have adopted a default colour (typically white) and size of mark as a boundary mark. Each jurisdiction allows for other marks to be used but the choice of mark by a surveyor needs to be based on its close similarity to the default boundary mark and its recognition by the general public as well as stability, durability and suitability for the environment in which the mark is to be placed.
2) Authoritative – marks placed, particularly boundary marks, need to be trusted that they have been accurately placed and correctly denote the boundary it purports to have marked. Each jurisdiction requires that only competent surveyors mark and deal with property boundaries and as such these surveyors may be authorised, licensed or registered by that particular jurisdiction to carry out the marking and surveying of boundaries. Jurisdictions in Canada

and the USA have gone a step further and require the surveyor to note their authorisation/ license/registration number on the mark itself.

3) Visible – corner marks and boundary lines need to be visible and easily identifiable to land owners and contractors carrying out work close to the boundary line. All jurisdictions researched require surveyors to place marks at boundary corners as well as intervening marks along boundary lines at particular intervals. Jurisdictions also require the direction of each boundary line at each mark placed to be identified using various methods including trenches, piles of stones, stakes, blazing of trees and logs, and painting. Some of the jurisdictions also required lot numbers to be identified on the mark itself using branding, stamping or attaching a metal identification tag. Each jurisdiction is quiet on how long such marks should be visible. Typically, visibility is only required until boundary works such as fences and retaining walls are completed. Some members of the public are happy to try to maintain the position of their boundary pegs indefinitely as it provides a guarantee regards the location of their property boundaries.
4) Durable and stable – all jurisdictions require marks to be placed to be durable and stable to counter such threats such as decay, pests and easy removal. New Zealand has indicated that reference marks should have at least a time span of 10 years and permanent marks a life span of at least 50 years. With the choice of alternative marks, the marking standards of all jurisdictions indicate that any alternative mark must be of similar durability and stability of the default marks described in the standards. All marking standards researched advise surveyors to consider the location of reference and permanent marks, in particular the likelihood of disturbance or destruction due to construction works. In this case, all the standards give surveyors some flexibility in their placement.
5) Permanent to allow re-establishment of boundaries – all jurisdictions have some method of permanency to allow for future surveyors to re-establish boundaries. For South Australia and Victoria this is based upon a network of permanent marks, for NSW, Tasmania and Western Australia it involves the traditional method of placing reference marks. All jurisdictions also require surveys to be connected to a geodetic datum of some kind for most type of surveys. Permanency or some method of enabling re-establishment in particular is quite important to surveyors but is also important to the general public as it alleviates the potential of confused and lost boundaries in the future and potential high survey costs as boundaries would need to be re-established from greater distances due to lost marks in the local area.
6) Standardised – all jurisdictions have indicated what the size, colour, look and material of survey marks placed in their jurisdiction should be. This fits into the need for the general public to recognise marks placed as survey marks but also sets a minimum standard that surveyors must meet.
7) Flexible – all marking standards have some flexibility regarding the types of marks that can be used. It is obvious that not one kind of mark is suitable for all situations and environments. As stated above, the standards do allow the surveyor some choice but when using alternative marks, the surveyor must make a professional judgement that the alternative marking meets most of the aspects of a survey mark as detailed above.
8) Evolving – even though not directly indicated in any of the standards, marking standards are forever evolving. Such changes include new geodetic datums, new surveying techniques, new materials for marks, and changing perceptions of society. It is obvious from research that all the marking standards have been reviewed and amended at certain intervals allowing for the standards to evolve as required. It is assumed that these changes and reviews would be undertaken in consultation with the surveying profession and the general public.

6 THE FUTURE

Before we look at a possible future for survey marking, we need to consider the current trends and changes occurring in society to try to determine what the future may look like. Some trends that may have an affect on survey marking into the future include:

1) Moving to a digital world – the last 50 years have seen the introduction and adoption of computers and electronics to assist in our day-to-day lives, the recording of data, banking, communication, navigation and the management of large systems. The surveying profession has not been immune to this. Gone are the days of log tables, calculations done by hand, and drafting of plans by hand. We live in an era where large amounts of land can be mapped very quickly with the same resources it took to survey much smaller areas in the past. This data is in a lot of cases also freely available through platforms such as Google Maps and SIX Maps, giving members of the public unprecedented access to data. This is changing the way we look at land and its management. One particular example is the development of a "Digital Twin" by NSW Spatial Services, where the State of NSW is being mapped so as to create a digital world where potential concepts and designs can be tested before being implemented in the real world. Another change that moving to a digital world has created is the ease and accessibility to navigate across the world. Finding a location is as easy as opening your mobile phone and either entering a location or selecting a location on a map and then following the directions displayed to navigate to the point chosen. Gone are the days of taking astronomical observations and using dead reckoning.
2) Urbanised world and the consolidation of rural lands – since the introduction of the Industrial Revolution, the trend has been to urbanise our world. This, together with the reduction of jobs in agriculture due to the introduction of machinery and the consolidation of farmland into large properties, has seen a huge increase of people living and working in urban areas. This increase of population requires the development of houses, offices, factories, roads, railways and other services. This has brought about an increase in various different hard surfaces and changes to the landscape. Another trend is the building of walls on boundaries and the increase of multi-storey developments. The trend of rural lands being consolidated into large properties to benefit from economics of scale has also seen a decrease in the need for rural boundary surveying and as such the type of marking that goes with surveying rural boundaries.
3) Possible introduction of a 3D cadastre and possibly a 4D cadastre – height, the third dimension, is becoming more important, especially with the increase of multi-storey development and therefore the need to relate boundaries to height via stratums and stratas. This has brought new management issues for councils and governments in visualising the landscape to assist in planning and providing services. Time, the fourth dimension, may also be added to the cadastre, especially with the introduction of a time-dependent geodetic datum and the greater need for analysing data over time.
4) Sustainability and access to material for survey marks – no resource is infinite and that includes material that is used for boundary marks. The wooden peg has been a long time standard, but is that type of material still sustainable into the future? Hardwood forests take a long time to develop and as such more emphasis has been placed on softwood forests. This has seen a decrease in the availability of appropriate hardwood and the increase in cost for such material. This has opened the opportunity to look at other materials, especially with the introduction of portable power tools, which make installing some materials a lot easier.
5) Public perception and cost of surveys to the public – the public perception of surveying is quite low compared to the past due to the lack of understanding of what is involved to establish boundaries. The majority of the general public also have a lack of understanding how much the establishment of secure property boundaries contributes to society. The other

trend is the rising cost of goods and services, in particular property. This is placing pressure to find ways to keep costs down by finding more efficient ways to provide services or providing value for money.

So, what does this hold for the future of survey marking? The first question that does come to mind is whether survey marking will still be required into the future. Some would argue that with the introduction of coordinated cadastres and easy access to navigation and positioning tools such as GNSS, marking will not be required. The property owner and contractors should be able to easily determine their location in regards the local geodetic datum and cadastre and then determine the location of their boundaries. Is this something the public wants? If it is, it is not something that will happen in the short term. It will require quite a bit of funding by government and effort by surveyors to accurately coordinate each boundary. It could also increase the amount of land disputes due to a lack of understanding of coordinate systems and measurement techniques by non-competent people, but it could open new opportunities and enable the development of new services and data.

Machine guidance is a prime example of this working on a smaller scale, with equipment operators determining their location without the need for surveyors to place numerous marks. However, this has not eliminated the surveyor as the surveyor needs to coordinate the site in respect to the datum which the equipment measures to, and place datum marks and benchmarks for operators to check upon in order to ensure that their equipment is measuring correctly. The surveyor is also there to provide advice and fix any problems that may arise.

This may be a possible long-term view, but what about the short term? Marks need to be placed so that fences and walls can be erected, and other improvements can be placed within the required offset of boundaries. This raises the question if our current marking system is suitable in the near future and the possible changes required to meet long-term expectations.

The wooden peg has met (and in most present cases still meets) the requirements of pegging as detailed above, but it is meeting several pressures in this modern world. Our urbanised world has put up quite a few barriers to placing survey marks including:

- Increasing number of hard surfaces that do not allow marks such as wooden pegs to penetrate.
- Increasing corners being inaccessible to marking due to a structure being placed on the corner or boundary, or corners are located at a certain reduced level.
- Increasing amount of marks being disturbed or destroyed due to lack of recognition of their importance or pressures to have other works constructed to tight timelines.
- Increasing costs for materials and installation. Wood was plentiful, but is this still the case and will it be into the future?

From the perspective of the public, it feels that corner marking is not important anymore as the public’s understanding is that the fence is the boundary until there is a boundary dispute. This may be correct if the fence is carefully erected on the boundary line, but as surveyors we know of many cases of this not happening.

A corner peg can be a god saver when undertaking a survey where all marks are gone, but how reliable is it for the boundary definition? Pegs are at the lower end of the hierarchy of boundary definition, just above occupations and dimensions. To be acceptable, they need to be stable. However, can they really be deemed stable in this urbanised world, especially after various construction activities have been undertaken nearby?

Options that may assist with countering the above pressures may include:

- Instigating a wider education of the general public of the importance and recognition of survey marks. Having a better idea of the types of survey marks and their importance may help with their acceptance, raise their profile, and assist with their protection. This may also assist with the profession's aim of lifting its standing within society as the public gains a better appreciation of our role and what skills and services we provide. It is noted that work towards this is occurring, in particular at NSW Spatial Services with the "Protecting survey marks" information sheet (NSW Spatial Services, 2019) and Surveyor General's Direction No. 11: Preservation of Survey Infrastructure (NSW Spatial Services, 2020). These have been quite successful but need to reach a wider audience, possibly through other means such as social media, television, radio and newsprint, and reconfigured to appeal to that wider audience. This of course will take time, funding and support by the profession.
- Making marks more visible and authoritative. Other jurisdictions require marks to have lot details or even the surveyor's details placed on the mark in some way. Even the inclusion of the words "Boundary Mark" may assist with better recognition and acceptance of their importance by the general public. The extra time and cost to install such marks will need to be highly considered in the implementation of this option. This may be offset by considering the amount of marks to be placed and using existing improvements to define a boundary. An example of this is South Australia where only new corners are marked and boundaries do not need to be marked if it can be defined by showing offsets to various improvements close to the boundary.
- Placement of offset marks on substantial structures such as kerbs instead of at the corner. Once again, they will probably require some sort of identification installed with the mark to ensure they are visible and recognised by the public. Lot details and possibly offset measurement could be noted on the mark. Examples of where this has occurred in the past are the placement of drill hole and wings in kerbs along boundary lines in many previous Department of Housing developments, and the marking of railway alignments. Stability may be a concern with this method as concrete kerbs may seem to be stable but are prone to movement due to settlement and movement of subgrade below the kerb.
- Investigating methods to protect marks such as cover boxes or visible ground marks with authoritative markings. This may mean moving away from the installation of marks currently used such as galvanised iron pipes, concrete blocks and drill hole and wings unless they can be identified as authoritative survey marks. De Belin (2012) has detailed his success in implementing the installation of cover boxes over existing underground marks, which has greatly helped in their preservation. Research and experimentation with different types of cover boxes should be considered such as PVC cover boxes similar to cover boxes used in irrigation or PVC pipes and caps. For surface marks, washers or identification plates could be installed with or alongside the mark to identify the mark as a survey mark. Once again, cost and time to install would need to be considered, but with the availability of portable drills this should be minimised. It is interesting to note that many utility providers already use these types of methods to protect their services, e.g. the numerous installations of on-ground marks with washers on concrete kerbs at intersections placed by AAPT to mark the location of their underground cables where they cross the road.
- Reviewing the current requirements for placement of reference marks and permanent marks, in particular the density of marks placed and their positioning. It is noted that some jurisdictions are moving away from the placement of reference marks to a strong network of coordinated permanent marks, typically consisting of very stable marks placed so they are intervisible, marked in an authoritative way, centrally recorded in a state-wide database, in areas unlikely to be disturbed and able to be occupied by GNSS. This network becomes a strong spine for the surrounding cadastre and goes back to the old survey principle of

“from the whole to the part”. These marks become a quasi-permanent marking of street alignments as was previously undertaken in the late 19th and early 20th centuries via alignment stones, posts and pins. A prime example of this is the redefinition of street alignments of various streets within the Sydney CBD after the 2000 Olympic Games by the City Council with reference to existing and new permanent marks and the ongoing maintenance of this network of permanent marks. As in this example, long-term maintenance of such a network is an issue and some consideration needs to be made in regards to sharing such an issue between local government, state government and the surveying profession.

- Reviewing the number of acceptable mark types. NSW has a number of acceptable types of marks compared to other jurisdictions, including reference to a number of historical mark types that may not be applicable anymore. This provides a high amount of flexibility to the professional surveyor but is probably adding confusion to the public and therefore ignorance in regards to the disturbance and destruction of such marks. Other jurisdictions have allowed flexibility by leaving the choice of mark to the surveyor and their professional judgement, but the mark placed must be as durable and stable as the default survey mark and recognised as a survey mark.

7 CONCLUDING REMARKS

The aim of this paper was for professional surveyors to gain a better understanding of how the current survey marking standard has developed, how it compares to other jurisdictions, and the importance and societal requirements surrounding boundary marking. The other aim was to encourage the profession to start considering the future and its effect on survey marking. Our world is not static, with the prime example being the introduction of a new static national datum (GDA2020) to cater for continental drift and moving towards a time-dependent datum (ATRF). As the world progresses, we need to evolve and improve on past practices, and become even more efficient. The surveying profession is not immune to this and has proven in the past to be great accepters of new technology.

Our marking standards have developed over the last 232 years, with a number of changes as new materials, techniques and technologies have been developed. It is also interesting to note how similar other jurisdictional marking standards are, with the only changes being size and type of mark but based on the same principles, i.e. marks need to be recognisable by the public, authoritative, visible, durable, stable, permanent, standardised and flexible. The future will see further changes required to our marking standards, especially the increasing urbanisation and digitising of the world, the ease of navigation and positioning, and changing societal views.

With the principles in mind, our profession has an opportunity to consider how our marking will operate in the future, with questions such as if marks are required, their type, and their density needing to be answered.

It should be noted that the ideas, opinions, suggestions and recommendations given in this paper are the author’s alone. By putting these forward, it is hoped to start discussion within the profession to think strategically about the future not only in regards survey marking but also the profession as a whole. Where do we see ourselves in the future and what role we will play? These are important questions to consider, unless we want these questions answered for us by someone else.

REFERENCES

ACT Legislation (2013) Surveyors (Surveyor-General) Practice Directions 2013 (No 1), https://www.legislation.act.gov.au/di/2013-217 (accessed May 2020).

de Belin F. (2012) Preservation? of survey reference marks, *Proceedings of Association of Public Authority Surveyors Conference (APAS2012)*, Wollongong, Australia, 19-21 March, 142-150.

Land Tasmania (2018) Survey Directions, Tasmania, https://dpipwe.tas.gov.au/land-tasmania/geospatial-infrastructure-surveying/directions-and-circulars/survey-directions (accessed May 2020).

Marshall I.H. (2002) *Marking the landscape* (2nd Edition), Board of Surveying NSW, 128pp.

NSW Legislation (2017) Surveying and Spatial Information Regulation 2017, https://www.legislation.nsw.gov.au/~/view/regulation/2017/486 (accessed May 2020).

NSW Spatial Services (2019) Protecting survey marks, information sheet, https://www.spatial.nsw.gov.au/__data/assets/pdf_file/0003/221736/Protecting_Survey_Marks.pdf (accessed May 2020).

NSW Spatial Services (2020) Surveyor General's Direction No. 11: Preservation of Survey Infrastructure, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed May 2020).

NT Legislation (1983) Licensed Surveyors Act 1983, https://legislation.nt.gov.au/Legislation/LICENSED-SURVEYORS-ACT-1983 (accessed May 2020).

NT Surveyors Board (2014) Survey Practice Directions 2014 – Surveys Outside Coordinated Survey Areas, https://surveyorsboard.nt.gov.au/__data/assets/pdf_file/0014/401630/Survey-Practice-Directions-2014-Surveys-Outside-Coordinated-Survey-Area.pdf (accessed May 2020).

NZ Legislation (2010) Rules for Cadastral Survey 2010, http://www.legislation.govt.nz/regulation/public/2010/0492/latest/DLM7127676.html (accessed May 2020).

QLD Dept Natural Resources and Mines (2016) Cadastral Survey Requirements, version 7.1, Reprint 1, https://www.dnrme.qld.gov.au/__data/assets/pdf_file/0013/105601/cadastral-survey-requirements.pdf (accessed May 2020).

SA Dept Planning, Transport and Infrastructure (2019a) Surveyor-General's Directions, https://www.sa.gov.au/__data/assets/pdf_file/0010/499240/Surveyor-Generals-Directions-February-2019.pdf (accessed May 2020).

SA Dept Planning, Transport and Infrastructure (2019b) Cadastral Survey Guidelines, version 3.0, https://www.sa.gov.au/__data/assets/pdf_file/0008/499211/Cadastral-Survey-Guidelines-Version-3.0-February-2019.pdf (accessed May 2020).

SA Legislation (2007) Survey Regulations 2007, https://www.legislation.sa.gov.au/LZ/C/R/SURVEY%20REGULATIONS%202007.aspx (accessed May 2020).

VIC Dept Environment, Land, Water and Planning (2018) Victorian Cadastral Surveys Practice Directives, https://www.propertyandlandtitles.vic.gov.au/__data/assets/pdf_file/0018/405225/Victorian-Cadastral-Surveys-Practice-Directives-Edition-2-2018Amended.pdf (accessed May 2020).

VIC Legislation (2018) Surveying (Cadastral Surveys) Regulations 2015, https://content.legislation.vic.gov.au/sites/default/files/050b358a-6f1c-3a69-9c28-b22c6e1a7b50_15-43sra002%20authorised.pdf (accessed May 2020).

WA Legislation (1961a) Licensed Surveyors (General Surveying Practice) Regulations 1961, https://www.legislation.wa.gov.au/legislation/statutes.nsf/law_s4561.html (accessed May 2020).

WA Legislation (1961b) Licensed Surveyors (Transfer of Land Act 1893) Regulations 1961, https://www.legislation.wa.gov.au/legislation/statutes.nsf/law_s4563.html (accessed May 2020).

Practical Use of Legislation and Common Law Practice for Surveyors

John McNaughton AM
Palmer Bruyn Surveyors
John.McNaughton@palmerbruyn.com.au

ABSTRACT

The work of general private surveyors is diverse: their professional advice can be sought on the accuracy of a description identifying a plot of land, the location of a fence or boundary, the distance of a dwelling from a road or watercourse, or the boundary of an area on which licensed activity can occur. Common to all these activities, however, is a well-developed skill of reading and deciphering written descriptions of boundaries whether for Old System or Torrens Title (including Limited Titles) or general metes-and-bounds descriptions as encountered in Government Gazettes. This knowledge is critical in order to advise clients accurately of the facts disclosed by written descriptions of boundaries, whether or not these boundaries are land titles or lands defined for government administrative purposes. This paper explains the practical use of legislation and common law practice for surveyors giving professional advice to their clients. This is done using two case studies. The first concerns the boundaries of Pastures Protection Districts, and the second concerns the boundaries of a part of the waterway of Lake Macquarie where commercial fishing is prohibited. In both cases, the surveyor's report saved each of these clients significant financial and personal cost. Comments are also made on methods of deciphering hand-written descriptions contained within conveyances, which are the basis of many Limited Titles. Finally, examples are given of actual jobs where clients suffered considerable financial loss because they were not provided with sufficient information to evaluate the commercial risk of their project. The detailed knowledge of planning law and practice, engineering design and practice, the thorough knowledge of the legal and practical application of the laws and regulations are topics on which all registered surveyors are examined to obtain registration. They are central to the work of all surveyors in general private practice.

KEYWORDS: *Cadastral, legislation, common law, boundary descriptions*.

1 INTRODUCTION

Registered surveyors are examined for registration in boundary definition in both rural and urban areas as well as town planning, engineering design and supervision and the use of surveying instruments. However, only surveyors in small, mainly country, private practices are required to regularly use the whole range of these competencies. The discussion in this paper focuses on only a few examples from the wide range of instructions that are the daily work of small practices.

It is usual to receive instructions to subdivide land into several lots. This can be anything from two to 20 lots and occasionally more. This work involves the use of the Surveying and Spatial Information Act, Local Government Act, Roads Act, Environmental Planning and Assessment

Act, Conveyancing Act and Real Property Act (NSW Legislation, 2020) as well as the associated Regulations and, from time to time, other laws which become relevant in certain circumstances as the project progresses.

Instructions to carry out delimitation surveys are also received fairly regularly, generally as single lots but occasionally as multiple lots. These surveys, of course, give rise to the main subject of this paper because it is essential to trace the Old System Title through at least 30 years of title.

Since many of these titles are now Limited Titles, it is even more important to be skilled in locating and deciphering Old System Conveyances. Contrary to what many legal practitioners and conveyancers seem to believe, these titles *cannot* be treated as titles without a limitation. This is reinforced by the fact that the Registrar General clearly states on each plan given 'limited' status that it has *not* been investigated by that organisation. It is therefore essential that the surveyor knows how to locate the relevant title deeds and then how to read and interpret them.

It is important to remember that a conveyance can be prepared and used by anyone. The fact that a conveyance has been registered does not mean that good title has been established. However, it would appear that this is the assumption made by many (if not most) legal practitioners and conveyancers by virtue of the fact that the conveyance has been registered. In fact, the Registrar General simply places the copy of the original conveyance in the register, based solely on the assurance (by statutory declaration) that the document is an exact copy of the actual conveyance. This gives rise to many interesting investigations for surveyors. This point is explored further in the section 4. First, this paper explains the practical use of legislation and common law practice for surveyors giving professional advice to their clients, using two case studies.

2 CASE STUDY 1: PASTURES PROTECTION DISTRICTS

As already noted, surveyors are required to work with a range of statutes and regulations. This may often arise in circumstances where someone is being prosecuted for some statutory infraction. The surveyor will often be called as an expert witness in such matters. The surveyor's task is, in effect, to explain how a 2-dimensional statutory description concerning land is understood in the real world. The following case study illustrates this point.

A farmer and grazier was moving a truck load of his own cattle from one of his farms to another of his properties. At around sundown he parked his truck in a picnic area on the side of a creek. A short time later a Pastures Protection Board inspector arrived and issued the grazier with a fine for transporting stock after sundown. This is a usual proscription in many Pastures Protection Board regulations. However, it is not used in all such districts.

An examination of the boundaries of the relevant Pastures Protection District disclosed that the alleged offence took place very close to the boundary of two Pastures Protection Districts. The boundary was described as being the boundary between two shires. At the end of the picnic area, remote from a bridge over the Hunter River (which formed a boundary of the picnic area), there were signs on both sides of the road stating entry into one shire going in one direction and entering the adjoining shire going in the opposite direction. The Pastures Protection Board inspector stated that the picnic area between the signs and the bridge over the creek was in his area and he therefore issued a fine.

The boundary of the Pastures Protection District was stated in the gazette as being the boundary between two shires. The Pastures Protection Board inspector accepted that the road signs showing the boundary of the two shires were correct. It was therefore necessary to find the legal boundary between the two shires. For this purpose, the surveyor was consulted and retained as an expert witness when the fine was challenged.

The relevant Government Gazette described the boundary between the shires by a metes and bounds description which said, in part, "…*thence by the centre line of the Hunter River downstream to the confluence… etc*" (Figure 1).

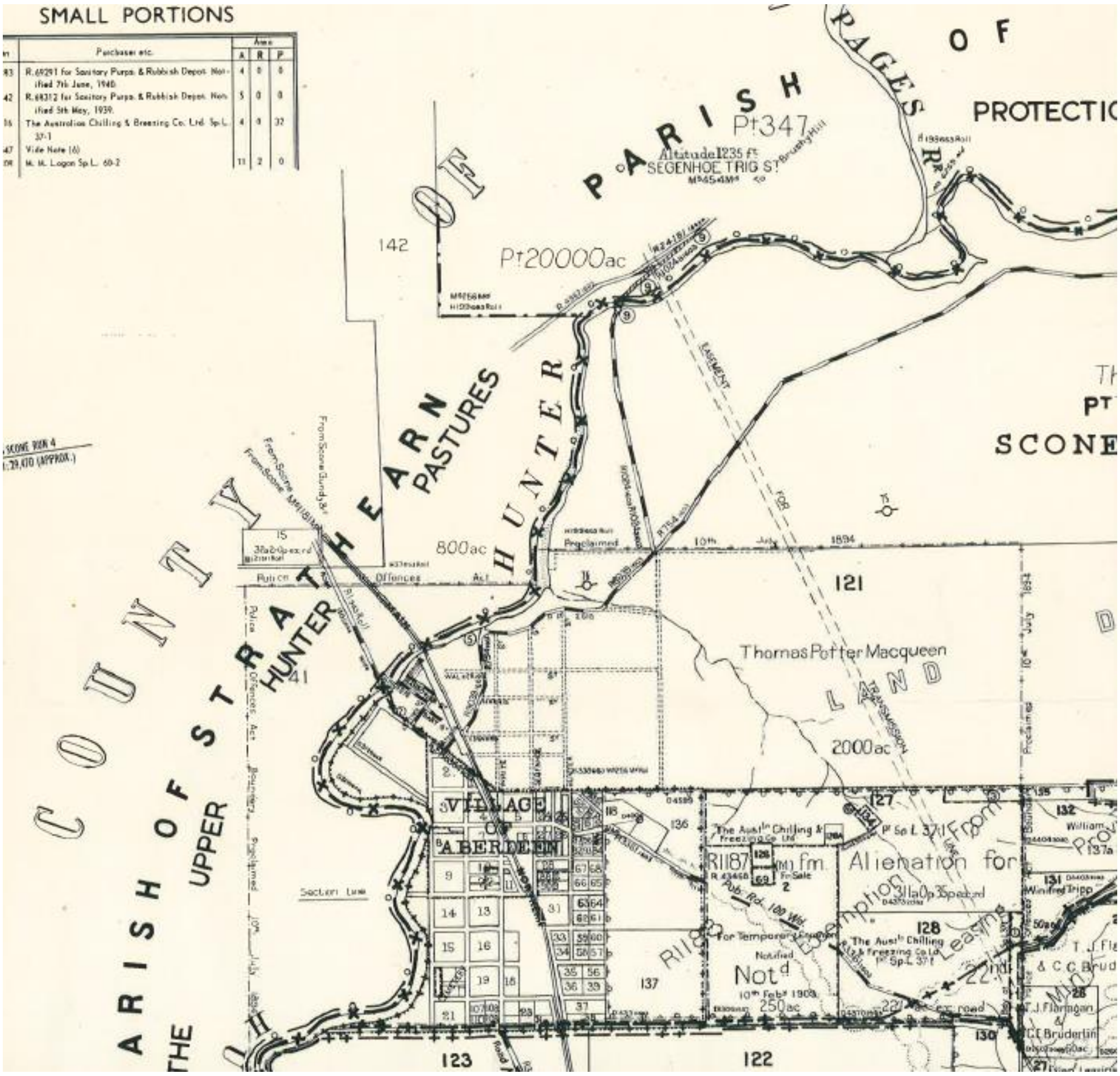


Figure. 1: Shire map.

An investigation showed that the actual boundary between the shires was the centreline of the river (Figure 2). Both shires were described in this way.

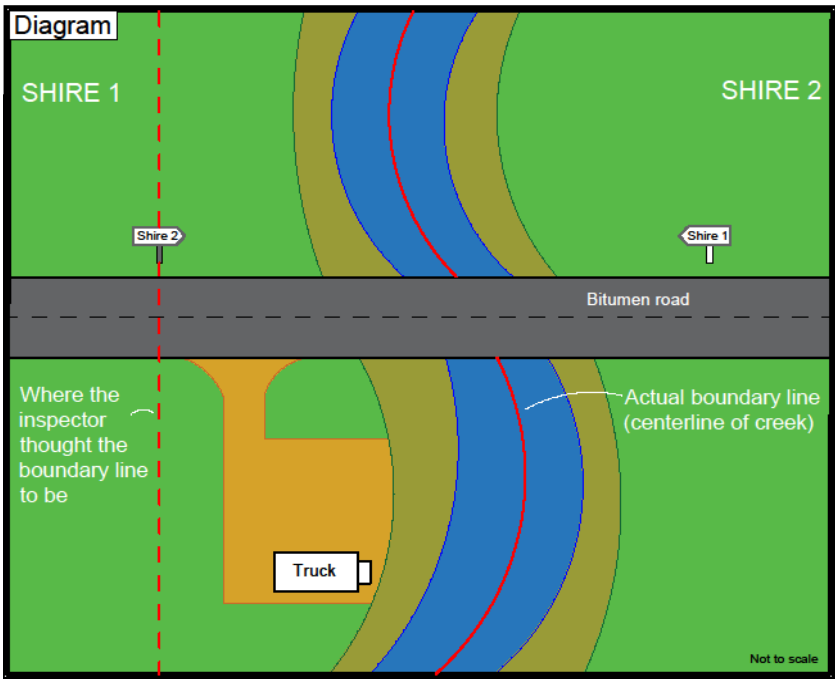


Figure 2: Shire boundaries.

Therefore, the signs mentioned above were placed for convenience rather than over the centreline of the river on the bridge. The other material aspect of these facts was that the Pastures Protection Board inspector who issued the fine was outside his jurisdiction and therefore had no authority to issue the fine. Another interesting fact to emerge was that the Pastures Protection Board for the land in question did not have a restriction on the transport of stock for any time, either day or night.

3 CASE STUDY 2: FISHING IN LAKE MACQUARIE

Professional fishers are banned under legislation from fishing in certain parts of Lake Macquarie, near Newcastle, NSW. The penalties for fishers who are prosecuted for infringing these rules are extremely harsh, including the confiscation of the equipment used in the illegal act. This includes, the boat, nets, traps, the catch and everything used by the fisher at that location. Additionally, there is a substantial monetary fine. Clearly, unless the fisher has other equipment, the confiscation of the equipment prevents them from earning an income until the equipment can be replaced.

It is therefore understandable that a fisher being prosecuted under relevant legislation for illegal fishing will challenge the validity of the prosecution if they can. In such circumstances, a surveyor may well be retained as an expert to locate the relevant boundaries delineating the areas in which fishing is and is not legal.

Lake Macquarie is an enormous body of water, and in some parts of the lake fishing is permitted. The Government Gazette describes the area where professional fishing (in fact all fishing using nets) is prohibited as being all of that part of Lake Macquarie to the west of a line drawn from the intersection of Thompson Road and The Esplanade at Speers Point to Marmong Point. A fisher was prosecuted for fishing in this area. The prosecution claimed that the offence took place at 3 am at a location about 500 m from Marmong Point and about 200 m to the west of the gazetted boundary line. This incident took place before the advent of Global Positioning

System (GPS) technology. Therefore, it became a question of how the fisheries inspectors located the position of the fisher at the time of the alleged offence.

A daytime field inspection at the Thompson Road and The Esplanade intersection looking towards Marmong Point showed that it was difficult to see the actual 'point' of Marmong Point. The reverse inspection from Marmong Point showed that it was even more difficult to identify the location of the intersection of Thompson Road with The Esplanade at Speers Point (Figure 3). This was during daylight on a clear day. The alleged offence was at 3 am. Unless clear beacons (lights) had been set up at both ends of the boundary, it was not possible at night to identify the ends of the line, and therefore the line of the boundary.

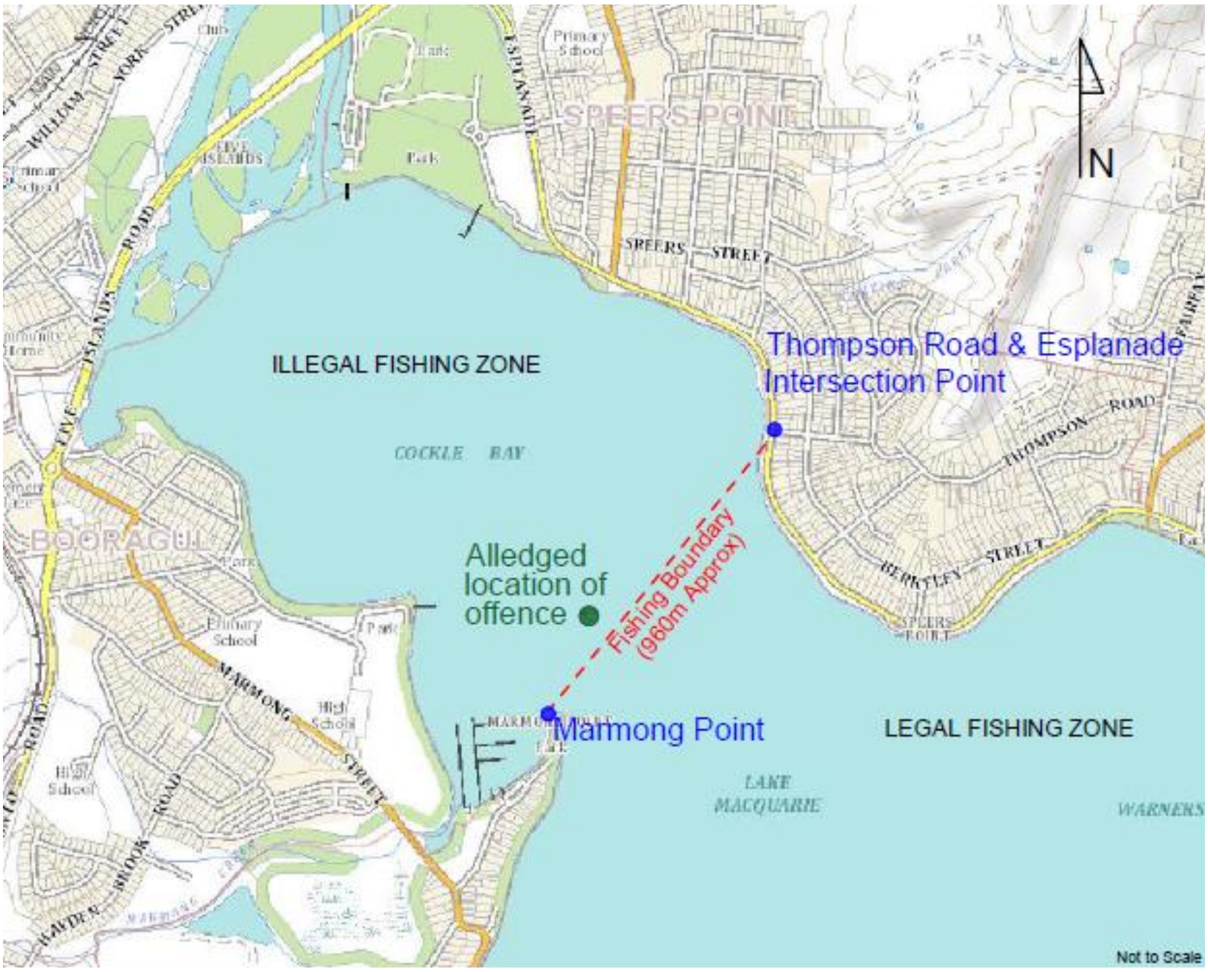


Figure 3: Fishing boundary at Lake Macquarie.

Since the fisher was alleged to have been about 200 m inside the prohibited area, it was critical to show how the location was determined, and how the terminal ends of the line were identified at night. Also, it had to be shown by the fisheries inspectors how, from a small boat, they could determine the location of the alleged offence, even if they could see the terminal ends of the boundary line. As noted previously, this took place before GPS was available, so the inspectors had to convince the court that they knew where the boundary line was, in relation to the position of the nets of the fisher.

The surveyor was retained by the alleged offender's legal representatives to ascertain the boundaries described in the Government Gazette. He was also instrumental in assisting the formulation of the appropriate questions that were put to the fisheries inspector in court, to test how the latter established the relevant boundary in order to determine that the fisher was in fact breaking the law. In carrying out this work, the surveyor located the boundaries of the relevant part of Lake Macquarie and examined the map supplied by the prosecution which showed the location of the alleged offence and the time it took place.

As a consequence of the surveyor's professional expertise, the fisher successfully defended the charge because, at the end of the day, the inspectors were unable to demonstrate to the court how they had established that the fisher's nets were in illegal waters.

Once again, the skill of the surveyor was in translating the metes and bounds description in the Government Gazette into 'real-world' boundary locations, i.e. translating the 2-dimensional description in the Government Gazette into the actual location of the boundary. Any qualified surveyor can establish where a boundary is located as this merely requires being able to read a metes and bounds description. This is the competency tested for qualification. However, the *skill* of the surveyor in this respect lies in converting written metes and bounds descriptions as shown in legal documents (in this case a Government Gazette) into the actual boundary locations of the physical world.

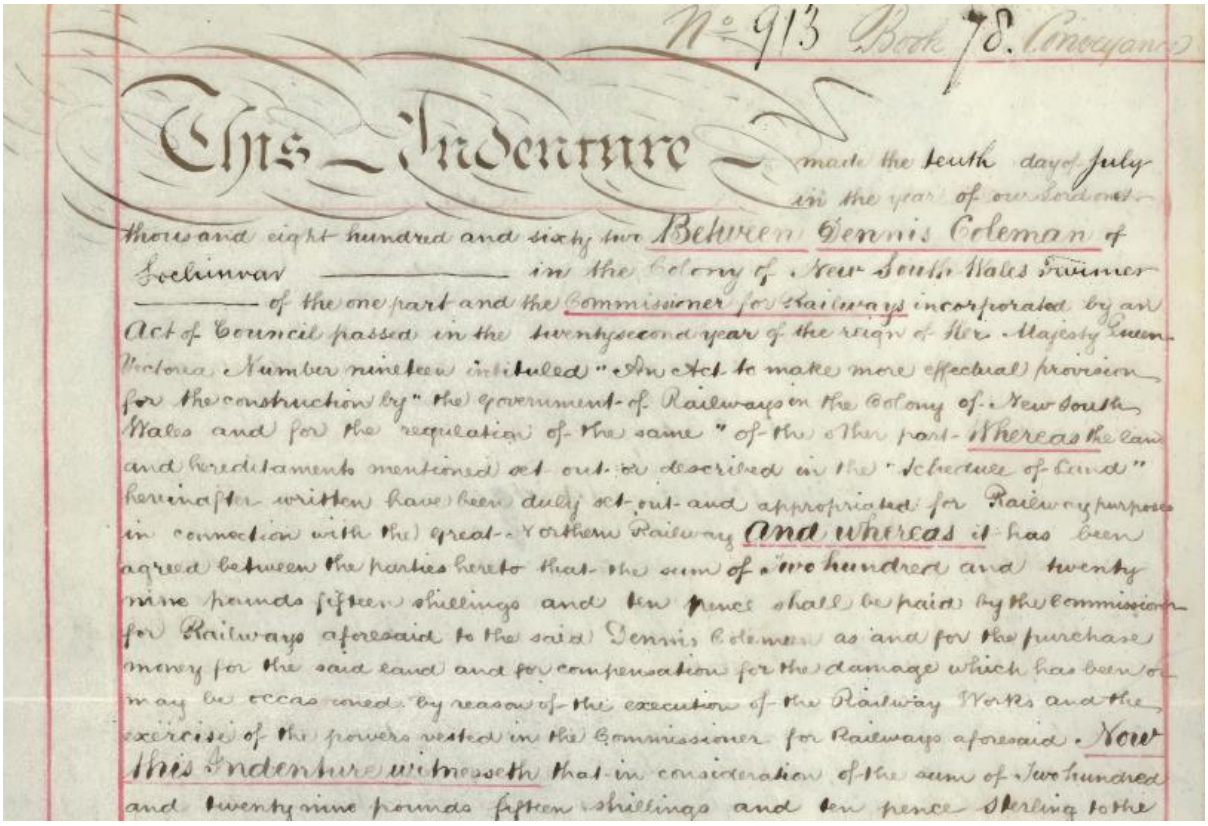
4 READING HANDWRITTEN CONVEYANCES

As noted above, many legal practitioners and conveyancers appear to assume that the fact that a conveyance is registered by the Registrar General means that the parcel of land to which the conveyance relates has good title. In respect of a Limited Title, this must actually first be established before the limitation can be removed. This, in turn, will involve locating, reading and interpreting Old System Title deeds, many of which will be handwritten. Here again, there is a difference between the *competence* of a surveyor to read a title deed and the *skill* involved in doing so. Technological advances in recent years mean that reading and deciphering copies of such documents has become much easier.

Nevertheless, the standard of handwriting in documents varies considerably. It will be difficult to read and comprehend a document if it is necessary stop at every few lines to interpret what is actually written (Figure 4).

It saves considerable time if the difficult words can be separately deciphered so that reading the document is possible without the 'stop-start' caused by having to guess what a word actually says. A simple yet effective way of preparing such a document for analysis is to photocopy the document and read it with the use of a 'highlighter' pen in hand. Whenever an unclear word appears, that word is marked, and reading continues until all the unclear words are marked with the highlighter. Then comes the somewhat tedious task of looking at each marked word, trying to decipher its meaning from the context of the surrounding words and then writing the correct word over the marked word. When all words are clear, the whole document can be read and understood in its entirety. It is essential that every word in the document is read and understood. Only thus can the (often strange) nuances which appear be understood.

Once the handwritten document is understood, it is usually necessary to plot the metes and bounds, i.e. the bearings, distances and abuttals, in order to check the accuracy or otherwise of the conveyance.



No 913 Book 78. Conveyance

This Indenture made the tenth day of July in the year of our Lord one thousand eight hundred and sixty two Between Dennis Coleman of Lochinvar in the Colony of New South Wales Farmer of the one part and the Commissioner for Railways incorporated by an Act of Council passed in the twentysecond year of the reign of Her Majesty Queen Victoria Number nineteen intituled "An Act to make more effectual provision for the construction by" the Government of Railways in the Colony of New South Wales and for the regulation of the same" of the other part Whereas the land and hereditaments mentioned set out or described in the "Schedule of Land" hereinafter written have been duly set out and appropriated for Railway purposes in connection with the Great Northern Railway And whereas it has been agreed between the parties hereto that the sum of two hundred and twenty nine pounds fifteen shillings and ten pence shall be paid by the Commissioner for Railways aforesaid to the said Dennis Coleman as and for the purchase money for the said land and for compensation for the damage which has been or may be occasioned by reason of the execution of the Railway Works and the exercise of the powers vested in the Commissioner for Railways aforesaid Now this Indenture witnesseth that in consideration of the sum of two hundred and twentynine pounds fifteen shillings and ten pence Sterling to the

Figure 4: Handwritten conveyance.

5 IDENTIFICATION SURVEYS

In recent years it has become most unusual for legal practitioners and conveyancers to obtain identification surveys for clients purchasing property. This is most likely due to the fact that the client is looking to save money. It is almost certain that such clients are either unaware of or underestimate the risk involved in not having accurate information identifying the parcel of land they are purchasing. This can lead to costly consequences, as the following example illustrates.

In an older part of Newcastle, a property owner had spent over $10,000 on designs and plans to demolish an existing garage and to erect a double garage with a studio apartment above. A usual condition of the local council for approving such development was that, before any building work commenced, the relationship of the existing house to the boundary had to be determined by a registered surveyor. Thus, the owner gave instructions to have the boundary marked so that the planned development could continue. Unfortunately for the property owner, the survey disclosed that the boundary fence stood on the adjoining property by about 250 mm (Figure 5).

This meant that there was insufficient land between the boundary and the existing house to allow the passage of even a small car. In other words, the money the property owner had expended on the designs and plans for the garage development was completely wasted. This could have been avoided if the owner had first paid for the identification survey.

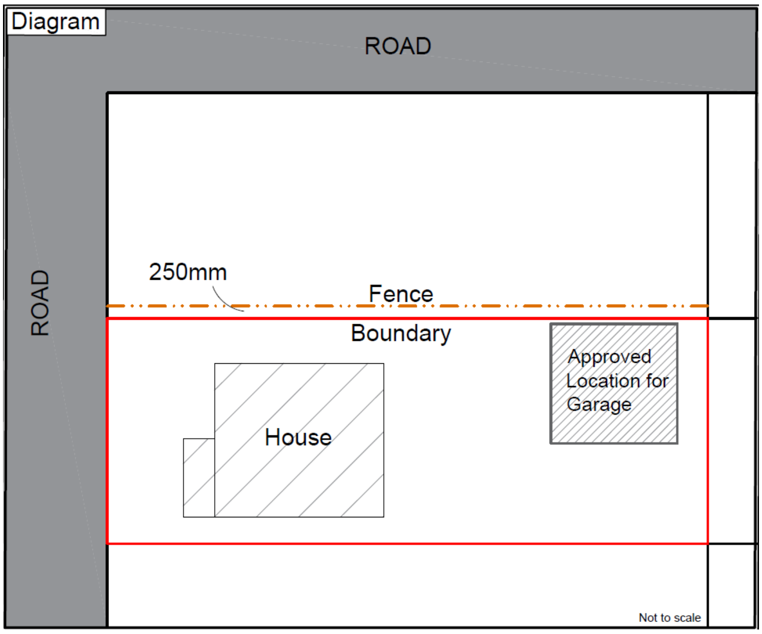


Figure 5: Garage and boundary.

6 CONCLUDING REMARKS

The purpose of this paper has been to give some insight into the diversity of work undertaken by small private surveying practices. The examples used show only a small part of the work done in small private practices. Hopefully, however, for colleagues working in other areas, they are a window on the usual daily activities of their private practice colleagues.

As shown, the detailed knowledge of planning law and practice, engineering design and practice, and the thorough knowledge of the legal and practical application of the laws and regulations, are central to the work of surveyors in general private practice.

REFERENCES

NSW Legislation (2020) NSW legislation, https://www.legislation.nsw.gov.au/#/ (accessed May 2020).

3D Positioning Systems for Underground Construction Robots

Steven Garlinge
Geodata KODA Australia Pty Ltd
steven.garlinge@geodatakoda.com
David Mares
Lend Lease Bouygues Joint Venture
d.mares@bouygues-construction.com
Daniel O'Shaughnessy
Geodata KODA Australia Pty Ltd
daniel.oshaughnessy@geodatakoda.com

ABSTRACT

As Global Navigation Satellite System (GNSS) technology does not work underground, total stations reign as the 3D positioning system of choice in tunnel environments. It follows that there has been limited development of extra-dimension solutions to automation-of-construction tasks. The current trend of mega-projects, and multiple mega-projects running concurrently, has seen the industry reconsider this issue. NorthConnex comprises of approximately 20 km of road tunnels (therefore, 40 km of walls) in which specialist drilling and fixing machines are employed to install permanent fixtures into the excavated and lined tunnels. The use of automated systems for roadheader and bolter positioning during the excavation phase is relatively mature, however the extension of these systems into the tunnel fitout processes is traditionally limited. This paper outlines how Geodata KODA Australia, in partnership with the NorthConnex project, has found opportunities to apply its software and systems to provide significant enhancement to multiple workflows where large, specialist machinery performs drilling and installation work over a huge scale to high accuracy requirements. Two machine types were targeted by the team. The first, ROBY, is a drilling and anchoring system with application to installing anchors into the roof of the tunnel for lighting, cable tray and fire safety systems. ROBY is required to contribute to drilling over 100,000 anchors with a high degree of accuracy. The second, Paneller, is a multi-bit drilling system which is designed with the specialist task of drilling for architectural wall panels. At peak, two paneller machines work towards the drilling of over 40 km of wall panels in NorthConnex. Such paneller machines were used as early as 1999, but only now have automated positioning systems been implemented. Other systems capitalise upon further extension to these techniques by implementing a single-prism positioning system in which certain assumptions and techniques ensure that a fast and accurate machine positioning solution is available to wall-trimming machines.

KEYWORDS: *Tunnelling, robots, automation, navigation, NorthConnex.*

1 INTRODUCTION

NorthConnex comprises of approximately 20 km of road tunnels (therefore, 40 km of walls) in which specialist drilling and fixing machines are employed to install permanent fixtures into the excavated and lined tunnels. The use of automated systems for roadheader and bolter positioning during the excavation phase is relative mature, however the extension of these systems into the tunnel fitout processes is traditionally limited.

Worldwide, the average big construction project takes 20% longer to complete than planned and runs a staggering 80% over budget (Garcia de Soto, 2019). This sobering thought saw the NorthConnex project partner with Geodata KODA Australia to find opportunities to apply software and systems to provide significant enhancement to multiple workflows where large, specialist machinery performs drilling and installation work over a huge scale to high accuracy requirements.

2 GETTING STARTED

It is worth noting that many other underground positioning systems exist, but they are limited by their inability to provide an accurate position that is suitable for placing mounting anchors to survey tolerance. As such, total stations reign as the 3D positioning system of choice.

Historically, there is limited development of extra-dimension solutions to automation of construction tasks. There are many reasons for this, but mainly, it seems to boil down to project-by-project thinking, which limits investment in ideas or initiatives that will take more than one project to be fully realised, and may provide, at best, neutral commercial benefit to the initial project sponsor. The current trend of mega-projects, and multiple mega-projects running concurrently, has seen the industry reconsider this trend.

2.1 Robotics

In 2014, KODA Engineering started integrating a modern robotics modelling concept (Denavit-Hartenberg, see Spong et al., 2004) into its software systems. Initially it was developed for multi-limb roadheader and bolter navigation, but it soon became apparent how useful the system was to be for niche positioning and automation products. Geodata KODA have successfully adopted this platform to several applications throughout 2018-2020.

Worth emphasising is the power of this robotics system overall. The key benefit is that any robotic limb, or machine, or combination of limbs, can be modelled by this system and represented via a simple configuration file. Previously (and currently by many others), machine dynamics parameters are hard-coded or limited to those that were thought of at the time of development. The configuration-based definition of machines makes this a thing of the past.

A good example of the power of the robotics modelling system is from earlier in the NorthConnex project, where bolters were fitted with full navigation systems. During calibration, a residual error was observed between calibrated and calculated models. Soon it was apparent that due to wear and tear and manufacturing tolerances, a degree of ‘slack’ existed in a particular movement joint. The solution to this was to create an additional joint to represent the defect. This required re-mapping sensor values from an existing extension sensor to the unplanned joint movement and then updating the configuration. The residuals from the calibration were immediately reduced from 100 mm to better that 20 mm – more than good enough for drilling for rockbolts – with no coding, no mechanical work and no electrical work.

2.2 Commercial Approach

From an economic perspective, the NorthConnex project was able to realise significant additional value from its fleet of total stations as purchased for the excavation phase. Approximately 13 units of the Leica TS16 1” instrument remain after the excavation process. ROBY and Paneller are finding a new life for at least 6 of these units directly.

Worth noting are the commercial aspects of the engagement of Geodata KODA to the NorthConnex project. A collaborative approach was adopted to great success. Such an approach served to de-risk each organisation in ways that a traditional contractual appointment would not be easily able to. Both companies were able to share purchasing and associated cash-flow challenges. Also, in many cases, Geodata KODA faced challenges caused by interfaces with other parties involved with the solution. By close integration with the principal contractor, all invested parties were rarely confused as to what their objective was: “create success for NorthConnex”.

3 THE ROBOTS

3.1 ROBY

3.1.1 General

For NorthConnex, two machine types were enhanced by the team. The first, ROBY, is a drilling and anchoring system with application to installing anchors into the roof of the tunnel for lighting, cable tray and fire safety systems (Figure 1). ROBY is required to contribute to drilling over 100,000 anchors with a high degree of relative and absolute accuracy.

Figure 1: ROBY in use.

In terms of the automatic drilling platform, ROBY itself is a mature product, having been developed in Europe and used before on another tunnelling project in Hong Kong. However, the system was only able to be viable on NorthConnex if a significant improvement to the machine positioning system was realised.

To guarantee such an improvement, two total stations were used to provide real-time positioning for the machines. Two prisms (front and rear of the machine) were each tracked by a single total station each. The two-point, continuous positioning from the total stations is combined with dual-axis level sensors on the machine to provide a solution for all six transformation parameters (scale not necessary) from the 'machine coordinate system' to the 'project coordinate system'.

3.1.2 Performance

In previous implementations, ROBY showed positioning times of several minutes. Now, from a cold start (very few times per day, ideally one), the system has a solution within 21 seconds, and when running, is supplied a position multiple times per second.

The speed and accuracy of the positioning system led to the (unplanned) development of a system to show the real-time position of the machine against all planned and previously drilled anchors while it was being advanced to the next drilling location. In this way, the machine was not moved too far, and anchors missed, nor was it moved too little, and the power of the system was left unrealised.

3.2 Paneller

3.2.1 General

The second, Paneller, is a multi-bit drilling system which is designed with the specialist task of drilling for architectural wall panels in the tunnel environment (Figure 2). During 2019, two paneller machines worked towards the drilling of over 40 km of wall panels in NorthConnex. Such paneller machines were used as early as 1999, but only now have automated positioning systems been implemented.

Figure 2: Paneller in use (NorthConnex tunnels).

Paneller uses the same dual-instrument, tracking-based positioning method as ROBY, but the software is also required to perform full 3D calculations of the position of the drilling machine relative to tunnel stringlines, then provide automation outputs to the machine hydraulics to guide the machine into place.

3.2.2 Performance

Manual positioning of Paneller takes a skilful operator and surveyor over 60 seconds to perform, with many interactions between them. Sometimes it is worse, and rarely better. With the combination of a real-time positioning system, and automation outputs, the machine is positioned in less than 15 seconds with involvement of the machine operator only. Anecdotal evidence also suggests that the positioning result with the automated system is more consistent and accurate overall.

3.3 Tunnel Trimer

3.3.1 General

A third system, Tunnel Trimmer (not used on NorthConnex), showcases an interesting extension to these techniques by implementing a single prism positioning system, in which certain assumptions and techniques are used to ensure that a fast and accurate machine positioning solution is viable in a restricted and fast-moving construction environment (Figure 3).

Figure 3: Tunnel Trimmer in use.

A dual-axis level sensor and single prism are measured continuously. Then, based on the known constraints of the solution (the machine is mounted on rail, tunnel geometry is correlated strongly to the position of the rail, the tool can only cut to the left of the machine, the prism is on the front of the machine, the total station is always in front of the machine, and the tool is held perpendicular to the reference surface (in plan only)), it is possible to generate a second, virtual, prism to supply a two-prism solution for the system to position the milling head in 3D.

This solution requires certain ‘administrative’ controls to work well, i.e. operator training and compliance to those constraints. To date, this has not proved to be an issue based on having motivated and interested operators, custom build hardware and a unique environment in which the reference surface is very well defined.

3.3.2 Performance

The Shaver project has shown that the traditional notions of (1) setout, (2) perform work and (3) check work can be shattered by intelligent automation systems. This familiar cycle features delays on the critical path, but also lagging information, which would be better suited to being displayed in real-time while the construction task is being undertaken.

Particularly demanding construction tolerances needed to be observed: (1) there could be no 'tights' and (2) over-excavation was limited to 20 mm. If over-excavation was observed, then the expensive and time-consuming repairs were penalty enough in themselves.

While this is not a novel concept (as many real-time automation solutions for construction machines exist), an ability to quickly, confidently and economically apply these systems to unique and novel machines is.

4 TECH TALK

4.1 Instruments

Leica TS16 total stations, with specialist software and hardware, and external command interfaces, provide an excellent platform for innovation and optimisation.

4.2 Data Types

Tunnel stringlines are commonplace, but extra value has been extracted from them in the execution of these projects. In simple cases, the tunnel profile in area and known height of the machine give a specific area for the machine to search.

In the case of Paneller, stringline definitions were enhanced to include 'null' elements as there were some areas where a valid wall panel solution was not provided by the design, or not needed. By incorporating null elements, it was possible to keep the wall strings for the entire length of the project as contiguous and well-integrated, without having to resort to multiple string definitions or shortcut fixes. When in the hands of surveyors, complex data types or design interpretation is easily handled, but that is not the audience of ROBY or Paneller. One must think how to simplify and make the available data more robust so that it is valuable to the end user.

Full 3D tunnel Triangulated Irregular Network (TIN) models were developed for the tunnels at NorthConnex. For ROBY, bolt patterns are draped to a final survey model, and then an approximate location for each pin can be determined. By doing this, the project can provide a safe, but accurate position for ROBY's drilling tool to seek before performing fine positioning to find the actual surface of the shotcrete. By providing an accurate and confident model of the actual tunnel rather than the design tunnel, many seconds of slow movement were eliminated per anchor.

4.3 Communications

In the case of ROBY, a two-way User Datagram Protocol (UDP) based JavaScript Object Notation (JSON) data protocol was developed between the positioning system and the robotic drilling platform. The main benefit of this approach was that the protocol could be expanded and enhanced as new ideas or requirements emerged. The main purpose was for exchange of real-time spatial information between the systems. The coordinates of the prisms, stations, time of measurement and estimated precision are transferred continuously to ROBY for it to use.

4.4 Automation Challenges

In the case of Paneller, the underlying positioning system remains very similar to that of ROBY, except that the information is transmitted internally in the software rather than via UDP. Paneller's special task required the software to provide automation outputs to the hydraulics of the machine based on the observed spatial information.

Again, the importance of communicating the accuracy and currency of the spatial information was critical. Indeed, there were some emergent challenges faced with certain combinations of lights and signals potentially having detrimental effects on the system if wires were broken or bulbs were blown. Some careful time spent risk assessing this saw some significant re-working of the initial solution to the robust solution that was deployed.

5 PERFORMANCE GAINS

The construction industry continues to see an increasing tendency for surveyors to be 'held captive' by construction activities, which demand near constant positioning support. This is a symptom of (a) more complicated designs, (b) attitudes of risk minimisation (both to project, and self) and (c) less skilled or spatially aware tradespeople. In the applications presented here there was incredible benefit in moving the surveying task away from the critical path. Specifically, the system runs itself without any need from operators or trades to interact with surveyors on a minute-to-minute basis.

Immediate, direct performance improvements were noted for all machines. As discussed above, the economic benefit of eliminating or minimising the need for spatial positioning to be performed on the critical path cannot be understated. All professions must contribute to the minimising of critical path activities, ensuring that those that do remain are adding essential value that is aligned with schedules and budgets.

It should be noted that such approaches do not necessarily reduce the amount of surveying work required, but reconfigure when, and under what conditions, the work is performed. Support of these systems requires (1) total stations and radios to be moved, configured and prepared, (2) batteries to be changed, (3) data to be configured and (4) control to be extended. The ability to plan and predict work is increased.

6 CONCLUDING REMARKS

By implementing and engaging in innovation today, we are creating a basis for the new ideas of the future. A particularly rewarding trend has been witnessed during this work. In all cases the current (or planned next-generation systems) include emergent ideas, which were not anticipated or conceived during initial scoping. Only during the early days of deployment did the actual power of the solution present itself, and some new ideas emerged. We hope that the recent work in this area provides further inspiration to our clients and the broader industry, and that successful projects like this become more commonplace.

It is worth reinforcing that these robotic and automation techniques are not designed to take away jobs from surveyors, but instead we hope (1) to continue meeting the demand for spatial positioning in the mega-project construction environment, often running 24 hours a day, 7 days a week, and (2) to continue providing positioning solutions in an industry environment where the supply of qualified, or suitably skilled, individuals is at a point of exhaustion. Solutions like these contribute to ensuring that the idea of a surveyor is maintained at high professional standard and not viewed as a para-professional, blue-collar worker, carrying around some expensive equipment.

REFERENCES

Garcia de Soto B. (2019) The construction industry needs a robot revolution, https://www.wired.com/story/the-construction-industry-needs-a-robot-revolution/ (accessed May 2020).

Spong M.W., Hutchinson S. and Vidyasagar M. (2004) *Robot dynamics and control* (2nd edition), Wiley, New Jersey, 303pp.

Surveying for the Newcastle Light Rail Project

Peter Sergeant
Monteath & Powys
p.sergeant@monteathpowys.com.au
Matt Richardson
Monteath & Powys
m.richardson@monteathpowys.com.au

ABSTRACT

In June 2017, Monteath & Powys were engaged by Downer as the survey managers for the Newcastle Light Rail Project (NLR). The 2.7 km long dual track was designed to run partially within the former heavy rail corridor from Wickham / Newcastle West and then along Hunter and Scott Streets through Newcastle's central business district to Pacific Park near Newcastle Beach (Newcastle East). As survey managers, Monteath & Powys were responsible for establishing a high-accuracy survey control network for the whole project, along with implementing measures to manage the preservation of survey infrastructure (POSI) requirements for cadastral reference marks and permanent state survey marks within and adjacent to the project. In addition, it was our responsibility to oversee construction quality control and conformance on behalf of Downer as the managing contractor. As part of the role, Monteath & Powys were required to liaise with all stakeholders, including Transport for NSW (TfNSW), Newcastle City Council (NCC), NSW Spatial Services, and survey sub-contractors engaged by the construction contractors, to coordinate survey control, sub-surface utility investigation (SUI), quality control, conformance and other contract requirements. Separately, we were engaged to carry out construction surveying for each of the six tram stops and the maintenance depot as well as weekly aerial photography across the whole of the site utilising a commercial helicopter due to restrictions on the use of Remotely Piloted Aircraft Systems (RPAS). This paper details Monteath & Powys' involvement in the project for over 18 months, utilising 46 individual staff members and carrying out over 12,000 man hours of work. The diversity, intensity and integrity of the work carried out was recognised at the 2019 Excellence in Surveying and Spatial Information (EISSI) Awards, with the award for most outstanding Infrastructure & Construction Project and also for the most outstanding overall project.

KEYWORDS: *Newcastle Light Rail, infrastructure, TfNSW, surveying, construction.*

1 INTRODUCTION

In June 2017, Monteath & Powys were engaged by Downer as the survey managers for the Newcastle Light Rail Project (NLR). The 2.7 km long dual track was designed to run partially within the former heavy rail corridor from Wickham / Newcastle West and then along Hunter and Scott Streets through Newcastle's central business district to Pacific Park near Newcastle Beach (Newcastle East).

As survey managers, Monteath & Powys were responsible for establishing a high-accuracy survey control network for the whole project, along with implementing measures to manage the preservation of survey infrastructure (POSI) requirements for cadastral reference marks and permanent state survey marks within and adjacent to the project (NSW Spatial Services, 2020). In addition, it was Monteath & Powys' responsibility to oversee construction quality control and conformance on behalf of Downer as the managing contractor.

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Separately, Monteath & Powys were engaged to carry out weekly aerial photography across the site and construction surveying for each of the six tram stops and the maintenance depot. A total of 43 individual staff members from Monteath & Powys were involved in the project in some capacity, including surveyors, draftspersons and administration staff. This paper details our involvement in the project.

2 CONSTRAINTS AND COMPLEXITY

The Newcastle Light Rail Project is 2.7 km long with our involvement commencing on the construction site from June 2017 for an intense 18-month construction period with light rail services commencing on 17 February 2019. One of the reasons Monteath & Powys were engaged on the project was the proximity of our head office to the subject site, as well as our large survey capability and the ability to scale our resources up and down as required.

With the light rail running across several major road corridors, previous heavy rail sites and along operating roadways, there were many complexities and time constraints involved. This led to many intense workload periods where Monteath & Powys personnel were required to work nights and weekends to minimise disruption to the public and ensure our clients met the required time schedule. Minimising disruption to the public was very important to Transport for NSW and Downer on this project, i.e. the construction program was strategically staged so that major components of the project were completed in specific sections to ensure each section was completed as quickly as possible with minimal disruption to traffic flow, business owners and the public in general.

This created several complexities to Monteath & Powys, particularly related to survey control, where we were generally confined to a very narrow corridor, with the entire road infrastructure including footpaths being demolished and replaced. A lot of our time on this project was spent ensuring survey control was fit for purpose and able to be issued to all sub-contractors on site with a great deal of confidence as well as ensuring our works outside of the construction zone did not impact on the public.

Completing this work in such a manner also destroyed the majority of survey marks within the road corridor, requiring a unique and structured approach in consultation with NSW Spatial Services in regards to the preservation of survey infrastructure. Additional complexities came from the client's request to provide aerial photography on a regular basis along the project route. Civil Aviation Safety Authority (CASA) requirements stipulate that an Unmanned Aerial Vehicle (UAV) or Remotely Piloted Aircraft System (RPAS) cannot be operated within 30 m of the public or an occupied building, i.e. a unique solution had to be devised to provide weekly aerial updates.

The other major complexity of this project was the existence of underground services and the requirement for an underground services model to be continually maintained and provided to Transport for NSW upon completion. Given the age and nature of the centre of Newcastle, the existing underground services had a lot of uncertainty with much of the original construction dating back to convict days. Monteath & Powys utilised a variety of techniques to locate and maintain the services model.

Additional complexities came towards the end of the project in relation to the accuracy requirements of the as-built conformance data. Monteath & Powys were able to utilise a rail trolley to accurately and confidently model the as-built rail locations to ensure conformance with the specifications provided. Much of the complexities came from the tight timeframe, long narrow shape of the project area and the location of the project itself, being the middle of a working city.

3 SURVEY

3.1 Survey Control

Prior to construction, Monteath & Powys established survey control throughout the project with a nominal spacing of 50 m between adjacent marks. Due to the required construction tolerances for the light rail track (slab track), control was required to be accurate to within ±3 mm in Easting, Northing and height. As a result, control was established using a high-accuracy total station (Leica TS30) with an angular accuracy of ±0.5” and distance measurement accuracy of 1 mm + 1 ppm to carry out the traverse to a combination of ground marks, fixed prisms and retro targets.

Heights for all ground marks were established by differential levelling using a Leica DNA03 digital level, with an accuracy of 0.3 mm established throughout. Ultimately the control network consisted of 400 marks, with the observations adjusted using Compnet least squares adjustment software, to provide confidence in the accuracy of the marks placed.

One of the major complexities on this project was the fact that the light rail was constructed in sections where the road would be demolished, including all footpath infrastructure, for an entire block at a time. This meant all survey control would be destroyed in this area, leaving only the survey control on either side. Given the tight accuracy tolerances, it was not possible to use retro targets on walls, and at each section additional control had to be re-instated from one side of the current construction area to the other.

This meant the site survey control was continually being updated and re-issued to the sub-contractors on site, i.e. communication was incredibly important between all stakeholders, including our client and the sub-contractors as well as the sub-contractors’ survey teams.

3.2 Preservation of Survey Infrastructure

As previously mentioned, when each section of light rail was to be constructed, the entire road corridor including footpath infrastructure was demolished. From our initial discussions with the client, we understood this to be the case where all existing survey marks on public record were to be destroyed.

As part of the project, Monteath & Powys were required to prepare a Preservation of Survey Infrastructure (POSI) strategy in accordance with the Surveying and Spatial Information Act and Surveyor Generals Direction No. 11 (NSW Spatial Services, 2020) due to the proposed or potential disturbance or destruction of multiple cadastral reference marks and permanent survey marks during the construction of the light rail. Consultation with NSW Spatial Services commenced on the same day that Monteath & Powys were awarded the contract in late June 2017, due to the tight timeframes to complete surveys of existing marks and gain approval for mark destruction prior to construction commencing in September 2017.

A robust approach to POSI was created in consultation with NSW Spatial Services, which required substantial initial survey work to locate all survey infrastructure from our newly created survey control network. Marks were also placed from the survey control network into side streets, allowing direct relationships to be established from the previous location of survey infrastructure to survey control that is still on site today following construction. This gave us a lot of confidence in re-instating survey infrastructure and producing POSI plans that are now available on public record. Our survey control techniques were also suitable for the re-instatement of state survey control marks, which, combined with the POSI plans, will leave the survey infrastructure along the Newcastle light rail route in a far superior state to pre-construction. Over 100 survey marks were included in the POSI survey.

3.3 Sub-Surface Utilities

Sub-surface utilities were a major part of this project, gaining an understanding of what was currently in the ground over the 2.7 km route and accurately producing a 3D model, which was able to be updated on a regular basis and issued to all stakeholders. Many of the underground services through the older area of the city were completely unknown with several of the structures and in particular drainage being constructed during the convict era. A lot of works had already been completed prior to construction commencing, with Monteath & Powys having some involvement early on. We were able to compile all of the existing information, which was checked for spatial accuracy in relation to our newly created survey control network and produced in 12D software, which became a standard on this project.

The Australian standards were also adopted for sub-surface utility classing with Monteath & Powys becoming the single point of contact for all service locations. Several of the service locations were completed by other sub-contractors on site with Monteath & Powys creating a standard procedure for providing these services back to our dedicated services surveyor, ensuring every service discovered on site was included into the overall survey model along with any relevant attributes including the class.

As the project progressed, additional services were placed and also included in the model, as well as several services becoming redundant. The services model became a live document that was continually updated and at the end of the project was able to be delivered to our client as a full and accurate underground services model for the entire route to be utilised on any future project.

3.4 Rail Conformance

A major part of Monteath & Powys' role was conformance checks on all works completed by both Downer and sub-contractors on site. The rail conformance was arguably the most critical conformance survey completed with a tolerance of ±3 mm. Monteath & Powys are fortunate to have a lot of rail experience and were able to utilise an Amberg GRP 1000 rail trolley to capture all as-built rail information with confidence. The Amberg GRP 1000 software allows us to record all required survey information in a single pass and produce a report highlighting any errors in a safe and efficient manner (Figure 1).

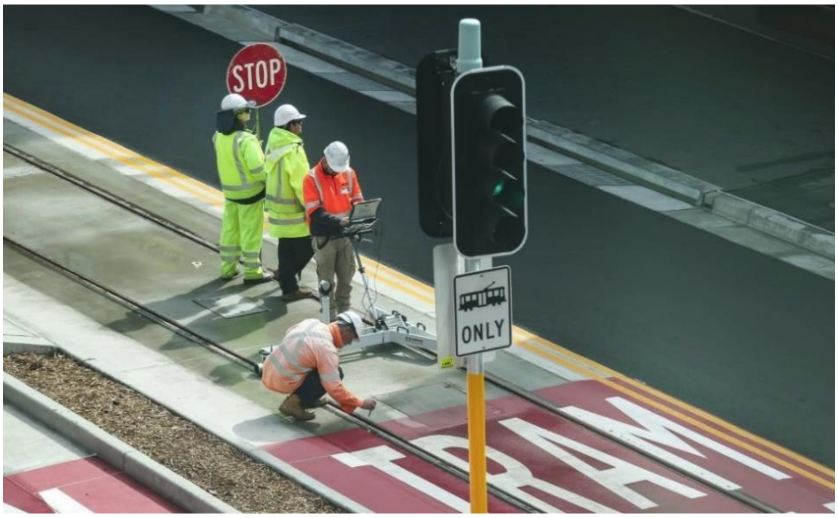

Figure 1: Monteath & Powys staff operating an Amberg rail trolley for conformance of the track prior to running the first light rail vehicle (image courtesy of Newcastle Herald).

3.5 Deformation Monitoring

During construction of a replacement large sewer main using micro tunnel methods, groundwater had to be reduced in the area of the launch and receival pits by using a dewatering process. Due to the proximity to the water table (street level being only about 2 m above mean sea level), the ground conditions consisting of a sandy loamy soil and the age of many of the buildings surrounding these sites with the potential for sub-standard (by current standards) foundations, engineers were concerned that the dewatering and construction process may lead to ground deformation of up to 50 mm and subsequent damage to surrounding buildings.

To manage this process, Monteath & Powys proposed a deformation monitoring program in parallel with other structural dilapidation assessments carried out by engineers to help inform the project during the dewatering and construction phases. This consisted of two initial precise digital levelling surveys to establish a reference baseline before dewatering commenced, followed by around-the-clock surveys during the dewatering phase, with a Trigger, Action, Response Plan (TARP) developed with the project team to manage to any eventuality. Once the dewatering reached a steady state and construction commenced, monitoring progressively reduced to daily and weekly surveys.

These surveys played a critical part of managing construction activities in close proximity to businesses and the general public, ensuring that the work could be carried out with as little disruption and risk to safety and property damage as possible.

3.6 Heritage Preservation and Interpretation

Several heritage items were also identified along the way, which were able to be captured in a fast and efficient format. An example was the requirement for 3D laser scanning on heritage items that were exposed along the route, which needed to be captured as quickly and as accurately as possible. Conventional surveys were also completed on items such as the original Burwood Railway, which was exposed when excavating Hunter Street (Figures 2 & 3).

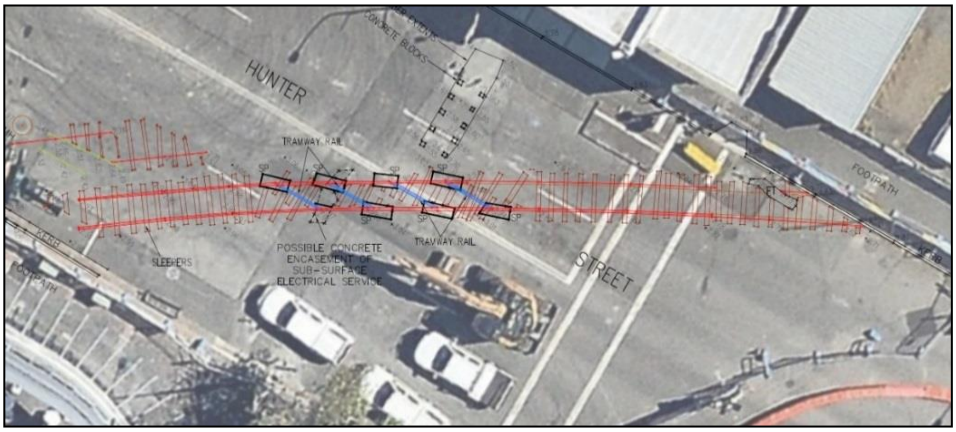

Figure 2: Overlay of heritage survey of Burwood Railway Line – Hunter Street, Newcastle.

Figure 3: Archaeology excavation of the Burwood Railway Line – Hunter Street, Newcastle.

Monteath & Powys were able to create a spatially accurate 3D model of these items, providing an accurate historical record for future use. A variety of challenges were overcome by using a range of progressive technical solutions on such a high-profile project.

4 AERIAL PHOTOGRAPHY

4.1 Initial Approach

Early in the project, it was requested to provide aerial imagery over the proposed light rail depot site near the former Wickham railway station using UAV technology. Due to the location of the site, several restrictions existed for the operation of RPAS (or drones) in the area due to the close proximity to several helicopter landing areas and the built-up urban environment. As a CASA-approved RPAS operator, we reviewed these restrictions and undertook a risk assessment of the proposed work in order to mitigate some of the safety risks and to manage legislative requirements under the Civil Aviation Act 1988. The outcome required an application to be made to CASA for approval to fly with a nominated restricted zone. Part of this approval process was to consult with operators of helicopter landing areas and gain their permission to operate.

The approval from CASA was forthcoming and was granted with strict conditions, such as our in-house operator maintaining radio contact with aircraft in the area and not overflying people or flying within 30 m of buildings. To fly within 30 m of buildings, CASA required landholder consent, which would be next to impossible in an urban environment like the Newcastle CBD with multiple high-density apartment buildings. A small section of the corridor complied with the requirements and this portion was captured successfully within the geographical and operational limits of the CASA approval, providing aerial imagery and Digital Terrain Model (DTM) deliverables.

Following this initial work, Transport for NSW enquired about the possibility of providing regular aerial photography across the entire project to document the progress and assist with forward planning. The use of a UAV was considered, but due to CASA restrictions on flying within 30 m of people and buildings, this would not have been possible within the legislated requirements for the majority of the corridor. Therefore, an alternative solution was required.

4.2 Alternative Approach

After some research, it was proposed that photography would be captured from a helicopter and an orthorectified image created. A local helicopter was chartered and using a high-resolution digital SLR camera, handheld photography was captured at a near-nadir orientation from approximately 1,100 feet above the ground, almost 3 times the maximum flying height for a UAV (Figure 4). A typical flight captured approximately 1,800 images with a combined file size of 20 Gb and took approximately 45 minutes to complete from take-off to landing. Processing was then completed by uploading the images and setting up the control on a dedicated computer, with the final processing taking place overnight.

Figure 4: Surveyor Matt Richardson demonstrating the method of aerial imagery capture.

4.3 Equipment

We utilised a Canon 5D DSLR camera and 135 mm fixed focal length L-series lens. Aerologistics, a local helicopter company, was engaged and provided a Robinson R44 4-seat helicopter with the doors removed to allow a clear working area. A number of complications were overcome to ensure reliable imagery was captured every time with consistent image overlap. The relationship between the speed of the camera and ground speed of the helicopter were critical to ensuring consistent overlap.

The frequency at which photos could be captured was directly proportional to maximum flying speed and therefore had a significant impact on the flight times and charter costs. While shutter speed was not much of an issue, the processing speed of the camera and remote trigger was a significant source of delays. High-speed SD cards were used to minimise file write times, and a smartphone-based camera trigger system with a customisable interval timer was used to capture photos with a delay of approximately 0.35 seconds between frames, which allowed for a ground speed of 15 knots while ensuring sufficient image overlap.

Due to the location of the corridor adjacent to many multi-storey buildings, shadowing across the site was also an issue. Flights were undertaken around midday to minimise shadows, but the exact timing was varied throughout the year as the seasons changed. In addition, Adobe Photoshop was used to adjust the lighting and minimise the impacts of shadows in the final orthoimage.

4.4 Risk Management

A rigorous risk assessment was completed in consultation with the helicopter provider for this task and a number of controls were developed to eliminate or minimise any risks to a safe level. Following initial training for working with the helicopter, a system was developed to tether all equipment and ensure the potential of falling objects was safely eliminated.

4.5 Processing

The images were downloaded straight after completing the image capture and sorted to remove any poor quality or unnecessary photos. The photos could then be imported into AgiSoft MetaShape and aligned using an automated alignment tool based on pixel matching before the control points were manually added.

AgiSoft MetaShape is a ‘structure from motion’ based photogrammetry package that was found to have a number of specific advantages over other UAV focused photogrammetry packages. Many modern photogrammetry programs require Global Positioning System (GPS) and Inertial Measurement Unit (IMU) data to calculate an initial fix, while MetaShape uses image sequencing and a bulk-matching routine to complete this initial fix. Additionally, most photogrammetry packages create orthoimages that are derived from colouring each individual mesh triangle with a ‘mean’ colour, whereas MetaShape has the ability to create a true orthomosaic with the raw imagery projected onto the mesh triangles.

Unlike UAV imagery, the digital SLR photos did not have GPS or IMU details to help with the initial orientation and alignment. The initial alignment was by pixel-matching between all 1,800 images. This process can be streamlined by capturing the images sequentially, flying along the corridor with minimal changes of direction. The average initial alignment time was around 3-4 hours.

The ground control used consisted of existing physical features, which had been located during the early works detail survey. Objects such as manholes, pit corners and pram ramp corners were able to be used as ground control, which were easily visible within the photos and did not require placing any additional survey marks across an already congested site. One consistent issue was the loss of survey control as demolition of entire sections of road and footpath occurred. The photogrammetry ground control was updated with new features as they were installed, and as-built surveys were completed.

With the control added, a final adjustment could be run prior to generating a point cloud model overnight. From the point cloud, an orthomosaic image was extracted, resulting in a very large TIFF file (about 4 Gb) with a pixel size of approximately 25 mm on the ground and horizontal accuracy of ±0.1 m. This resolution was high enough to count reo-starter bars within the concrete slabs. AutoCAD was used to combine the high-resolution orthomosaic with standard-resolution Nearmap background imagery.

4.6 Deliverables

The final image was produced in a variety of formats (including TIFF, DWG and KMZ), allowing the image to be opened in a variety of software packages, the most accessible of which was Google Earth. These KMZ files could be converted into Google Earth super-overlays, allowing multiple weeks of imagery to be loaded into Google Earth and switched between with the click of a button. This allowed easy visual checking of progress and change tracking, with engineers being able to step back through time week-by-week without reloading any files.

The processes were streamlined to the point where we could fly the site on Thursday and provide multiple 4 m long orthorectified image prints and electronic files to the clients by Friday lunch time to display on their office walls (Figure 5). This gave our clients the ability to quickly and easily inspect any part of the site and enable project discussions to take place with current data in a readily identifiable format.

Figure 5: An example of the deliverable image provided to the client.

5 CONCLUDING REMARKS

This paper has outlined Monteath & Powys' involvement in an iconic project for Newcastle over a period of 18 months (Figure 6), amounting to over 12,000 man hours of work between 46 individual staff members. We were required to liaise with all stakeholders and survey sub-contractors engaged by the construction contractors, to coordinate survey control, sub-surface utility investigation, quality control, conformance and other contract requirements.

This project allowed Monteath & Powys to demonstrate the company's capability on a large infrastructure project in an urban environment with numerous challenges that required the application of many different surveying specialities. Given the high profile of this project, we were aware of community expectations and our responsibility to conduct our activities in a professional manner. The project's location meant we were incredibly visible to the public, which was evident when our survey team featured in the local media. It was a credit to our staff members on the ground, the way they conducted their daily tasks and the professional manner they dealt with all community interactions.

Figure 6: Delivery of the first light rail vehicle.

ACKNOWLEDGEMENTS

Monteath & Powys would like to acknowledge the role of the Managing Contractor for the project, Downer, and the project team overseeing the construction. We would also like to acknowledge the good work and support provided by each of the surveying sub-contractors involved in various stages of the project and contributing to its success: Aurecon, Scope Surveying, Veris, DeWitt Consulting and RPS.

REFERENCES

NSW Spatial Services (2020) Surveyor General's Direction No. 11: Preservation of Survey Infrastructure, https://www.spatial.nsw.gov.au/surveying/surveyor_generals_directions (accessed May 2020).

Review of Digital Survey Plans in NSW

Adrian White
Spatial Services
NSW Department of Customer Service
Adrian.White@customerservice.nsw.gov.au

ABSTRACT

Significant progress has been made in digitising large parts of the NSW land title system. For example, over 95% of mainstream conveyancing dealings are now lodged electronically in NSW. The NSW Government has also transferred the majority of old land title records into a digital format. This includes the capture of intelligent digital data (LandXML) files for over 500,000 registered Deposited Plans. However, the creation of intelligent digital cadastral data by surveyors is lagging behind. The surveying profession continues to lodge around just 5% of plans using LandXML. Despite the low update, there are many benefits from going digital, in terms of reducing development holding costs through greater efficiency, increasing surveying business productivity, reducing rework and manual data entry, improving data quality and underpinning new innovative value added services for the community. In order to address this, the NSW Government and NSW Land Registry Services (LRS) have undertaken a collaborative review process, working closely with industry to understand why reforms to date have not been successful and to make recommendations for how NSW can achieve 100% digital survey plans. This presentation provides an overview of the review findings and outlines the implementation roadmap.

KEYWORDS: *Digital, surveying, cadastre, LandXML, plans.*

Being Productive Working at Home

Michelle Blicavs
Association of Consulting Surveyors
michelle@acsnsw.com.au

ABSTRACT

Michelle Blicavs is a Certified Association Executive and has been managing small to medium sized businesses for more than 25 years. Most of us know Michelle from her role as CEO at the Association of Consulting Surveyors (ACS) where she leads a small team providing support, advocacy and leadership for the private surveying sector. In late 2019, Michelle came down with glandular fever, which meant she had to work from home for 3 months whilst she recovered. What she did not know at the time, was that this would be practice for the coronavirus/COVID-19 lockdown in 2020. Michelle was able to implement new processes and disciplines for herself and her team that have served to see ACS continue to be successful during the pandemic. This presentation provides you with a renewed focus on how to start each day fresh, not be lost in isolation and find a new energy for a more productive period even while working at home.

KEYWORDS: *Work from home, productivity, efficiency, mental health, isolation, tools and techniques*.