FROM PORTS TO PORTALS

SURVEYING AND SPATIAL DIRECTIONS

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Editorial

These proceedings contain the papers presented at the Association of Public Authority Surveyors Conference (APAS2012), held in Wollongong, NSW, Australia, on 19-21 March 2012. Papers were not peer-reviewed but have been subject to changes made by the Editor.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 conference.

Authors are welcome to make their paper, as it appears in these conference 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. (2012) Likely impact of the approaching solar maximum on GNSS surveys: Be alert but not alarmed, *Proceedings of Association of Public Authority Surveyors Conference (APAS2012)*, Wollongong, Australia, 19-21 March, 66-82.

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Coordinate Systems used in Railways in NSW and their Effects on Cadastral Surveying, Engineering and Mapping

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ABSTRACT

This paper describes the common coordinate systems used in the railways in NSW. The range of coordinate systems includes the Map Grid of Australia (MGA), Integrated Survey Grid (ISG), Railway Integrated Grid (RIG), local plane systems and also a Cassini-Soldner grid used in Sydney. A brief description of each of these coordinate systems is given as well as some of the peculiarities of some of these systems. Examples of each of these systems are presented together with a number of the variations that can be found. The effects of coordinate systems on the process of the definition of railway boundaries are discussed with examples from recent works. The cadastral and environmental footprints of proposed works are some of the early issues raised in a number of projects and if not addressed can cause problems at a later date. Cadastral and environmental processes often have long lead times and are therefore often on the critical path for a project. Other effects of coordinate systems in use include the long-term maintenance of engineering infrastructure, including the more obvious rail tracks and the less seen underground services that are essential for the safe and efficient operation of a railway. The products produced on a typical project include local mapping products to support a wide variety of operational, maintenance and construction works, showing above ground and underground infrastructure and the associated formation works required to support this infrastructure. Some observations from a number of recent projects are discussed and a number of recommendations are presented.

KEYWORDS: *Coordinate systems, mapping, railway, cadastre, NSW.*

1 INTRODUCTION

There are many coordinate systems that have been used over time throughout the railways in NSW. These systems have each been implemented to solve problems and provide a framework for current and future works using the information and tools available at the time and taking into account the uses of the information. Some of these systems are not what they seem, so understanding the details of the particular system can make the difference between straight forward survey work and many hours of hair pulling and concern as designs not fit together.

No discussion about railway coordinate systems would be complete without at least mention of the most used and common system of "line", "chainage" and "offset". This is the system that most railway information is collected and disseminated in, and is understood throughout the industry. Although not the subject of this paper, this system is none-the-less significant due to its widespread use and the ease that staff have in measuring and applying the information. This paper, however, examines the Cartesian coordinate systems more familiar

to surveyors, describing some of their properties, and implications to those using the information.

2 EARLY SURVEYS AND DESIGNS

The early surveys for the construction and maintenance of the railway, track, formation, structures and cadastre, were based on traditional traverse and closure calculations. These surveys typically traversed the centreline directly, reducing the amount of calculations. The process often dealt with secant and tangent lines for curves. The boundary was often parallel to the track centreline. Details of boundary definition based on the original railway plans are available in Webber (1983).

Vast lengths of railway were surveyed using this method, with calculations often undertaken in tents at night using tables, and later the mechanical calculators for basic mathematical calculations. Evidence of this is sometimes found in longer curves where the curves were broken into multiple compounding curves of the same radius each with its own intersection point. This was done for the purpose of marking, to ensure that the curve was not too far from the tangent line between the intersection points. These alignments were later monumented (a process of permanent marking), and the intersection points and other critical points in the framework were marked together with recovery points near the critical points on the centreline as well as regular intervals along the centreline. It will be noted that in all the records found for this work, coordinates do not seem to have been considered.

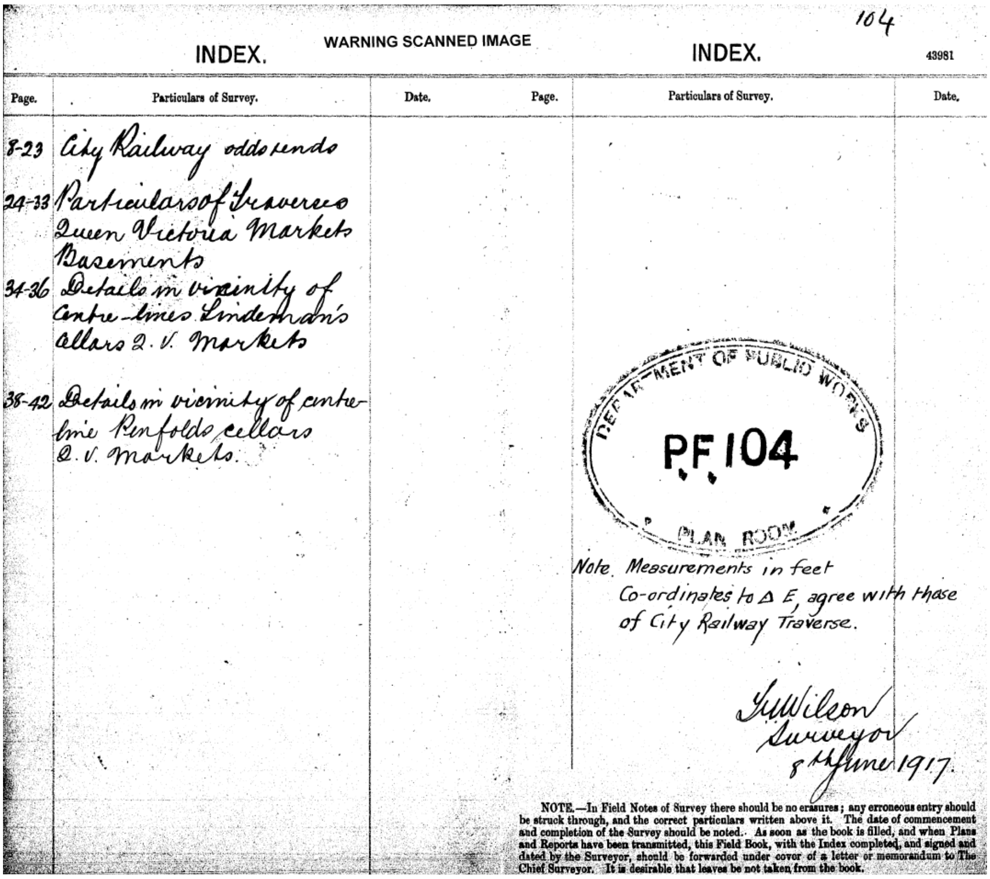
Understanding the processes that were used in these times helps with boundary definition in the re-establishment of the original alignment, which in-turn allows for a calculation of the likely original boundary intentions.

3 EARLY LOCAL COORDINATE SYSTEMS

In some areas, surveyors began to implement a coordinate system to aid in the process of planning, design and construction. Such systems seem to be varied in their application and foundation. Most of these systems appear to have been implemented for the purposes of a particular project. These systems were sometimes maintained and extended to adjoining areas by local survey staff. Over time, most of these systems have effectively been lost because the survey marks have been left undocumented, or the marks have been destroyed. It is also fair to say that the standards used for the survey control in these systems varied greatly, from high level instrumentation and methods to courser methods using lesser level instrumentation. There was rarely any network adjustment and traverse adjustment ranges from minimal to more thorough techniques.

A good example of an early coordinate system which can still be re-established is the coordinate system used for the design and construction of the City and Eastern Suburbs Railway. The control traverse extended through the city and out along the route to Bondi and then on to Randwick, Kensington and back through Sydenham and Erskineville. Records have been found showing this system in use as early as 1917.

Figure 1 shows a survey referring to Trig E and coordinates from the City Rail Way traverse. There are also many records showing traverse stations throughout the streets of the city on this coordinate system.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DEPARTMENT OF PUBLIC WORKS
PF 104
PLAN ROOM

Note. Measurements in feet
Co-ordinates to Δ E, agree with those of City Railway Traverse.

J.W. Wilson
Surveyor
8th June 1917.

NOTE.—In Field Notes of Survey there should be no erasures; any erroneous entry should be struck through, and the correct particulars written above it. The date of commencement and completion of the Survey should be noted. As soon as the book is filled, and when Plans and Reports have been transmitted, this Field Book, with the Index completed, and signed and dated by the Surveyor, should be forwarded under cover of a letter or memorandum to The Chief Surveyor. It is desirable that leaves be not taken from the book.

Figure 1: Extract from PF104.

This coordinate system was a Cassini-Soldner coordinate system, and seems to have been used by the Public Works Department at the time. The railway records have not revealed the details of this projection except that its origin was Trig "E". By back calculation Trig "E" is the trigonometrical station at Sydney Observatory, on the same meridian as the transit telescope in the observatory. See Figure 2 for the current SCIMS record of Trig E.

Figure 2: SCIMS Record of Trig Station E.

This coordinate system had no false Eastings or Northings, so coordinates were north or south and east or west of the origin, and of course in feet.

Investigations completed by a number of railway staff over recent years have indicated that the results were comparable to today's methods and very reliable. Many of the surface control marks were later made into PMs and the railway description lived on in SCIMS, so both the original coordinate values and Integrated Survey Grid (ISG) values were available for many marks. After elimination of outliers a similarity transformation using a large number of common marks could be undertaken.

The Eastern Suburbs Rail Way records from the construction show the coordinates for the alignment and the traverse. The information is detailed and complete. There are also indications of miss closes that were measured in the tunnels during the construction.

The plans from the time indicate that there was a miss close in the traverse of 0.2 of a foot (about 0.060 m) at Central Station. It appears that there may have been two traverses that met at Central Station. Rather than adjusting the survey values, there were simply two sets of values at the overlap. Figure 3 shows how the different values were used. There are also two sets of coordinates for the traverse stations on either side of this divide. This is just an example of where the taking of coordinates at face value can be misleading.

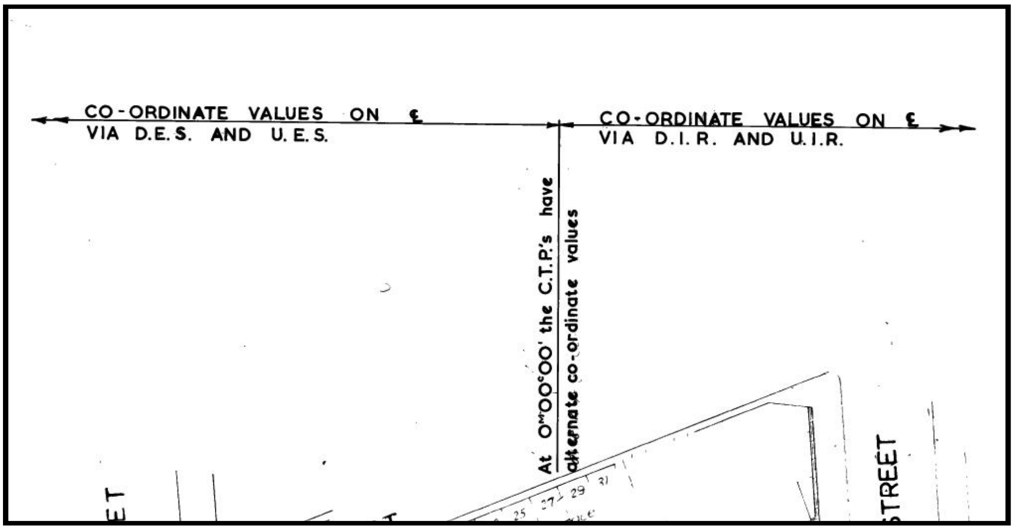

Figure 3: Extract from plan 2SS 1003.

4 INTRODUCTION OF ISG

The 1970s saw the introduction of the Integrated Survey Grid (ISG) (Lands, 1976). The development of this survey grid was seen by many railway surveyors as the way forward and a number of different implementations of ISG were made.

One of the key properties of ISG was the scale factor which was designed to be close to unity and as such should not need to be considered. This scale factor was however enough to cause some concern and there were cases where ISG values were adopted for a central mark and azimuth, the coordinates extended with a unity scale factor. The coordinates were sometimes, but not always, truncated to remove confusion. However, the origin of the coordinates was not always well documented, i.e. it was not always clear which system a coordinate came from since the values for common marks (and alignment points) would be similar when such systems joined.

4.1 Lands Department Support

Preceding planned upgrading works along many railway corridors, the Lands Department of the time was requested to supply ISG control that could be further broken down by the railway surveyors. As this was the early days of the roll-out of ISG, it was often necessary for the surveyors to place most of this control and carry out all the necessary observations to provide the required ISG coordinates.

The control provided by Lands was up to the task of the time but, as with all control, could be improved if additional resources were available. As further development of the network of ISG around the rail corridors proceeded, it was necessary to readjust the networks, altering the coordinates that had been adopted by the railways. Due to the vast amount of work undertaken by the railways and the engineering designs and plans produced from this work, the values from later adjustments of the survey observations were not used and the original coordinates were held fixed.

4.2 Scale Factors

Scale factors are the issue most often quoted as the reason not to use coordinate systems. Many people struggle with the concept of a scale factor between the coordinate plane and the ground. Engineers want to know that 100 m on a design is able to be measured as 100 m on the ground. This issue is one that needs to be carefully managed. Surveyors need to take care of these issues and ensure that prefabricated pieces of infrastructure will fit on foundations constructed to the design.

Although this particular issue has much merit, it can be worked around during the construction phase (a concrete road, pipeline or rail track that is different in length by the scale factor presents no issues to the correct operation of the asset).

4.3 Refining the Network

Over time the survey control network includes further observations, additional marks, extra legs and connecting lines, strengthening the network. Readjustments and changing of coordinates is a natural consequence of the process.

The railway breakdown of control, engineering observations and design calculations has all been based on the original coordinates and now differs from the ones available from SCIMS.

The process of the infill survey, design and design documentation effectively holds control fixed with the original values, and the railways' version of ISG and SCIMS grow apart. (This may also happen with MGA but the hope is that a stronger initial network will minimise both the frequency and magnitude of this separation.)

The result of the further refinement is a measurable difference in the coordinates available from SCIMS and those used by the railways. This has caused some outside surveyors to spend much time questioning both the survey skills and supplied data. These are easily cleared up once the full history is known but can lead to tensions in the short term.

5 RAILWAY INTEGRATED GRID

The Railway Integrated Grid (RIG) was developed to differentiate railway coordinates from ISG coordinates. A RIG coordinate can be identified by its coordinate values. A RIG coordinate has a false Easting set at 800,000 m and the false Northing was set at 700,000 m. All other grid factors are the same as ISG. Two major uses of RIG are briefly explained in the following sections.

5.1 Approximate ISG

In many areas there was insufficient control available to establish ISG along the railway corridor. There was still a desire to use the principles of ISG but no reliable origin was available in the area. In these cases a common practice was to establish the ISG value of some point from whatever was available. Sometimes this could be sourced from SCIMS where a mark had only a low order coordinate and at times the best method available was to scale a coordinate off the topographic mapping of the area.

Once a coordinate was available, the next step was to determine an azimuth. An azimuth could be determined using the above methods, a magnetic compass or sometimes a sun observation. As in the previous case, the control was then densified and the coordinates altered by the different false Eastings and Northings.

5.2 Frozen ISG

Where ISG control was available the values were adopted and densification of the control undertaken. To identify this as railway control and remove the effect of updates to the ISG network, the values were changed by adding to the false Eastings and false Northings. This control was then used for railway engineering purposes and maintained using only the original and derived survey information.

6 AMG IN QLD

During this time the NSW railways were responsible for the standard gauge railway line from the NSW border through to Brisbane. The exact boundary between QLD and NSW responsibility changed but the effect was the same. QLD did not adopt ISG but an unpublished half-degree overlap of ISG/AMG stations in QLD was available from LIC and used to push ISG over the border. There were sections of track being maintained that lay outside the extent of ISG. Within these areas, the Australian Map Grid was used where available (along with its much larger scale factor).

7 RAIL MAPPING IN MID 1990s

In 1994 a project was undertaken to map particular railway infrastructure throughout NSW. Details of this project were presented to APAS in 1995 (Latella, 1985). One of the by-products of this project was the establishment of pairs of PMs or SSMs in public lands adjacent to railway locations at an interval of approximately 50 km along each rail line. The effect of this was to make the introduction of coordinates along a number of lines a real prospect and together with the then new geodetic GPS receivers, railway surveyors were able to move further towards their goal of coordinated alignment throughout the network.

8 INDUSTRY SLIPPING BACK TO LOCAL COORDINATES

During recent years there has been a trend of putting major infrastructure development out to private industry to construct and deliver the project. As survey is a small and almost not mentioned part of these projects, the specifications have often not included things like coordinate systems. In these cases the projects often decide to implement a local coordinate system. The reasons often include the removal of scale factors, the use of smaller numbers in the documentation, and the reduction in effort in calculations. All these factors are of course easily overcome using modern computer systems.

The reasons for adopting local systems often seem strong when viewed from the project perspective. When the "life-of-asset" view is taken, there are much stronger arguments to adopt the common coordinate systems of the locality. A number of these arguments are covered in section 10.

9 RAIL SAFETY ACT AND ITS IMPLICATION ON COORDINATE SYSTEMS

The Rail Safety Act 2008 No 97 strengthened the constraints on entering the rail corridor, which has implications for the use of PMs and SSMs that have been placed within the rail corridor. This has brought a change to the practice of placement of survey marks, with PMs and SSMs being placed outside the corridor but within line of sight of the rail corridor.

Access to those marks within the rail corridor can be arranged through the local authority, with appropriate safety arrangements made. This restriction covers RailCorp, Australian Rail Track Corporation (ARTC), Country Rail Infrastructure Authority (CRIA), other private railways and those run by Victoria.

10 ARRIVAL OF MGA

With the introduction of the Geocentric Datum of Australia (GDA) and the associated Map Grid of Australia (MGA, see ICSM, 2006), RailCorp and ARTC are slowly converting the survey infrastructure and associated design information to MGA. This is occurring through primarily project works and is destined to leave significant sections in their current coordinate systems. Converting to MGA has a number of advantages beyond the integration to state based coordinate systems. Some of these advantages are discussed below.

10.1 Definition of Railway Boundaries

Many surveys for projects need to include boundary definition. Existing information on land boundaries is often available in MGA. There are significant advantages in being able to overlay the boundary information over detail mapping. These advantages stem from the freedom of many to see impacts of proposed activities near boundaries.

Being able to use the detail survey information of tracks and alignment monuments also allows the cadastral surveyor to utilise this information in the determination of the railway boundaries without having to have two separate survey data sets.

10.2 Cadastral Footprint for Proposed Works

Where proposed works extend to near or beyond the railway corridor, it can be necessary to acquire land or lease land during the construction program. The surveyor needs to prepare plans showing the proposed acquisition or lease so that property negotiations can be undertaken with adjoining land holders. The extent of the acquisition or lease is dependent on the extent of works for cuttings, embankments, access roads, construction and maintenance compounds, drainage structures and utility installation. There are advantages to the project of having the proposed work and the cadastral surveys on the same coordinate system helps to make this process as smooth and seamless as possible.

10.3 Environmental Approvals – Foot Prints

The environmental approval process is a long lead time process. Early level plans, overlaid on cadastral information and existing environmental data sets, are extensively used to efficiently identify the environmental impact of the works and areas where alternatives should be examined. There are also requirements to provide mapping to support the environmental approval process.

10.4 Underground Services

Underground services are a significant asset and can have a significant impact on design and construction of railway projects. The location of underground services is critical to the success of a project, and having this location based on the same coordinate system as other project information allows the early detection of clashes. To this end the services need to be mapped by coordinates and not just a line on a plan as errors can occur when interpreting plans and trying to put two disparate sets of data together.

Where the mapping has been carried out using a different coordinate system, it is essential that sufficient common points exist between the underground services data set and the detail mapping data sets. The best such common point are survey control points but other include significant infrastructure which is clearly identifiable in each data set.

10.5 Long Term Maintenance

The long term maintenance of the railway infrastructure is aided by the use of a suitable and long term coordinate system. There will always be improvements made in the value of coordinates of survey control marks, but if the differences are kept to a minimum and the adopted values are recorded with the design and boundary definition, the future survey task will be kept to a manageable and affordable level.

11 CONCLUDING REMARKS

There are a number of different coordinate systems that have been used within the rail environment. The casual user might assume that these coordinates match those generally available outside of the rail corridor, but this assumption can cause problems in the detail. The basis of coordinates on a plan needs to be included on the face of the plan. The use of MGA throughout the railways should be encouraged. This should also be extended to other infrastructure projects.

ACKNOWLEDGEMENTS

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Control Surveys: Why things are the way they are and not the way you think they should be!

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ABSTRACT

Control surveys can be realised in many guises, from large geodetic networks down to a set-out grid for a construction project. They all serve the same purpose, i.e. providing a base framework that will underpin some abstract or real infrastructure. This paper looks at how the rules that govern control surveys have developed and the processes used to achieve various targeted outcomes. The terms Order and particularly Class are fundamental in defining the processes associated with a control survey. New Global Navigation Satellite System (GNSS) technologies, such as Real Time Kinematic (RTK) and Network RTK (NRTK), now test our defined processes in determining Class and Order. The new Surveyor General's Direction No. 12 "Control Surveys and SCIMS" presents methods to accommodate these technologies to achieve Class C. These new technologies appear to be simple, accurate and productive but in a regulated environment things are not as simple as they appear. Rules still apply, and if followed correctly the desired outcomes can be achieved. Even so, for many surveyors, the new paradigm of absolute position observation versus relative measurement is indeed a "leap of faith". Hopefully, this paper will promote the reader to think outside the square when conducting a control survey because things are not always as they appear!

KEYWORDS: *Class, Order, control surveys, GNSS, SCIMS.*

1 INTRODUCTION

What are control surveys? Most surveys are control surveys of some specification or standard; the keywords here are specification and standard. Generally, control surveys provide a framework that meets a standard that is required for a particular outcome. The International Terrestrial Reference Frame (ITRF, see Altamimi et al., 2011) is a global datum and can be considered as a global control survey, but this is not really how it is perceived. It is not driven by a set of formalised specifications, but nonetheless it is an extremely precise realisation of monuments on the earth's surface. For a review of coordinate systems, datums and associated transformations the reader is referred to Janssen (2009).

On the other end of the scale, a simple builder's profile is also based on a control survey of sorts. Usually, a *surveyor* will peg out the house position with offset pegs and the builder will place his string line profiles over them. The general requirement is that the set-out complies with the building plan.

So, between the global-scale ITRF and the simple house set-out the scope and size of control surveys can be quite variable. This paper is focused on the control surveys that are defined in Special Publication 1 (SP1, see ICSM, 2007) and the soon to be released Surveyor General's

Direction No. 12 “Control Surveys and SCIMS” (draft available online, see LPI, 2012a). These control surveys are the types of surveys that result in the realisation of a datum and involve terms like station occupations, redundancy, network design, variance factors, Class, Order, observation variance, error ellipses and many other terms that surveyors are not always comfortable or familiar with. As well as these terms, there are also new technologies and methodologies which challenge the concept of control survey requirements as defined by existing directions. This paper hopes to demystify some of these concepts and separate technology from standards where this area has become somewhat blurred.

2 STANDARDS

Why do we have standards? Without standards the control of quality outcomes cannot be guaranteed. Today, accepted standards define most things in our day-to-day environment. There are standards for electrical work, plumbing, motor vehicle design, building, television advertising – the list goes on and on.

In survey work, standards define accuracy of outcomes. For control surveys, the standards are empirical values referred to as Class, Order and Uncertainty (the implementation of which has been challenging due to aspects of the concept, see Roberts et al., 2009). Specifications on the other hand, provide the processes needed to achieve standards, such as equipment and operational procedures.

2.1 Class

Class is the term/value we assign to a survey and subsequently the points or stations in that survey that defines the survey as achieving a certain standard. The determination of Class is defined in SP1 (ICSM, 2007) as:

“Class is a function of the planned and achieved precision of a survey network and is dependent upon the following components:

- the network design,
- the survey practices adopted,
- the equipment and instruments used, and
- the reduction techniques employed,

all of which are usually proven by the results of a successful, minimally constrained least squares network adjustment computed on the ellipsoid associated with the datum on which the observations were acquired.”

“The allocation of Class to a survey on the basis of the results of a successful minimally constrained least squares adjustment may generally be achieved by assessing whether the semi-major axis of each relative standard error ellipse or ellipsoid (i.e. one sigma), is less than or equal to the length of the maximum allowable semi-major axis (r) using the following formula:

$$r = c\ (d + 0.2) \qquad (1)$$

where
r = length of maximum allowable semi-major axis in mm,
c = an empirically derived factor represented by historically accepted precision for a particular standard of survey,

d = distance to any station in km."

The values of c assigned to various Classes of survey are listed in Table 1.

Table 1: Classification of horizontal control surveys according to SP1 (ICSM, 2007).

Class	C (for one sigma)	Typical applications
3A	1	Special high precision surveys
2A	3	High precision national geodetic surveys
A	7.5	National and state geodetic surveys
B	15	Densification of geodetic survey
C	30	Survey coordination projects
D	50	Lower Class projects
E	100	Lower Class projects

This appears to be a fairly uncomplicated definition. The first part is straight forward: terms like equipment and instruments, reduction techniques and survey practices are all familiar terms and descriptions. These terms are all subject to certain specifications and reductions. For example, does the Class require a rigorous formula to reduce measurements? Is a minimum number of occupations of stations specified? Is instrument certification a requirement?

The next part of the definition uses words like least square adjustment, semi-major axis and relative standard error ellipse. It is this part of the definition where things start to get disinteresting. A lot of people turn off at this part. In order to meet the requirements of the definition, the surveyor needs good least squares adjustment software and good fundamental understanding of what this part of the definition is alluding to.

Equation 1 defines the 1-sigma (1σ) maximum semi-major axis of the relative error ellipse for two stations a given distance apart where *d* is in kilometres. As a rule-of-thumb, the value *c* in Table 1 can be interpreted as a parts-per-million (ppm) value. For example, for a Class 2A survey where the distance between adjacent stations is 2 km, the maximum allowable size of the semi-major axis of the relative error ellipse is about 3 ppm or 6 mm. Similarly, the maximum Class C relative error ellipse over the same distance is about 30 ppm or 60 mm.

An important word in the definition of Class is *successful* in referring to the least squares adjustment. This generally implies that the adjustment Variance Factor (VF) is close to unity, that in-turn suggests a normally distributed set of observation residuals. This also indicates that the observation variance estimates are correct so that the relative error ellipse sizes are 'true'. It also indicates that you have confirmed that your observations agree with themselves as a stand-alone survey.

2.2 Order

The Order of a survey is an evaluation of semi-major relative error ellipses which result from constraining the least squares adjustment to fixed coordinates. SP1 (ICSM. 2007) defines Order as:

"Order is a function of the Class of a survey, the conformity of the new survey data with an existing network coordinate set *and* the precision of any transformation process required to convert results from one datum to another. Stations in horizontal control surveys are assigned an Order commensurate with the Class of the survey and the conformity of the survey data

with the existing coordinate set. The Order assigned to the stations in a new survey network following constraint of that network to the existing coordinate set may be:
a. not higher than the Order of existing stations constraining that network, and
b. not higher than the Class assigned to that survey."

The highest Order that may be assigned to a station from a survey of a particular Class is shown in Table 2.

Table 2: Relationship between Class of a survey and the highest Order to be assigned (ICSM, 2007).

Class	Order
3A	00
2A	0
A	1
B	2
C	3
D	4
E	5

As the concept of Order is based upon the Class of the station as well as the fit of the survey network to the existing coordinate datum, the Order correlated to Class alone may be degraded by its fit to the existing coordinate set or as a result of the configuration of the ties used to constrain it to the existing datum. The allocation of Order to a station in a network, on the basis of the fit of that network to the existing coordinate set, may generally be achieved by assessing whether the semi-major axis of each relative standard error ellipse or ellipsoid, with respect to other stations in the fully constrained network, is less than or equal to the length of the maximum allowable semi-major axis. This technique is identical to that employed in the determination of Class and makes use of the same formula (Equation 1). The values of c for various Orders of survey are shown in Table 3.

Table 3: Order of horizontal control surveys (ICSM, 2007).

Order	C value (for one sigma)
00	1
0	3
1	7.5
2	15
3	30
4	50
5	100

The derivation of Order for a station within a constrained least squares adjustment follows a similar process to that of determining Class. The above definition of Order does not include the wording "successful least squares adjustment". But the evaluation of Order requires similar techniques as Class to achieve an adjustment VF of unity. It may be necessary to downgrade your observation variances to fit to the constrained coordinates and achieve that VF value near unity, which then implies a normalised residual set and relative error ellipses which are 'true'. You have determined the Order of your survey in terms of its constraints. It is quite possible to determine that a survey is Class 2A but Order 4.

Assigning Order to a mark or station "must remain within the subjective judgement of the geodesists of the relevant authority" (ICSM, 2007). This means that you have control over the Class of your survey if you follow the specifications. As long as the specifications do not

change, the Class should not change. However, the assigned Order can change at the discretion of the relevant authority, but it must still comply with Table 2.

2.3 Class and Order for Heighting

Similar tables and formulas are used in the derivation of Class and Order for vertical survey work. There is a distinct difference in the classification of differential (spirit) levelling and heights derived by other techniques such as trigonometric or Global Navigation Satellite System (GNSS) heighting. Differential levelling is based on the formula (ICSM, 2007):

$$r = c\sqrt{d} \tag{2}$$

whereas other heighting methods are tested using Equation 1. In both cases, the value of r is now 1-dimensional and defined as the maximum allowable error in millimetres. The value d continues to represent the distance in kilometres, while c is determined according to Table 4. Note that for non-differential levelling the values for c are the same as for horizontal Class.

Table 4: Values of 'c' assigned to each Class of survey (ICSM, 2007).

Differential Levelling $r = c\sqrt{d}$		**Trigonometric and GNSS Heighting** $r = c\,(d+0.2)$	
Class	**C (for one sigma)**	**Class**	**C (for one sigma)**
L2A	2	2A	3
LA	4	A	7.5
LB	8	B	15
LC	12	C	30
LD	18	D	50
LE	36	E	100

2.4 Uncertainty

Uncertainty is a relatively new concept in terms of control surveys, even though it is discussed in SP1. There are two types of uncertainty, i.e. positional and local.

SP1 (ICSM, 2007) defines Positional Uncertainty (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. The reference frame *must* be described in the metadata. In Australia, the currently defined reference frame for horizontal positions is GDA94 and for heights is AHD. In New Zealand, the currently defined reference frame for horizontal positions is NZGD2000. Positional Uncertainty is reported as the total uncertainty propagated from the zero order network (the AFN in Australia) or, in case of AHD heights, the total uncertainty propagated from the AHD tide gauge bench marks."

This definition means that as you drill down through network layers, the Positional Uncertainty of a point grows larger. The point's uncertainty is an accumulation of observational error. This is not too difficult to implement but it requires knowledge of point error ellipse sizes of each and every constraining point if it is derived by layers. It can also be derived by adjustment if the entire point network is run as a single network adjustment, an approach which is being proposed for the planned new static Australian datum (tentatively called GDA2020). Positional Uncertainty is a term proposed to replace Class.

Local Uncertainty is the term used to represent/replace Order. SP1 (ICSM, 2007) defines Local Uncertainty (LU) as “the average measure, in metres at the 95% confidence level, of the relative uncertainty of the coordinates of a point(s), with respect to the survey connections to adjacent points in the defined frame. Each relative uncertainty used to determine this average is the uncertainty between the coordinates of two related points.”

The implementation of Local Uncertainty is a little more difficult to implement (Roberts et al., 2009). The rule with Class and Order is that the Order can never exceed the Class. In the case of uncertainty, LU will exceed (i.e. be better than) PU. Survey projects should stipulate a LU in lieu of PU to define the required survey standard. This is the reverse of the Class and Order rule.

3 SPECIFICATIONS

As mentioned earlier, specifications provide the processes needed to achieve standards. SP1 (ICSM, 2007) provides a vast amount of detail about specifications for various Classes of survey. The new Surveyor General’s Direction No. 12 (LPI, 2012a) is not as specific but targets the requirements to achieve Class C and meet submission standards for inclusion in the Survey Control Information Management System (SCIMS, see LPI, 2012b) that is maintained by Land and Property Information (LPI), a division of the NSW Department of Finance & Services.

SP1 contains specification tables outlining requirements to achieve various Classes for:

- Astronomical azimuth observations
- Electronic distance measurement (EDM)
- EDM reduction procedures
- Horizontal angle measurement
- Differential levelling equipment characteristics
- Differential levelling equipment testing
- Differential levelling equipment procedures
- Differential levelling reduction procedures
- EDM height traversing equipment characteristics
- EDM height traversing equipment testing
- EDM height traversing observation procedures
- EDM height traversing reduction procedures
- Trigonometric heighting observation requirements
- Global Positioning System (GPS) method vs. Class
- Real Time Kinematic (RTK) recommended processing requirements
- GPS data attributes for “absolute” positioning
- Tables for inertial survey systems
- Tables for horizontal control surveys by photogrammetry

SP1 also contains sections on station occupation, optimisation and network design, network adjustment assessment, datum transformations, recommended marking practices and recommended documentation practices. All these specifications and guidelines provide a pathway to achieving desired Class and Order outcomes.

3.1 Specifications and SCIMS

The new Surveyor General's Direction No. 12 (LPI, 2012a) draws on the principles outlined in SP1 (ICSM, 2007). The Direction provides a guide as to what LPI requires before it will place coordinates, heights and quality of survey monuments on public record in the Survey Control Information Management System. More specifically, it outlines the minimum requirements for LPI to place coordinate values on survey marks in SCIMS at an established level, i.e. horizontal Class C and vertical Class B or LD or better.

An important aspect of this Direction refers to consultation: Details of LPI's full requirements and the interpretation of this Direction *must* be discussed *and* agreed with an LPI Senior Surveyor *prior* to commencement of *control* surveys *to be placed on public record*. The document addresses all aspects required by LPI in the determination of at least Class C horizontal and Class B or LD vertical surveys. These are summarised in the following sections.

3.1.1 Assigning Class

This is the most technical element of the control survey process. Assigning Class is the result of the survey meeting the required specifications and practices and passing the required statistical analysis tests.

3.1.2 Mark Placement

The quality of marking impacts directly on the determination of a survey's Class. It is even more significant in assigning Order. Surveyor General's Direction No. 1 (LPI, 2009) details different types of approved permanent marks. At this time, there is no Class associated with different mark types. The effective Class of a star picket in soil and a concrete observation pillar can be the same! LPI considers that mark stability is a significant element in the determination of Class and Order. Beware that poor mark location will impact on the assigning of Class.

3.1.3 Equipment

Instrumentation must be able to deliver the appropriate precision for the desired Class. Class C requires distance measuring instrumentation that can measure to better than 30 ppm. A 5" total station meets Class C, while an EDM which has a measurement standard deviation of 5 mm + 5 ppm can achieve Class B. Note that a 3rd order level may produce results which look like Class LA but it is still Class LC.

3.1.4 Network Design and Geometry

Surveyor General's Direction No. 12 is mainly concerned with the determination of Class. However, without proper network design and geometry, and connections to existing SCIMS control marks, an appropriate Order cannot be determined. Therefore, LPI requires that connections to existing local control in and adjacent to the survey must be part of the design.

Surveys should not be over-observed or over-specified. Observations should be made between adjacent marks. Strong survey networks are characterised by connections between adjacent marks and good geometrical design. The network design should determine coordinates by interpolation, not extrapolation.

3.1.5 Observations

The Direction addresses issues with both terrestrial and satellite-based observations. Terrestrial observations should meet the required specifications for the desired Class. It is extremely important that observations are in reduced sets, both directions and distances. The assigning of Class is based on the characteristics of reduced data, not the evaluation of hundreds, if not thousands of individual pointings! Definitions of reduced sets or groups are available in SP1.

Distances need to be clearly defined as their type:
- Spatial
- Ground at a given height
- Mean sea level
- Ellipsoidal

LPI requirements for GNSS observations are extensive. Important issues are log sheets containing checked heights of antenna, start times, station labels, file names, etc. LPI requires that all marks be double occupied for Class C. In order to avoid scale issues, the best orthometric/ellipsoidal height, the current AUSGeoid model (AUSGeoid09, see Brown et al., 2011) and best known coordinates are used to seed processing. Absolute antenna models are particularly important when there is a mix of model types which occurs when using CORS networks or mixtures of receiver/antenna types (Janssen and Haasdyk, 2011a).

3.1.6 Computation and Adjustment

LPI strongly recommends that submissions have been subject to a least squares adjustment to resolve any issues associated with the work. Observation data should be submitted in an organised and unambiguous digital format. The submitted data must also be supplied in the form of an input file to a least squares adjustment. This requires that direction/distance data be reduced to appropriate reduced/abstracted sets. Realistic standard deviations should be applied.

Provided the submitted data is in an acceptable format and a copy of the least squares adjustment input file is supplied, LPI will perform its own least squares adjustment of the data using its own internal packages.

It is essential that support information is supplied that justifies any non-standard parameters or variances applied within the submitted adjustment. These can include re-weighting/rejection or scaling of observations, solving for rotational and scale parameters or scaling of error ellipses.

3.1.7 Survey Report

A survey report is essential if the submission is to be included in the SCIMS database. The Direction states that the report should include information on:
- The overall job, including purpose, background and intent.
- Fieldwork equipment, observation techniques, sketches, photographs, etc.
- Data processing, including software used and options applied.
- Network design and geometry.

- Adjustment, including software used, options applied, constraints, analysis and results.
- Recommendations for Class.
- Data archive, presentation and formats.
- Submission statement.

If available, digital diagrams should be included in the submission. In order to allow submissions of high quality, LPI provides a survey report template and a sample report, available at http://www.lpi.nsw.gov.au/surveying/surveying_services/survey_information.

3.1.8 Check List

A check list is included in the Direction to ensure that submissions are complete and meet LPI requirements. This check list summarises the requirements and guidelines for externally sourced data of control surveys to be included in SCIMS at an "established" level. This check list must be completed and signed as part of the submission.

4 ACHIEVEING THE DESIRED CLASS

The attainment of a desired Class is the result of using appropriate observation techniques, suitable equipment, correct reduction processes, suitable network geometry and finally the passing of tests based on Equation 1 and Table 1. If everything is correct, the least squares adjustment has a variance factor (VF) of unity (or close to), and the observation standardised residuals should be normalised and fall under a bell curve. If this is the case, then the sizes of the relative error ellipse semi-major axes are "true".

Surveyor General's Direction No. 12 refers to a particular table a number of times. This table provides a guide to the achievable Class of a survey, given the expected sizes of the relative error ellipses and the distance between adjacent stations (Table 5). This is a very important aspect of control survey work. As the distance between adjacent marks becomes smaller, the achievable Class for a particular instrument specification becomes lower.

The size of the error ellipse of a point is governed by the standard deviations (STD) of the observations which derive that point. For example, these could include an angular STD of 3", an EDM distance STD of 3 mm + 3 ppm or a GNSS vector STD of 10 mm + 1 ppm. If these values produce a VF close to unity, then the observation residuals are normalised and the error ellipses are "true".

If the VF is not close to unity, then the error ellipses are "not true". The sizes of error ellipses are directly related to values of the observation STDs, regardless of the VF. Some adjustment packages allow the user to scale the error ellipses by the VF, but this is bad practice in adjustments where multiple observation types are used, particularly 3-dimensional adjustments.

Table 5: Class derived from station density and point error ellipse size (at one sigma). The relative error ellipse size used in the determination of Class is stated in parentheses.

Point and (Relative) Error Ellipse / Station Density (km)	0.005 m (0.007 m)	0.010 m (0.014 m)	0.015 m (0.021 m)	0.020 m (0.028 m)	0.025 m (0.035 m)	0.030 m (0.042 m)	0.035 m (0.049 m)
0.1	C	D	E	E	–	–	–
0.2	C	D	E	E	E	–	–
0.4	B	C	D	D	E	E	E
0.6	B	C	C	D	D	E	E
0.8	A	B	C	C	D	D	D
1	A	B	B	C	C	D	D
2	A	A	B	B	C	C	C
5	2A	2A	A	A	A	B	B
10	3A	2A	2A	2A	A	A	A

Table 5 is also independent of the instruments and/or methods used. The highlighted cell is the achieved Class if two adjacent marks 600 m apart with point error ellipses of 0.015 m (i.e. a relative error ellipse of 0.021 m) are tested.

Performing the test in this example for Class 2A using Equation 1, $c = 3$ and $d = 0.6$, so the semi-major axis of the relative error ellipse (REE) must be less than 0.0024 m. Clearly, the 0.021 m semi-major axis of the REE is greater than 0.0024 m, i.e. the test fails at Class 2A. Testing for Class B, $c = 15$ and $d = 0.6$, resulting in a REE of 0.012 m. Obviously, 0.021 m is larger than 0.012 m, i.e. the test also fails at Class B. Similarly, the test value for Class C is 0.024 m, and 0.021 m is less than 0.024 m, i.e. the test passes at Class C. Whether or not this is a valid method of determining Class at these station densities may be debateable but it is the current standard.

As geodetic surveys and breakdown surveys have merged, the inter-station distances have gradually reduced. Historically, control surveys began as geodetic surveys providing a national framework. These surveys were originally based on large triangulation networks with painstakingly measured baselines at various locations to control scale. Azimuth was controlled by stellar observations (Laplace) at various locations. These networks were observed with 1”-2” instruments. Accepting that the results were statistically acceptable, then the geodetic network achieved something near Class A, i.e. about 7 ppm. The GDA94 re-adjustment included quality EDM and GPS baselines which improved the overall result to 3 ppm or Class 2A.

As the amount of breakdown surveys have reduced the inter-station distances and the quality of measurement has improved, control surveys are migrating from the macro scale to the micro scale. The downside of this development is that for most linear measurements there are two components, a constant noise value and a distance dependent noise value (stated in ppm). As inter-station distances decrease, it is the constant noise value which restricts the use of particular instrument types to achieve certain Classes. Reflecting on Table 5, it is easy to recognise the challenges for deformation monitoring applications in reducing the size of errors associated with observations. Observation pillars eliminate centring errors, the best instrumentation is required, and network geometry plays an important role.

The constant noise value will eliminate particular instrument types for various Classes at certain station densities. An instrument with the measurement specification of 1 mm + 5 ppm is more suitable for high-density work than equipment which delivers 7 mm + 0.7 ppm. However, at lower station densities the latter instrument performs better.

4.1 Quality of Measurement

Standards and specifications are also about traceability and responsibility, that is why there are standards for almost everything in modern living. Traditional survey instruments operate autonomously, are self-contained and can be calibrated. A total station will deliver horizontal angles, vertical angles and measured distance without the need for any external requirements other than a power supply and a reflection of the signal.

Equipment manufacturers generally supply an accuracy statement. The following has been extracted from a Leica Viva TPS datasheet – note the superscripts:

Angular Measurement
Accuracy Hz, V[1] 1'' (0.3 mgon), 2'' (0.6 mgon), 3'' (1 mgon), 5'' (1.5 mgon)
Distance Measurement Distance Measurement (Prism)

Range[2]

Round prism (GPR1)	3500 m (12,000 ft)
3 Round prisms (GPR1)	5400 m (17,700 ft)
360° prism (GRZ4, GRZ122)	2000 m (7,000 ft)
360° mini prism (GRZ101)	1000 m (3,300 ft)
Mini prism (GMP101)	2000 m (7,000 ft)

Reflective tape (60 mm x 60 mm) 250 m (800 ft)

Accuracy[3,4] / Measurement Time

Standard	1 mm + 1.5 ppm
Fast	3 mm + 1.5 ppm
Tracking	3 mm + 1.5 ppm
Averaging	1 mm + 1.5 ppm

[1] Standard deviation ISO 17123-3
[2] Overcast, no haze, visibility about 40 km; no heat shimmer
[3] Standard deviation ISO 17123-4
[4] To round prism GPR1

This is the expected measurement accuracy of the instrument according to the manufacturer. Estimates of centring accuracy and atmospheric effects must be added, considering that 1ºC is equivalent to 1 ppm, and 3 mbar is equivalent to 1 ppm. It is important to note that, depending on the length of the line, temperature and atmospheric pressure can be significant sources of error!

GNSS equipment cannot be calibrated since it does not operate autonomously. Results are dependent on a number of components. The control segment, the space segment and the user segment were all initially designed to provide a single point position. The survey component is reliant on these segments to provide information allowing the relationship (spatial vector) between two or more receivers operating simultaneously to be derived. The final component is processing software used to actually derive the spatial relationships for survey applications.

This has now been developed to the point where the spatial component is delivered in real time through the instrument interface, e.g. via single-base RTK or Network RTK utilising a continuously operating reference station (CORS) network. How do you calibrate this process?

LPI has used GNSS techniques since 1987. It has built a vast repository of GNSS baseline observations. Initially measured lengths were of geodetic nature over very long distances. This experience enabled LPI to develop a 'feel' for what appropriate observation variances would be, particularly the distance dependent (ppm) component. As measured distances became shorter, the constant component of the baseline measurement emerged. Consequently, although not calibrated, LPI uses GNSS measurements with confidence, using manufacturers' figures only as a guide. The same approach is taken by LPI in its development of positional observation variances that are now emerging with tools like CORSnet NSW (Janssen et al., 2011).

4.2 Relative Measurement

The common use of GNSS today has seen the introduction of non-familiar techniques and processes in the determination of coordinates. Traditional control survey techniques are modelled on the relative measurements between adjacent stations. Relative error ellipses are computed in the least squares solution based on the propagated observation variances. So, in a minimally constrained adjustment with minimal redundancy, the size of point errors increases with distance from the single constraint. Redundancy helps to reduce the size of error ellipses.

A typical relative measurement between two marks based on terrestrial observation techniques (in this case a direction and a distance) is shown in Figure 1. The ellipse is flattened because in this case the precision of the distance measurement is better than the directional measurement. Note that a standard deviation of 1" in direction is equivalent to 5 ppm! The associated error will be even greater when centring and atmospheric errors are taken into account. Modern distance measurement equipment generally provides distance dependent error components of well below 5 ppm, while the constant error components are typically below 3 mm.

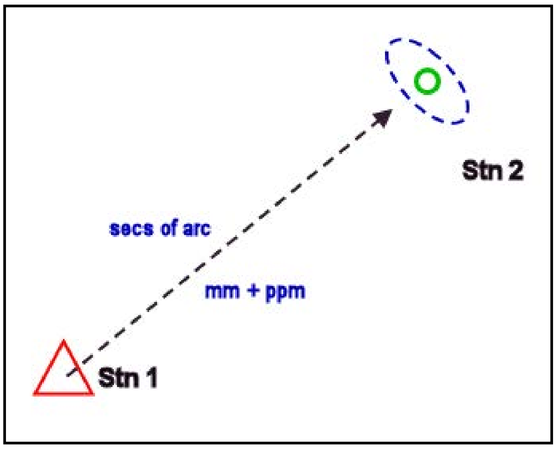

Figure 1: Error ellipse from a relative measurement.

The same model can be applied to GNSS baseline measurements or those GNSS measurements that are based on a relative measurement from one point to another. This is generally referred to as static GNSS measurement and implies that there is a difference in coordinates from one station to another. It is also considered to be an independent measurement. In the case of GNSS, the error ellipse around Stn 2 would be circular since the standard deviation of the Easting and Northing components is known to be of the same magnitude.

Using this relative measurement technique, a network of observations can be constructed. By including closing measurements and redundant observations, estimates of the observation precisions can be determined (Figure 2). This leads to the classification process of observation standard deviations, standardised residuals, variance factor near unity, and therefore error ellipse information that is "true".

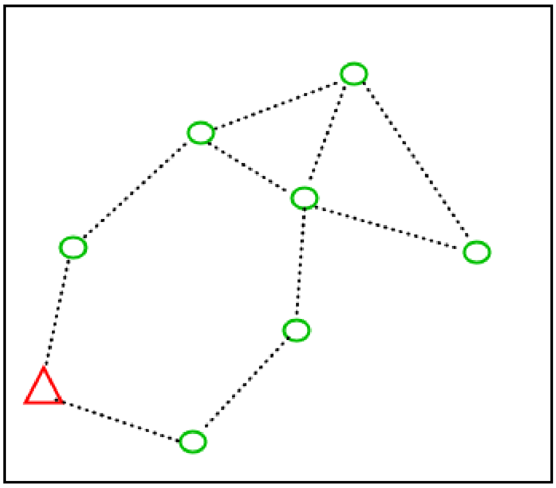

Figure 2: A simple relative observation network.

This approach has been the traditional model that defines control surveys. Its strength lies in its internal redundancy and the feedback that relative observations provide. It should also be pointed out that increasing the number of observations into a point will reduce the size of the error ellipse since *redundancy increases confidence*.

The Class of the survey in Figure 2 would be determined by the sizes of the relative error ellipses between *all* stations, not just those observed! This leads to a very common scenario of using two control stations (Figure 3).

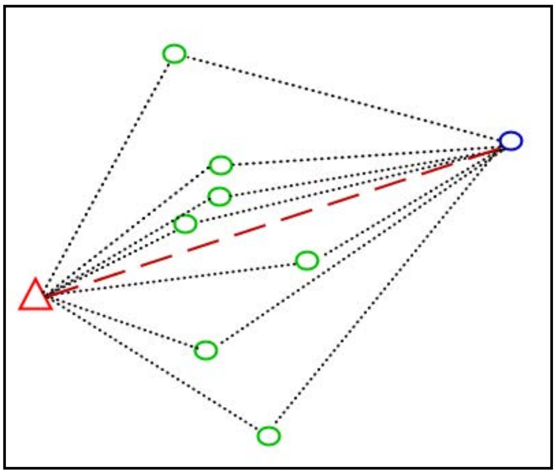

Figure 3: A network with two control stations.

Figure 3 illustrates a fairly common procedure where remote/robotic terrestrial equipment or RTK/NRTK GNSS is employed. It can be seen that this network meets a number of Class C requirements specified in SP1 and the Surveyor Generals Direction No. 12. Where it can fail is in the relative error ellipse test. If the adjustment software only generates relative error

ellipses *for lines observed*, then most of these type networks pass the Class test. If the distance between the red triangle and the blue circle is large in comparison to the relative distances between the green circles, then the relative error ellipses between the adjacent green circles will be large. With modern computing equipment it is simple and prudent to calculate the relative error ellipses for all possible station relationships. Again, this comes back to the station density that controls the values in Table 5. It is also based on the assumption that GNSS errors propagate at some distance dependent (ppm) value.

In order to avoid this type of situation where LPI may reclassify the Class of the survey, ensure that discussions have been held with an LPI Senior Surveyor *before* commencing the survey. This may lead to a re-think in the network design or the inclusion of inter-station distances which could be sourced, e.g., from cadastral measurements.

4.3 Positional Observation

This type of observation has grown out of techniques where modern equipment delivers coordinates as its observation. Again, this can be terrestrial where the instrumentation has been configured to deliver coordinates of points instead of the measurements used to derive them. However, observed positions are more typically provided with GNSS equipment. These positions can be obtained in RTK mode, using NRTK connected to a CORS network, or via Geoscience Australia's online processing service, AUSPOS (GA, 2011).

In the relative measurement survey, observations are used to derive coordinates and estimate the quality of those coordinates based on the observation variances. However, modern GNSS equipment delivers the coordinates and its *own* estimate of the quality which is generally overly optimistic (Janssen et al., 2012). Consequently, this challenges the definition of Class where the determination of Class is based on relative error ellipses. It also negates the requirements of network design and geometry, but some things still apply such as double occupations, calibrating poles and tribrachs, solution types and quality.

As illustrated in Figure 4, each of the point position observations, whether they be RTK or NRTK, have some error ellipse associated with them. A single occupation of a point will provide a coordinate, a height and some internal error estimates. A second occupation of the point at least 30 minutes later will confirm the position and provide some estimate of repeatability (Janssen and Haasdyk, 2011b). It is this repeatability of a number of different points which provides an estimate of the associated error ellipse.

It is important that a single value is adopted for all points in the survey so that the results are normalised. Once the estimated error ellipse is adopted, relative error ellipses can be calculated and the Class of the survey can be determined based on Table 5. This is a simplistic method with very little other than repeatability to determine an outcome. Since this method is completely uncorrelated, every point will have exactly the same error ellipse and every relative error ellipse will be the same.

Unlike relative measurements, in this technique a point has no relationship with its adjacent neighbours and it is never known, i.e. it is always an estimate. Surveyor General's Direction No. 12 nominates a position error estimate value of 0.02 m for point observations using CORSnet-NSW (LPI, 2012a). The quality of and confidence in this type of survey can be improved by the inclusion of other observations such as cadastral or traverse information.

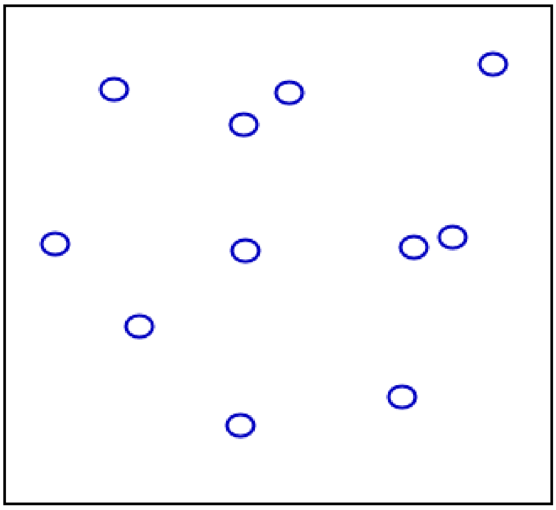

Figure 4: A position observation network.

The above scenario describes the determination of Class for position observations but is realised in the datum of the RTK base station or the NRTK datum. Since CORSnet-NSW uses the GDA94(2010) realisation of the national datum, a site transformation is required to obtain coordinates consistent with local survey ground control and local AHD71 heights (Janssen and McElroy, 2010). A simple block shift in Easting, Northing and Height is sufficient to transform RTK/NRTK observations onto local SCIMS control for surveys requiring centimetre-level accuracy, provided AUSGeoid09 is applied (Haasdyk and Janssen, 2012).

4.4 Adjusting to a Datum

Surveyor General's Direction No. 12 is mainly concerned with the Class of surveys and submissions for inclusion into SCIMS. It only touches briefly on the determination of Order of the surveys submitted, as the classification of Order remains solely with LPI. However, Order can only be determined by LPI if a survey is connected to existing horizontal and vertical control marks, otherwise the survey cannot be connected to the survey control network. Surveys should be connected to adjacent control points surrounding the area of the survey. It is poor practice to "jump over" existing marks if they are unsuitable for your equipment to occupy.

The relative measurement adjustment process for Order is similar to the adjustment process for Class, except now the control point constraints may increase the observation residuals, the standardised residuals are no longer normalised and the relative error ellipse information is "not true". In order to resolve these issues, the observation variances are changed to suit the quality of the control, compute a variance factor near unity and derive "true" error ellipses. These error ellipses can be tested for Order the same as Class, remembering that the Order of marks cannot be better than the Class or the Order of the constraining stations. For example, a Class B survey constrained to Order 3 stations can only yield Order 3 results!

Adjusting position observations to a datum has the same requirements. Control stations in, around and adjacent to the survey area should be occupied. Since position observations are mainly specific to GNSS surveys, the results will be 3-dimensional. Including known height points will assist in determining estimates of AHD71. Control marks need to be occupied twice, i.e. the same as unknown points, with occupations at least 30 minutes apart (Janssen et al., 2012).

4 CONCLUDING REMARKS

This paper has attempted to provide some insight into the control survey process, particularly in regards to the impact of satellite positioning technology. It has been difficult for many to accept that position observation is in fact a control survey; the process itself lacks the relationships between adjacent points that characterise control surveys. It is the author's view that positioning technology will be challenged in the high-density environment at the Class C level. These constraints will last some time since the fundamental measurement noise is associated with the frequency band of the satellite systems and the receiver observation resolution.

This has been somewhat negated in the past by observing longer periods to reduce the Root Mean Square (RMS) of observations. Short-term ambiguity resolution of only 1 to 2 minutes will always be subject to some noise. Improving GNSS receiver technology to observe at an order of magnitude better may overcome the noise component issue. Nevertheless, the issue of calibration will continue.

Regardless of the techniques used, the requirements of Class and Order remain the same and are "black and white". The challenge is to maintain the standards and specifications of measurement and now positioning technologies. It is increasingly important for spatial professionals to use the appropriate tools for the desired outcome. A sobering comment by Mr Les Gardner, LPI Senior Surveyor states that "it's not that the standards aren't keeping up with the technology, technology is not keeping up with the standards!"

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Site Transformations: A Block Shift in Thinking

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ABSTRACT

In order to use CORSnet-NSW in concert with local Survey Control Information Management System (SCIMS) marks in New South Wales (NSW), a site transformation (also known as a site calibration or localisation) is required. This site transformation accounts for any differences between the legal coordinate system as realised by SCIMS, and observations in the more homogenous GDA94(2010) realisation of the national datum as provided by CORSnet-NSW through Real Time Kinematic (RTK) or Network RTK (NRTK) services. This paper demonstrates that a simple block shift in Easting, Northing and Height, using AUSGeoid09, is sufficient to transform RTK or NRTK observations onto local SCIMS control for surveys requiring centimetre-level accuracy. At each of seven test areas distributed across eastern NSW, a minimum of 4 control marks (each with 7 observations) and a minimum of 11 test points (each with 10 rounds of observations) have been occupied using both RTK and NRTK. From the NRTK data, multiple unique site transformations are computed for each test area. Comparisons are made between a 7-parameter similarity transformation, a 4-parameter horizontal transformation plus separate height shift and a simple block shift, all with and without applying the AUSGeoid09 model. Compared to the other more complex transformations, the block shift returns similar or better agreement with SCIMS control marks and has a number of additional benefits. By using a block shift, transformation parameters are more intuitive, outliers in control are easier to detect, the site transformation can be computed with a single control mark if necessary, the geometry of the control marks does not affect the transformation results, and any errors in height control or height observations do not map into horizontal results.

KEYWORDS: *CORSnet-NSW, site transformation, control, block shift, distortion.*

1 INTRODUCTION

The Geocentric Datum of Australia (GDA94) is the basis for horizontal geodetic infrastructure in Australia (ICSM, 2006), while vertical coordinates are referred to the Australian Height Datum (AHD71) (Roelse et al., 1971). For a review of coordinate systems, datums and associated transformations in the Australian context the reader is referred to Janssen (2009). A review of Australian height systems and vertical datums can be found in Featherstone and Kuhn (2006).

CORSnet-NSW is a rapidly growing network of Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) providing fundamental positioning infrastructure for New South Wales that is accurate, reliable and easy to use (Janssen et al., 2011; LPI, 2012a). The network also provides stimulus for innovative spatial applications and research using satellite positioning technology. It is built, owned and operated by Land and Property Information (LPI), a division of the NSW Department of Finance & Services. CORSnet-NSW currently (February 2012) consists of more than 80 CORS tracking multiple satellite constellations, and efforts are underway to expand the network to over 120 stations by the end of 2013.

In order to use CORSnet-NSW in concert with local ground control marks on public record in the state's Survey Control Information Management System (SCIMS) database (LPI, 2012b), a site transformation (also known as site calibration or localisation) is required. This site transformation accounts for any differences between the legal coordinate system as realised by SCIMS, i.e. GDA94(1997), and observations in the more homogenous GDA94(2010) realisation of the national datum as provided by CORSnet-NSW through Real Time Kinematic (RTK) and Network RTK (NRTK) services (Janssen and McElroy, 2010; Janssen et al., 2011).

This paper demonstrates that a simple block shift in Easting, Northing and Height, using the latest geoid model for Australia (AUSGeoid09, see Brown et al., 2011), is sufficient to transform RTK or NRTK observations onto local SCIMS control for surveys requiring centimetre-level accuracy. An extensive dataset consisting of 2,200 occupations using RTK and NRTK in seven study areas distributed across eastern NSW has been gathered to investigate the effect of applying different site transformation methods. Multiple unique site transformations are computed for each test area. Comparisons are then made between a 7-parameter similarity transformation, a 4-parameter horizontal transformation plus separate height shift and a simple block shift, all with and without the AUSGeoid09 model. This paper reports on the results obtained using the NRTK datasets collected in the seven test areas. As expected, the NRTK results showed slightly superior precision and accuracy compared to RTK, but both techniques exhibited the same behaviour.

2 SITE TRANSFORMATIONS

The GDA94(2010) realisation of the national datum is essential to provide real-time users in NSW with reliable, horizontal positioning at the 2-centimetre or better level (Janssen and McElroy, 2010). As a result, CORSnet-NSW users obtain positions referenced to GDA94(2010). While this is suitable for applications where users are interested only in absolute accuracy and repeatability (e.g. precision agriculture), spatial professionals are generally required to connect to the existing local survey control network due to legislative and/or contractual requirements or to be compatible with spatial data already referenced to local control. In order to obtain output that is consistent with local ground control marks in NSW, it is therefore essential to perform (or confirm) a site transformation for every CORSnet-NSW real-time survey where existing survey control is located nearby.

The site transformation is performed by observing several established ground control marks of sufficient quality *immediately surrounding* (and, if present, within) the survey area, i.e. the network should not ignore or span existing local control. The transformation is then calculated between the coordinates observed from CORSnet-NSW, in GDA94(2010), and the local

SCIMS coordinates, in GDA94(1997). This is typically achieved via a menu tool incorporated in the GNSS rover software. Once the site transformation is performed and found acceptable, it is automatically applied by the rover, and real-time GNSS positioning is then reported in coordinates compatible with the existing local control network. It is important to note that the site transformation should only be applied to observations *within* the area encompassed by the control marks used, i.e. extrapolation should be avoided. The use of site transformations is already established good practice to reduce the effect of distortions in GDA94(1997). However, in NSW it is now essential to account for the larger differences in coordinates between the two realisations of GDA94.

In an ideal world, real-time GNSS positioning should be directly compatible with coordinates specified on local survey ground control marks. Therefore a consistent, state-wide geodetic infrastructure based on GDA94(2010) coordinates, or something similar, is the ideal solution. The planned introduction of a new static national datum for Australia (tentatively called GDA2020), based in large part on GNSS observations, is expected to solve this problem in the near future. Theoretically, this will remove the need for site transformations, but GNSS best practice will continue to require sufficient observations at control marks to validate results.

In the meantime, CORSnet-NSW users have several options in regards to the method applied to perform the required site transformation. This paper compares a 7-parameter similarity transformation, a 4-parameter horizontal transformation plus separate height shift (here termed “horizontal and vertical” transformation, or simply “hz & vt”) and a simple block shift, all with and without the AUSGeoid09 model, in order to determine which method is the most suitable in practice.

2.1 7-Parameter Similarity Transformation

The 7-parameter similarity transformation is also known as Helmert transformation. It is based on Cartesian coordinates (X,Y,Z) and accounts for the difference between two 3-dimensional reference frames by applying seven parameters: three translations along the coordinate axes, three rotations about the axes and one scale factor. It assumes that the scale factor is the same in all directions, and thus preserves the relative shape of the network while modifying the underlying point coordinates.

It is important to note that at least three common points (i.e. ground control marks) are required to determine the transformation parameters, and all common points must be known in horizontal position and height. This well-known transformation is used extensively as a tool to transform between global and national datums (e.g. Altamimi et al., 2011; Haasdyk and Janssen, 2011, 2012). In this study, the 7-parameter similarity transformation was performed as the Leica “Classic 3D” transformation.

2.2 Horizontal and Vertical (Hz & Vt) Transformation

This transformation treats the horizontal and vertical components separately, by combining a 4-parameter horizontal transformation with a separate height shift. The horizontal transformation applies coordinate shifts along the Easting and Northing axes, a rotation about the vertical axis and a scale factor. The height shift is generally based on a best-fitting, tilted plane though the available height control. This separation of horizontal and vertical components was achieved by employing the Leica “TwoStep” transformation (Leica

Geosystems, 2004). This method initially transforms the observed coordinates to a different ellipsoid if required (which was not necessary in this case, so a 'null' transformation was applied). The method then employs the true map projection on which the ground control coordinates are based (i.e. Universal Transverse Mercator projection in the case of SCIMS) to achieve preliminary Easting, Northing and Height coordinates for comparison against expected SCIMS coordinates. The main benefit of decoupling the horizontal and vertical components in the transformation is that any errors in the height control do not affect horizontal control (and vice versa).

A minimum of three common points is required to reliably determine the transformation parameters. However, the common points can be matched in position and height, in position only or in height only. This transformation is also possible with less than three common points, simply resulting in a reduction of the number of parameters determined. This provides some flexibility to the user, i.e. the same transformation methodology can be applied for all jobs, independent of how many control marks are incorporated. However, it is important to note that the quality of the transformation may suffer if less than three common points with 3-dimensional control information (or the equivalent distributed over a larger number of control marks) are used.

2.3 Block Shift

This 3-parameter transformation applies an average origin shift, resulting in a simple block shift along the Easting, Northing and Height axes. Each component is treated separately, and neither rotation nor scale factor are determined. Only one common point is sufficient to determine the transformation parameters (albeit without any residuals). As with the hz & vt method, the same transformation methodology can be applied for all jobs, independent of how many control marks are incorporated. However, it is strongly recommended and good practice to use a minimum of three common points with 3-dimensional control information (or the equivalent distributed over a larger number of control marks) to reliably determine the transformation parameters. As mentioned earlier, the decoupling of horizontal and vertical components means that any errors in the height control do not affect horizontal control (and vice versa).

In this study, the block shift transformation was performed by simple (unweighted) averaging of the difference between coordinate observations and expected control coordinates. Alternatively, the Leica "TwoStep" method can be used by setting scale and rotation to zero, and the height model to "Avg Height Shift". Both methods return the same results.

3 DATA COLLECTION AND TESTING METHODOLOGY

In order to investigate the performance of different site transformations in a practical real-time scenario, RTK and NRTK solutions were obtained on a number of established marks. A minimum of 4 control marks (each with 7 observations) and a minimum of 11 test points (each with 10 rounds of observations) have been occupied using both RTK and NRTK. This test was performed at each of seven test areas distributed across eastern NSW. The test areas exhibited a range of NRTK scenarios and cell sizes routinely encountered in practice. All observations were performed with a high-quality bipod for rover antenna stability, using Leica Viva GNSS receivers. Absolute antenna modelling was applied to all GNSS rovers involved (Janssen and Haasdyk, 2011a).

Between four and six established survey control marks were selected as site transformation points to determine the site transformation parameters. These were chosen to be of the highest class and order possible, i.e. A1 horizontal and LCL3 vertical, or better. Detailed definitions of the terms class and order can be found in ICSM (2007) and LPI (2012c). In each study area, each control mark was observed only once for 5 minutes, i.e. not following best practice as described in LPI (2012c), using NRTK and applying the averaging technique. This was followed immediately after re-initialisation by another occupation using single-base RTK. The coordinates obtained were used to determine site transformation parameters (separately for RTK and NRTK). The observations were accepted if the resulting 7-parameter transformation produced residuals not exceeding 25 mm in Easting and Northing, and not exceeding 50 mm in height.

This procedure was repeated several times over multiple days to obtain seven unique site transformations each for NRTK and RTK, for each study area. It should be noted that, when using RTK/NRTK in practice, site transformation points should always be occupied at least twice, for a minimum of two minutes using the averaging technique, as described in LPI (2012c). The first observation determines the GDA94(2010) coordinates, and additional observations provide redundancy. For this study, however, it was decided to perform a single long occupation of each control mark (but repeated for each unique transformation) to highlight the effect of individual control observations on each resulting transformation, considering that a sufficient number of observations was available to determine any outliers.

Within the area surrounded by the site transformation points, 11-15 high-quality established marks with a class/order of at least B2 horizontal and LCL3 vertical (or B2 vertical if not optically levelled) were selected as test points. These test points were chosen to exhibit ‘typical’ conditions accepted for GNSS surveys, i.e. a good skyview with low to moderate obstructions. Test points were observed for 1 minute using NRTK (applying the averaging technique), followed immediately after re-initialisation by another occupation using single-base RTK. After all test points were occupied once, the procedure was repeated to obtain 10 rounds of observations on each test point at different days and times of day. The fieldwork consisted of 2,200 separate occupations and was conducted over several days in January and February 2011.

Using the Leica Viva Simulator, each of the seven unique NRTK or RTK observation sets at the control marks was used to determine the 7-parameter, horizontal and vertical (hz & vt), and block shift transformation parameters, all with and without AUSGeoid09. These parameters were then applied to the 10 repeat observations at the test points, in Leica Geo Office (LGO). The agreement of the output coordinates with SCIMS was assessed in Excel and Matlab. It should be noted that the same results would have been obtained by computing and applying any of these site transformations in the field, in real-time.

For each of the seven study areas, Figures 1-3 show the location of the test points surrounded by the site transformation points and the closest CORSnet-NSW sites, as well as a map indicating the slope of AUSGeoid09 across the area (using 10 mm contours). Most of the test areas are relatively small (less than 3 km across) and have a correspondingly small change in AUSGeoid09 values ($\Delta N < 30$ mm). The exceptions are Albion Park and Woolgoolga which are larger areas and exhibit large changes in AUSGeoid09 (about 12 and 6 km across, with ΔN of 555 mm and 299 mm respectively). The slope of the AUSGeoid09 model is somewhat similar in all areas, ranging from 18 ppm to 56 ppm. Notably, in all areas, the AUSGeoid09

model is little more than an inclined plane. It should be noted that NRTK operation in the Woodburn, Woolgoolga and Kempsey study areas (Figure 3) is for testing purposes only, due to the larger than recommended inter-CORS distances currently available in these areas.

This extensive dataset has previously been used to investigate NRTK and single-base RTK performance using CORSnet-NSW in terms of precision (repeatability) and accuracy as compared to local SCIMS control (Janssen and Haasdyk, 2011b, 2011c). More detailed information about the seven study areas can be found in these publications. As mentioned earlier, the present paper focuses on the analysis of site transformations obtained using NRTK observations, due to their superiority in regards to precision and accuracy compared to single-base RTK.

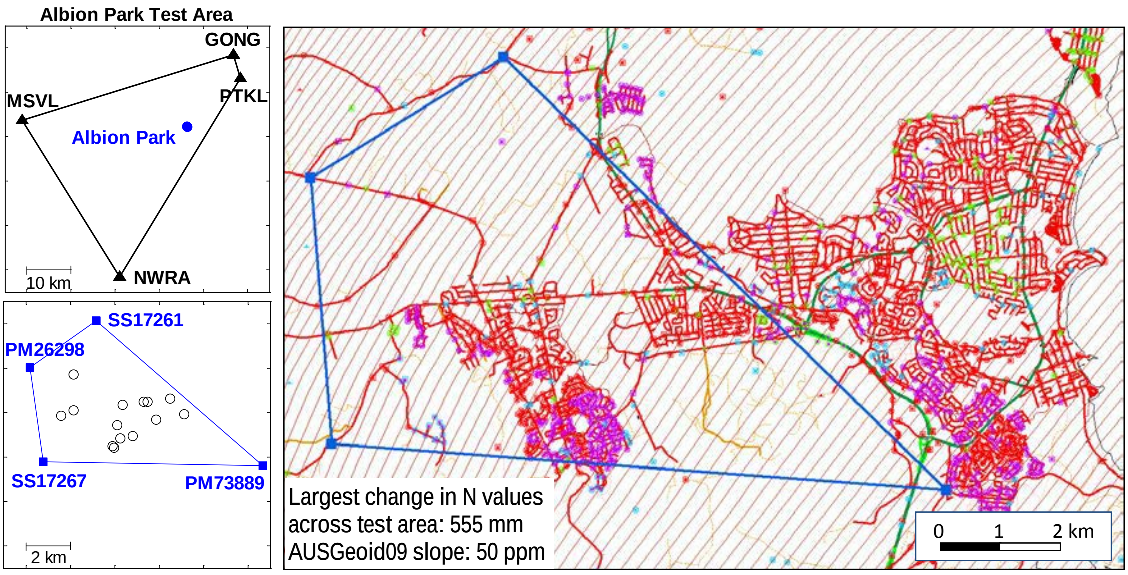

Figure 1: Albion Park test area, showing surrounding CORSnet-NSW sites (black triangles), site transformation points (blue squares), test points (black circles) and AUSGeoid09 contours (10 mm).

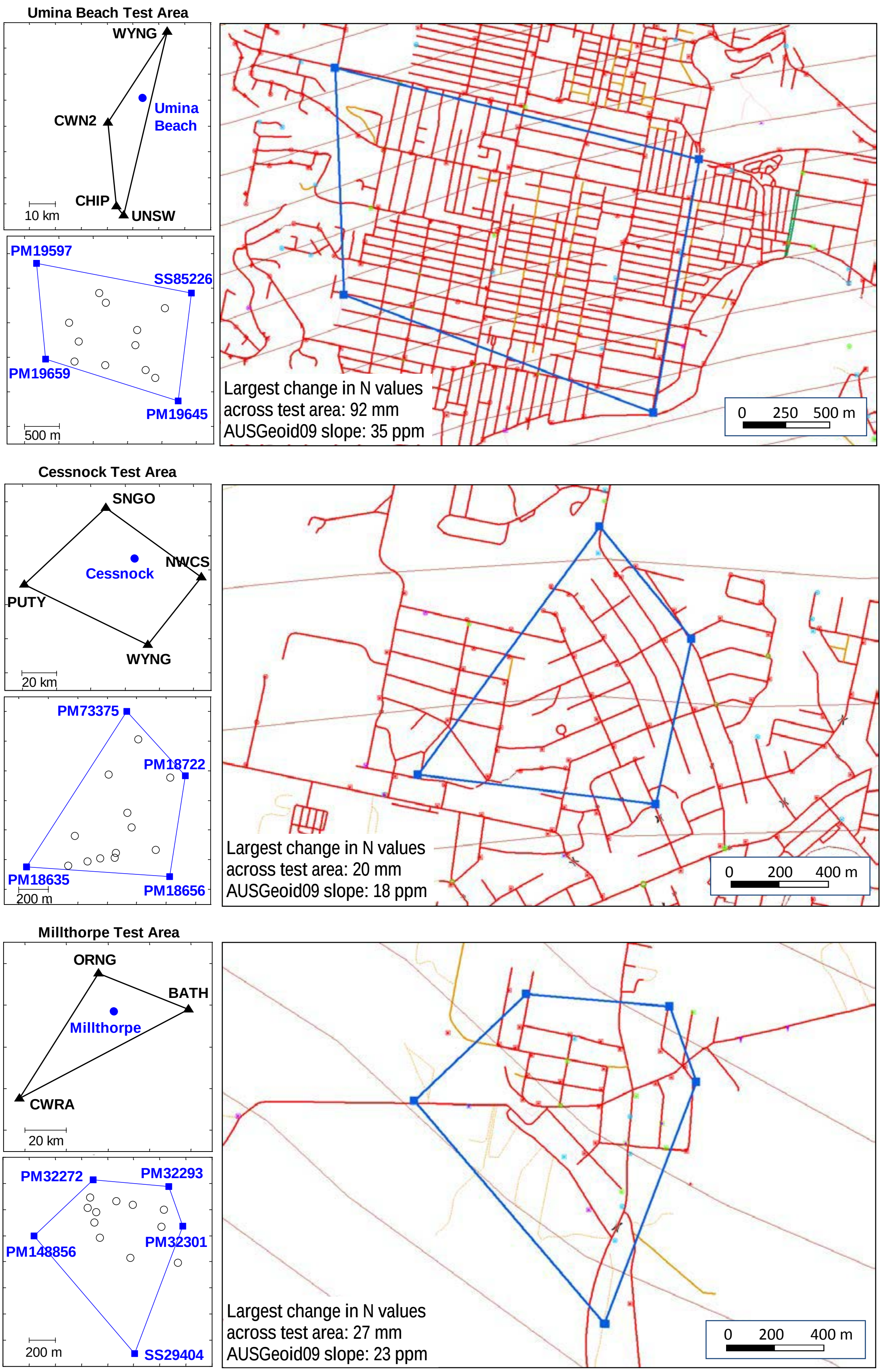

Figure 2: Umina Beach, Cessnock and Millthorpe test areas, showing surrounding CORSnet-NSW sites (black triangles), site transformation points (blue squares), test points (black circles) and AUSGeoid09 contours (10 mm).

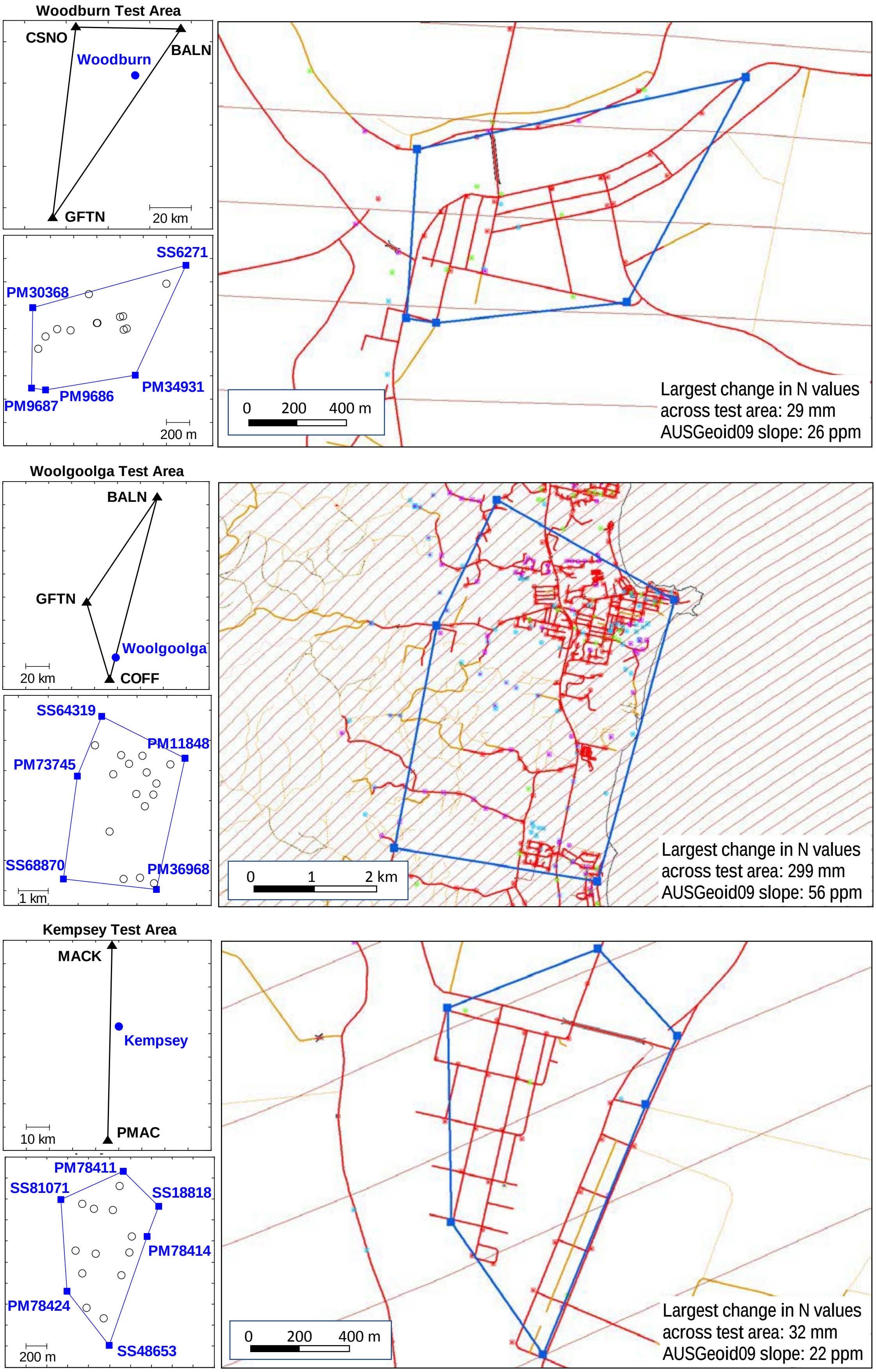

Figure 3: Woodburn, Woolgoolga and Kempsey test areas, showing surrounding CORSnet-NSW sites (black triangles), site transformation points (blue squares), test points (black circles) and AUSGeoid09 contours (10 mm). Note that NRTK operation in these three areas is for testing purposes only.

4 DATA ANALYSIS AND RESULTS

4.1 Initial Comparison of Transformation Methods and Importance of AUSGeoid09

The performance of the 7-parameter, hz & vt and block shift transformations was assessed by comparing real-time observations on established marks in the seven study areas against their published SCIMS coordinates. As an example, Figure 4 shows the resulting deviations from SCIMS in the horizontal (i.e. distance from official position) and vertical coordinate component for the Albion Park test area. For every test point surveyed, each of the ten 1-minute occupations is shown individually. AUSGeoid09 was applied, and only the first of the seven site transformations of each method (here represented by different symbols) was considered in this figure.

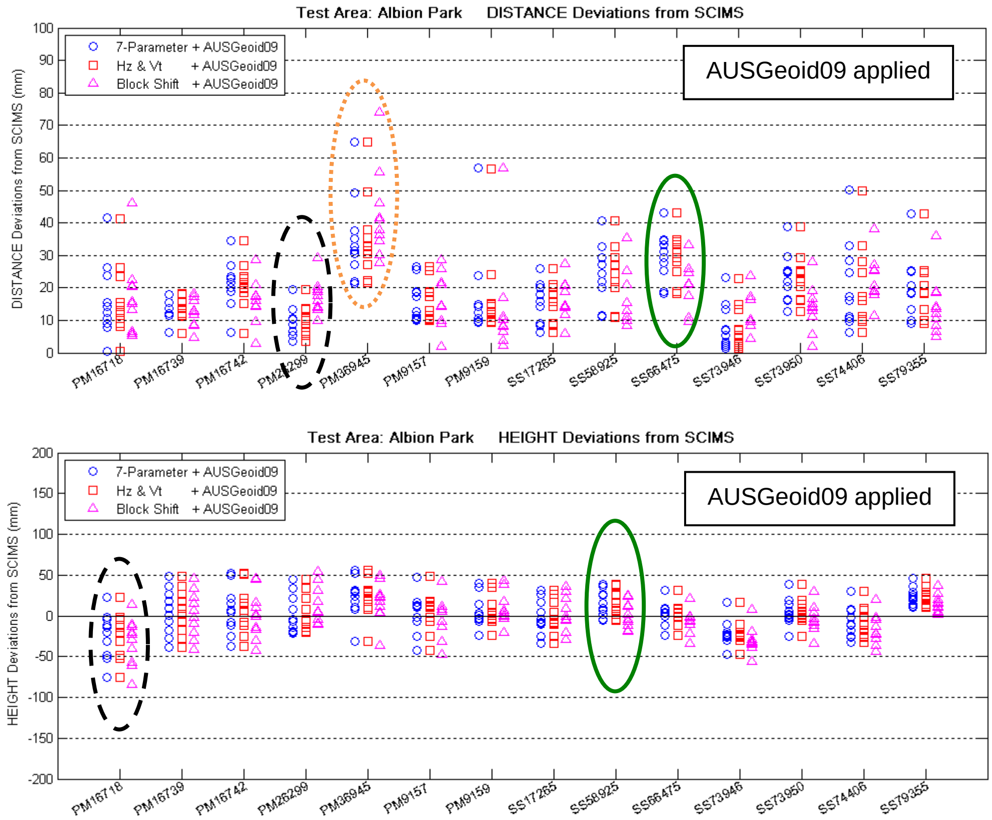

Figure 4: Horizontal and vertical NRTK accuracy vs. SCIMS in Albion Park,
using different site transformation methods (AUSGeoid09 applied).

It can be seen in Figure 4 that the 7-parameter transformation and the hz & vt transformation (blue circles and red squares, respectively) yield essentially identical results in both horizontal position and height. At several marks, the block shift transformation (magenta triangles) provides slightly better agreement with SCIMS (e.g. SS66475 in the horizontal and SS58925 in the vertical component, circled with solid green). At other marks, the block shift performs slightly worse (e.g. PM26299 in the horizontal and PM16718 in the vertical component, circled with dashed black). The remaining study areas showed comparable results.

Cases where a consistent offset from the official SCIMS coordinates persists regardless of the site transformation employed (e.g. PM36945, circled in dotted orange in Figure 4) indicate a possible issue with the published SCIMS coordinates, e.g. due to mark movement, and show that poor control can be identified with redundant observations.

In order to investigate the effect of ignoring AUSGeoid09 in the site transformation process, the above analysis was repeated without the use of AUSGeoid09 (Figure 5). As expected, the results for the horizontal component are almost identical for all three transformation methods when compared to those results obtained with AUSGeoid09 (see Figure 4). Not surprisingly, however, there are significant differences in the vertical component, particularly in regards to the block shift. If AUSGeoid09 is ignored, the block shift in height is determined as the *average* difference at the site transformation control points between the GNSS-observed ellipsoidal heights and the official orthometric AHD71 heights stated in SCIMS. Consequently, the block shift is unable to account for any changes in AUSGeoid09 values within the test area.

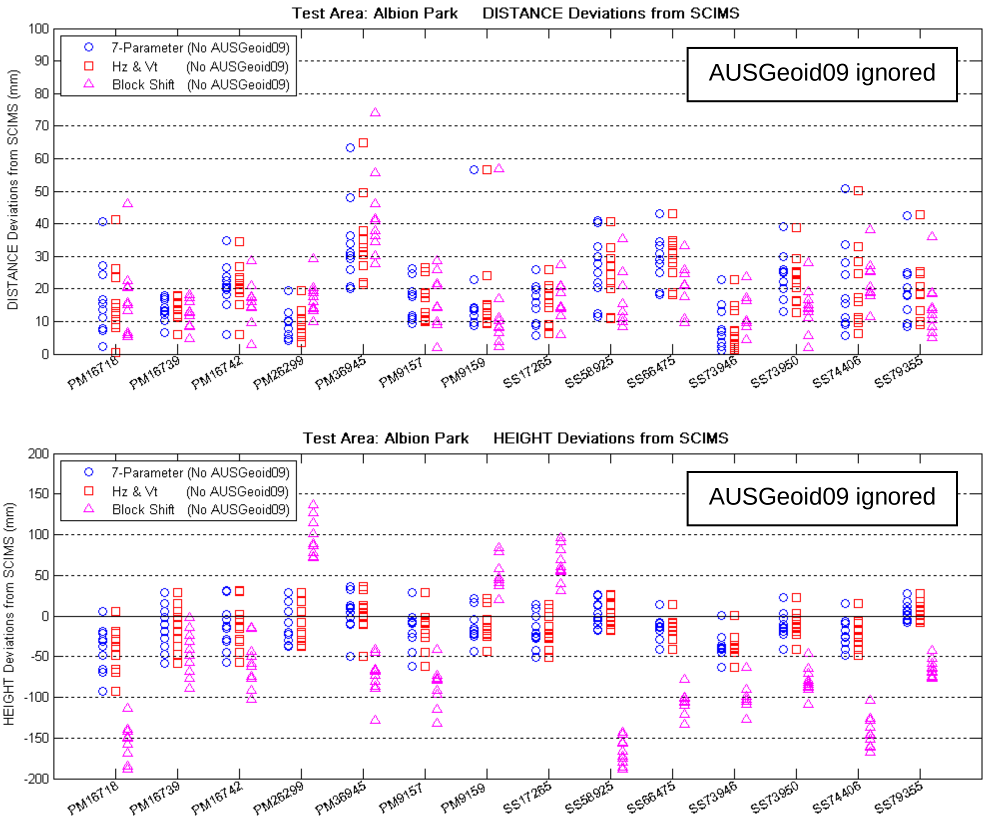

Figure 5: Horizontal and vertical NRTK accuracy vs. SCIMS in Albion Park, using different site transformation methods (AUSGeoid09 ignored).

It should be noted that the negative effect of ignoring AUSGeoid09 in the site transformation is less pronounced in smaller areas with a much smaller variation in N values. For instance, while the Albion Park area exhibits a relatively large change of 555 mm in AUSGeoid09 values (see Figure 1), the change amounts to only 29 mm in the Woodburn area (see Figure 3). In order to illustrate the effect of these N value variations, Table 1 lists the agreement with SCIMS across the two test areas, obtained with the different transformation methods. The average agreement with SCIMS is quantified by the Root Mean Square (RMS) of the difference between observed and expected coordinates for the horizontal and vertical coordinate components. A low RMS indicates a better agreement with SCIMS. In this case, these RMS values were calculated across all occupations (10 rounds) on all test points (11-15) in the test area, and then averaged across the seven unique site transformations observed. Since good agreement was found between the repeated site transformations in each test area, these *averaged* RMS values are representative of the full dataset collected.

Table 1: Agreement with SCIMS, in distance and height, quantified by the average Root Mean Square (RMS) in millimetres for three transformation methods (with and without applying AUSGeoid09).

RMS Distance Test Area	7-Parameter (AUSGeoid09)	7-Parameter (no geoid)	Hz & Vt (AUSGeoid09)	Hz & Vt (no geoid)	Block Shift (AUSGeoid09)	Block Shift (no geoid)
Albion Park	22.0	21.8	22.0	22.0	21.1	21.1
Woodburn	20.2	20.2	20.2	20.2	19.7	19.7

RMS Height Test Area	7-Parameter (AUSGeoid09)	7-Parameter (no geoid)	Hz & Vt (AUSGeoid09)	Hz & Vt (no geoid)	Block Shift (AUSGeoid09)	Block Shift (no geoid)
Albion Park	26.9	28.7	26.9	28.7	26.0	99.9
Woodburn	51.2	51.2	51.2	51.2	50.6	51.5

As highlighted in Table 1, the performance of the block shift transformation in Albion Park deteriorates significantly (by a factor of 3.8 in height) if AUSGeoid09 is ignored. On the other hand, excluding AUSGeoid09 from the block shift transformation in Woodburn has only minor consequences (~1 mm). This can be explained by the inability of the block shift to account for significant changes in N values across the test area unless a geoid model is applied.

The information collated in Table 1 also demonstrates that the 7-parameter transformation and the hz & vt transformation are almost indistinguishable, confirming what has already been shown visually in Figures 4 and 5. As expected, ignoring AUSGeoid09 in the hz & vt and the block shift transformations does not affect the horizontal component at all because in both cases position is decoupled from height. In regards to the vertical component, the hz & vt transformation follows the pattern of the 7-parameter transformation, i.e. the RMS worsens slightly if AUSGeoid09 is not included in the process.

While the omission of a geoid model in the 7-parameter transformation can produce acceptable results in some cases (Janssen and Haasdyk, 2011c), it is advised and best practice to use AUSGeoid09 for all transformation methods. Applying AUSGeoid09 is essential if a block shift transformation is employed, or if the geoid surface is not a simple plane over the area in question.

4.2 Repeatability of Site Transformation Parameters

The repeatability of the transformation parameters calculated during a site transformation was investigated by inspecting the parameters obtained from the seven site transformations performed in each test area. As a representative example, Tables 2-4 list the parameters obtained for the 7-parameter, hz & vt and block shift transformations in the Albion Park test area. AUSGeoid09 was applied in all cases.

Table 2: Repeatability of site transformation parameters for the 7-parameter transformation in Albion Park (AUSGeoid09 applied).

7-Parameter	Shift dX (m)	Shift dY (m)	Shift dZ (m)	Rotation X (”)	Rotation Y (”)	Rotation Z (”)	Scale (ppm)
1st	44.728	-40.965	-53.333	-2.35	-1.55	-0.34	2.9127
2nd	7.202	-10.529	18.863	-0.59	0.67	-0.35	3.1447
3rd	60.849	2.340	-51.489	-1.10	-2.05	-1.21	2.1597
4th	16.844	-32.599	-10.344	-1.39	-0.18	0.02	3.0416
5th	15.515	-1.527	0.574	-0.57	0.04	-0.60	1.8962
6th	7.033	5.390	5.125	-0.12	0.15	-0.44	0.9024
7th	29.095	-33.331	-33.859	-1.39	-1.13	0.13	2.3879

Table 3: Repeatability of site transformation parameters for the hz & vt transformation in Albion Park (AUSGeoid09 applied). The rotation is applied around the centroid of the test area.

Hz & Vt	Shift dE (m)	Shift dN (m)	Rotation (")	Scale Factor	Shift dH (m)
1st	-0.032	-0.004	1.30	2.900	-0.036
2nd	-0.034	0.004	0.90	3.152	-0.047
3rd	-0.032	0.007	0.60	2.156	-0.036
4th	-0.032	0.002	0.90	3.039	-0.044
5th	-0.031	-0.001	0.80	1.900	-0.031
6th	-0.023	-0.002	0.40	0.910	-0.038
7th	-0.033	0.008	0.50	2.381	-0.045

Table 4: Repeatability of site transformation parameters for the block shift transformation in Albion Park (AUSGeoid09 applied).

Block Shift	Shift dE (m)	Shift dN (m)	Shift dH (m)
1st	-0.032	-0.004	-0.037
2nd	-0.033	0.004	-0.048
3rd	-0.032	0.007	-0.037
4th	-0.032	0.002	-0.044
5th	-0.030	-0.001	-0.032
6th	-0.023	-0.002	-0.039
7th	-0.033	0.008	-0.046

It is evident that the parameters describing the 7-parameter transformation are not intuitive as they refer to Cartesian coordinate axes, with an origin at the centre of the Earth. All of the seven parameters show considerable variation between repeated site transformations (e.g. several 10s of metres in the translation parameters dX, dY and dZ). The parameters for the hz & vt and block shift transformation methods are more intuitive because they refer to grid coordinates, separating horizontal and vertical coordinate components.

In the hz & vt transformation, the shifts in Easting and Northing are comparable across the seven individual site transformations (±5 mm), while the Height shift shows more variation between repeats (±10 mm). The Height shift parameter is determined based on the average shift of the sloped plane correcting for the difference between the GNSS-derived and the AHD71 heights at the control points. In this case the slope is insignificant, but it should be emphasised that the slope quickly becomes significant if AUSGeoid09 is ignored in the site transformation (data not shown). In addition, there are noticeable variations in rotation and scale for individual site transformations, and no attempt was made to determine if these parameters were actually statistically significant.

The block shift parameters are virtually identical (±1 mm) to the shift parameters from the hz & vt transformation. Consequently, the Easting and Northing shifts are very similar across the seven individual site transformations (±5 mm), while the Height shift shows a little more variation than the horizontal parameters (±10 mm).

It should also be noted that, while individual transformation parameters may change significantly between repeat site transformations (as with the 7-parameter method), the effects on the transformed coordinates of the test points are generally small (at the cm-level, see section 4.3). However, it is important to note that this statement is only valid if it is assumed that no local distortion and no change in CORS coordinates and/or SCIMS coordinates has

taken place between repeats. It is strongly advised against using a site transformation in practice that was calculated a considerable time before the survey takes place. As mentioned earlier, it is GNSS good practice to perform (or confirm) a site transformation at the start of every real-time survey.

4.3 Effect of Site Transformation Geometry

In the 7-parameter and hz & vt transformations (but not the block shift), the scale and rotation parameters effectively allow the observations to be stretched and skewed to fit the existing control. As a consequence, the transformation geometry (i.e. the relative distribution of the common points used to calculate the transformation parameters) has an effect on the output coordinate repeatability/quality. Obviously, the quality of the GNSS observations (and the SCIMS coordinates) on the control marks also affects the coordinate output (rubbish-in-rubbish-out principle). Since the same observations were used to compute 7-parameter, hz & vt and block shift transformations, this section focuses on the effect of the site transformation itself on the quality and variability of output coordinates for the test points.

The variability in the transformed test point coordinates, solely due to the adoption of a new site transformation, was investigated across all seven test areas. As an example, Figure 6 illustrates this behaviour in regards to the horizontal position for the three transformation methods investigated in the Albion Park test area. The location of the control points is shown as blue squares with the variability of the seven control point occupations (one for each unique site transformation) indicated by 'error' bars showing the range of coordinates (i.e. raw point observations, no transformation applied). The location of the test points is shown as black circles with 'error' bars indicating the effect that the seven unique site transformations have on the transformed coordinates of a single occupation at each test point. All 'error' bars have been scaled (by the same amount) to improve visibility. It should be noted that this analysis focuses on the relative effect on the test points depending on the geometry of the control points, i.e. the absolute values are of no interest in this context.

In Figure 6 it can be seen that the 7-parameter and hz & vt transformations introduce variability in the transformed coordinates depending on the relative geometry of the control and test points, as well as the quality of the observations at the control points. For example, the control point in the south-eastern corner of the test area exhibits a much larger variability in Northing than in Easting between the seven occupations. Since this particular control point is located at some distance from the others, the transformation is rotated to accommodate any errors at this control point, and the test points in the vicinity exhibit the same behaviour. It should be noted that extrapolated points would suffer even more significant variation.

Similarly, test points located in the south-western corner of the test area are affected more by the higher variation in Easting at the south-western control point. The 7-parameter and hz & vt transformation methods stretch and skew the transformation in order to fit the observations (including their error) to the SCIMS coordinates (including their error) at the given control marks, by massaging these errors into extra parameters.

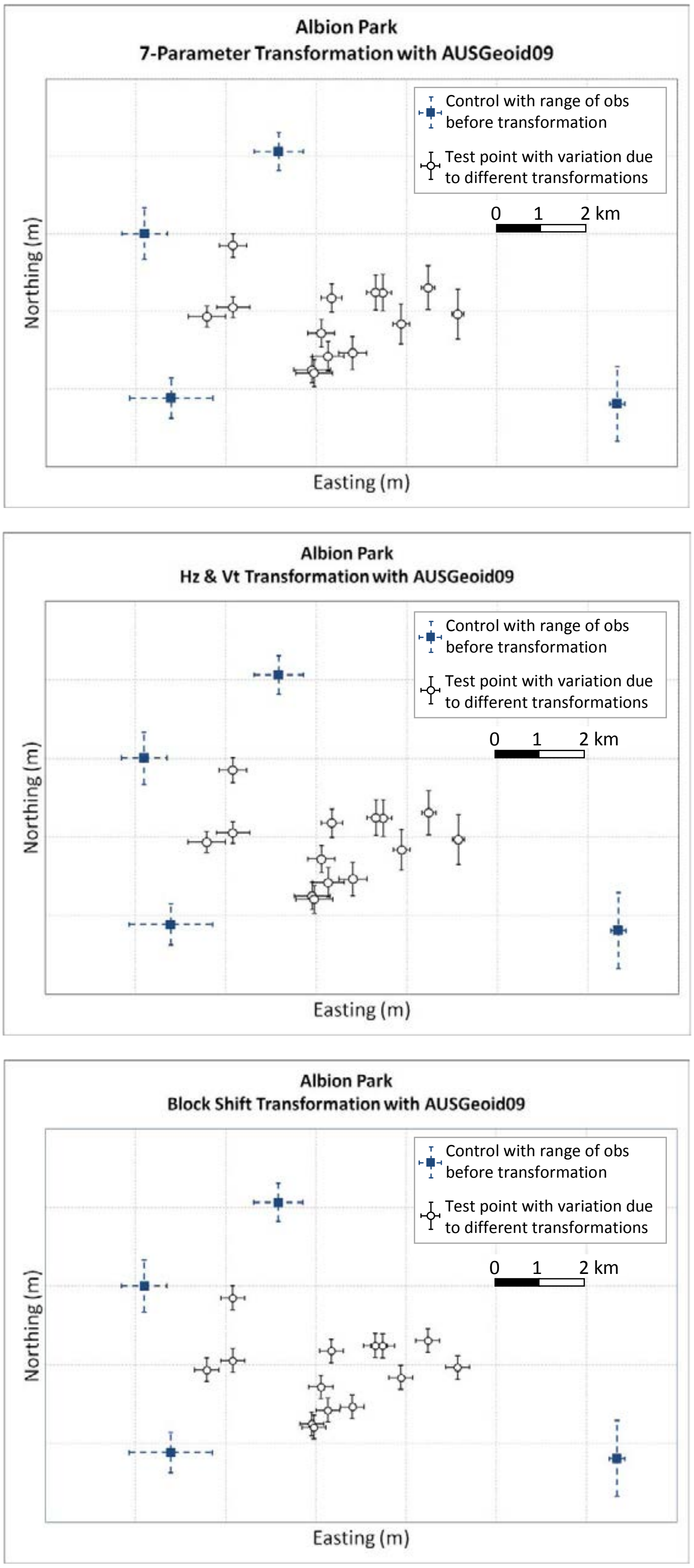

Figure 6: Variability of horizontal output coordinates at each test point (single occupation), solely due to the geometry and observation variability of the control points, for different site transformation methods in Albion Park (AUSGeoid09 applied). All 'error' bars are scaled by 50,000.

In contrast, the effect of the block shift is uniform across all test points, and is generally of a smaller range (better precision) than the 7-parameter and hz & vt transformations. Notably, the variation in transformed coordinates at the test points is independent of the geometry of the control points, and is the same for all test points in the transformation area. In practice, this means that a new block shift transformation will change all existing observations by exactly the same amount. Also, the observations are not scaled or skewed to fit the control, i.e. the block shift transformation does not 'hide' any errors in the control nearly as effectively as the other transformation methods, but can instead can be used to identify these errors, as shown in section 4.4.

Table 5 quantifies the variability in test point coordinates due to the site transformation for Albion Park by specifying the range (i.e. summation of the absolute minimum and maximum differences from the official SCIMS coordinates) and the RMS (i.e. average agreement with SCIMS) for the Easting, Northing and Height components. The results confirm that the 7-parameter and hz & vt transformations provide almost identical results, which are outperformed by the block shift.

Table 5: Average variability in test point coordinates solely due to the variation in transformation parameters for the Albion Park test area (AUSGeoid09 applied). All values are in millimetres.

Transformation Method	**Range Easting**	**Range Northing**	**Range Height**	**RMS Easting**	**RMS Northing**	**RMS Height**
7-Parameter	11.2	16.3	25.4	3.5	5.1	8.4
Hz & Vt	11.3	16.3	25.4	3.5	5.1	8.3
Block Shift	10.6	12.1	16.0	3.4	4.2	5.3

The remaining test areas exhibit a very similar pattern. In all cases, the average range of the block shift is slightly better (up to 5 mm and 10 mm smaller in the horizontal and vertical components respectively), while the average RMS is generally the same or slightly better (by 1 mm horizontally and 2 mm vertically), compared to the other two transformation methods. This confirms that the effect of the variability amongst the individual site transformations is larger for the 7-parameter and hz & vt transformations when compared to the block shift, i.e. the transformed test points will generally not change as much when applying a new block shift rather than a new 7-parameter or hz & vt transformation.

4.4 Identification of Outliers at Control Marks using the Block Shift Method

The block shift transformation is able to identify (and not 'hide') control marks (or observations at those marks) that do not fit with other nearby control, by highlighting any observations with significant residuals. In contrast, the 7-parameter and hz & vt transformations are able to employ additional scale and rotation parameters to fit the observations to the control marks (see section 4.3). With the limited (or minimum) number of control points often used to determine the transformation, finding errors in observations or control coordinates can be more difficult (or impossible) with the 7-parameter and hz & vt methods.

GNSS rover software generally reports the residuals of the site transformation calculation in Easting, Northing and Height (calculated from the difference between transformed and expected control point coordinates) to help the user identify outliers. In the Albion Park test area (Figure 1), it was found that all residuals for the 7-parameter and hz & vt transformations passed our performance criteria (25 mm in Easting and Northing, and 50 mm in Height) and the largest residual was 27 mm in the Height of PM26298. In contrast, the largest residual for

the block shift was 54 mm (in the Northing of PM73889), and all seven block shift transformations showed a consistent disagreement at this control mark with average residuals of 38 mm in Northing. It should be noted that PM73889 is the south-eastern point discussed in section 4.3, which was shown to have a large effect on the 7-parameter and hz & vt transformations. Although this control mark is still within A1 specifications, it should be used with caution in the transformation and extra or alternative control marks should be employed in the area if possible. Only the block shift transformation method was able to highlight this issue.

In a similar fashion, a poor observation on a control mark, e.g. due to multipath or centring errors, would be highlighted by the block shift and hidden by the 7-parameter and hz & vt transformations. Of course, this study only employed a single observation at each control point to calculate each site transformation, while it is recommended best practice to always use two or more observations to achieve redundancy and enable outlier detection.

In general, it was also identified that the residuals of a block shift transformation are always larger than those of the other two transformation methods. It is the responsibility of the GNSS user to determine what is 'fit for purpose' when determining the agreement of observations to the existing control. However, while the residuals at the control marks may be larger for the block shift, the average agreement of the transformed test point coordinates with SCIMS remains much the same for all transformation methods (see section 4.5).

4.5 Effect of Site Transformation Methods on Transformed Coordinates in Practice

This section investigates the effect of the different site transformation methods on the transformed coordinates in practice, following the initial assessment presented in section 4.1. Since the 7-parameter and hz & vt transformations have been shown to produce near-identical results, the remainder of this analysis is limited to the comparison of the most rigorous transformation (i.e. 7-parameter transformation) and the simplest transformation (i.e. block shift). AUSGeoid09 is applied in all cases. In order to assess the effect on the transformed test point coordinates in practice, the agreement with SCIMS was investigated in each of the seven test areas. This agreement was quantified by the average RMS in horizontal position (i.e. distance from SCIMS position) and height, incorporating all test point occupations *and* the seven unique site transformations observed for each method. It should be noted that one site transformation in the Cessnock test area exceeded accuracy specifications and was therefore removed from the analysis.

Figure 7 summarises the performance of the 7-parameter and block shift transformations in each test area, reducing the information gathered from the extensive fieldwork undertaken to a few RMS values. It can be seen that both transformations generally provide comparable results in the horizontal position (within about a millimetre). In regards to heights, the RMS is generally slightly better (lower by 1-2 mm) when the block shift is used, with one exception in the Woolgoolga test area where the 7-parameter transformation performs better by almost 2 millimetres. The RMS values reported here are somewhat exaggerated, because each unique transformation is based on a single observation at each control point. As recommended, at least two observations should be included at each control mark to improve the precision of the transformation and consequently the agreement with SCIMS.

Considering the context of this study, this shows that there is hardly any difference between the three transformation methods in practice, provided AUSGeoid09 is applied to take

variations in AUSGeoid09 across the survey area into account. However, as demonstrated in the earlier sections, the block shift has advantages over the 7-parameter and hz & vt transformations such as easier outlier detection and greater versatility when faced with limited control or separate horizontal and vertical control.

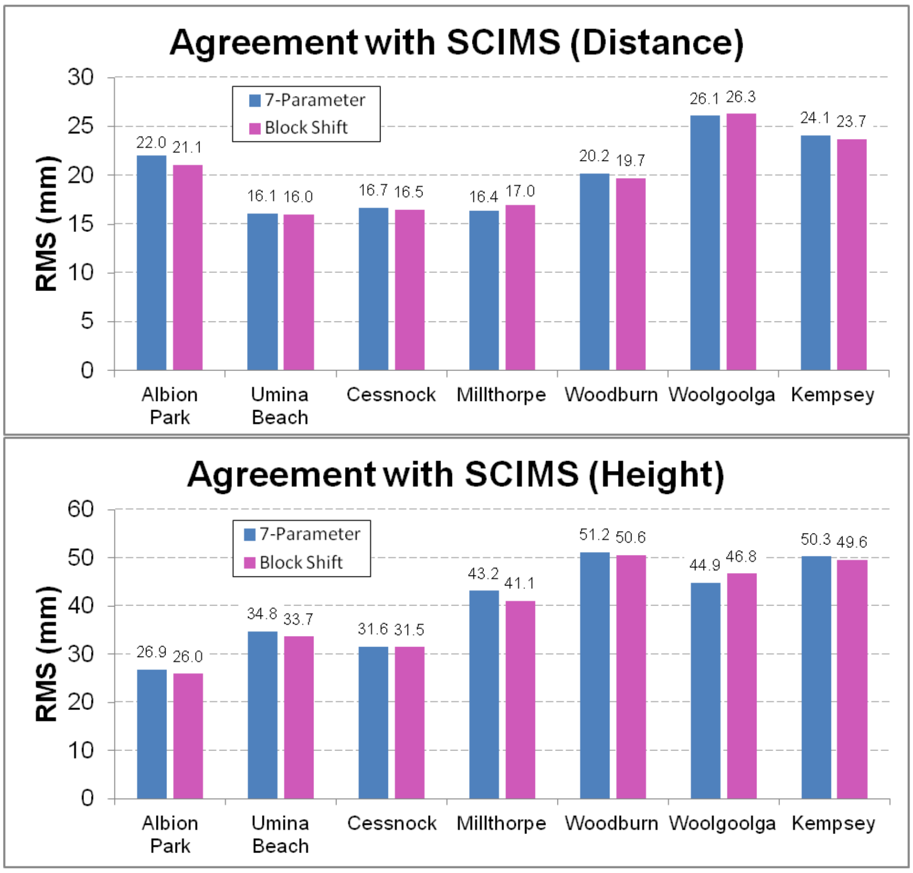

Figure 7: Agreement with SCIMS, quantified by the average Root Mean Square (RMS) in millimetres for 7-parameter and block shift transformations (applying AUSGeoid09) in each test area.

It is important to complete a site transformation even in areas where there appears to be little disagreement between GDA94(2010) and GDA94(1997). In the test areas investigated in this study, applying no site transformation always resulted in poorer agreement with SCIMS, by 30% to 800% (data not shown). Performing a site transformation is always GNSS good practice to verify the fit of observation with local control at the time of the survey.

5 CONCLUDING REMARKS

In order to use CORSnet-NSW real-time positioning services in concert with local SCIMS marks in New South Wales, a site transformation is required. An extensive dataset consisting of 2,200 occupations in seven study areas distributed across eastern NSW has been analysed to investigate the effect of applying different site transformation methods. Comparisons were made between a 7-parameter transformation, a 4-parameter horizontal transformation plus separate height shift (here termed “hz & vt”) and a simple block shift.

It was found that a block shift in Easting, Northing and Height is sufficient to transform NRTK or RTK observations onto local SCIMS control for surveys requiring centimetre-level accuracy, provided AUSGeoid09 is applied. At a practical level, it is generally not required to

solve for scale and rotation parameters since, by definition, GDA94(2010) and GDA94(1997) share the same ellipsoid and coordinate axes.

Compared to the more complex 7-parameter transformation, the block shift returns similar or better agreement with SCIMS in the test areas investigated (up to 12 km across) and has a number of additional benefits. By using a block shift, transformation parameters are more intuitive, outliers in control (observations or SCIMS values) are easier to detect, the site transformation can be computed with a single control mark if necessary, the geometry of the control marks does not affect the transformation results, and any errors in height control or height observations do not map into horizontal results.

The block shift transformation method also has the great benefit of allowing the user to employ the same site transformation methodology whether control is sparse or in ample supply. In fact, if there is only a single control mark in the area, it is perfectly valid to create a transformation using that single control mark in order to achieve coordinates consistent with local control.

The GNSS rover equipment employed may not provide a specific menu tool to perform a block shift transformation. However, generally an option comparable to the separate hz & vt transformation is available. By manually defining certain parameters (i.e. setting the rotation and scale parameters to zero) and setting the height model to simple averaging, it is possible to turn the hz & vt transformation into a simple block shift for use with any number of control marks.

Regardless of the site transformation method employed, the quality of the site transformation is always dependent on the number and even distribution of the common points utilised, and the quality of the GNSS observations. It is strongly recommended to follow GNSS best practice and observe a minimum of three known control marks of sufficient quality *immediately surrounding* (and, if present, within) the survey area to calculate the transformation parameters. The nearest existing control marks should be used, i.e. the network should not ignore or span existing local control. Every mark (including existing control) in the NRTK/RTK survey should be observed at least twice to provide redundancy, thereby lowering the risk of outliers in the control point observations flowing into the calculation of site transformation parameters. The latest AUSGeoid product (currently AUSGeoid09) should be used as part of the site transformation – this is essential if the block shift method is employed.

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Aspects of Being an Expert Witness

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ABSTRACT

Surveyors are regularly being called on to be an Expert Witness on many civil litigation, boundary, planning and development issues and often in the Land and Environment Court (L&EC) for a multitude of interrelated development matters. The professionally independent activities of a surveyor generally equips the individual with the basic skills required for the role and with some additional training, the opportunity to act as an Expert Witness provides increased professional avenues to explore and enjoy. Responsibility to act professionally, impartially and portray confidence and skill in a chosen field makes surveyors ideal expert witnesses, and the right to be an expert is a privileged position. The role of the Expert Witness in the L&EC is to assist the Court impartially, as against an advocate for one side or another, on matters relevant to the expertise of the individual. It is paramount that the expert understands that they have a duty to the Court and not to the party who engages the expert in the first place. This paper looks at the role of the Expert Witness in the L&EC and provides a summary of considerations and fundamentals that an Expert Witness needs to provide to the Court. A specific case study for understanding how this role was executed provides some understanding of how a surveyor, as an expert in development matters, can be utilised to untangle relative complex issues so that the Court can critically examine logical findings and recommendations. The training provided by the Institute of Arbitrators & Mediators, Australia was critical to the understanding of how the L&EC utilises Expert Witnesses in both hearings and conciliation meetings and utilising these acquired skills was fundamental to a successful appeal. The expectations of what a surveyor does are fundamentally not changing but these new areas of activity are slowly developing the profession into a more complex entity that ultimately displays the professional training and skills that are well recognised within related professions.

KEYWORDS: *Expert witness, Land and Environment Court, legal*.

1 INTRODUCTION

An expert is a person who has specialised knowledge based on training, study or experience and that an opinion expressed by an expert must be wholly or substantially based on the person's training, study and/or experience.

Expert evidence is now a role that can be undertaken by surveyors. Fundamentally the duty of an **expert witness is to assist the court impartially** on matters relevant to an individual's area of expertise **and not to the party by whom they are retained**. The principles are now set out in Schedule K to the *Supreme Court Rule* which has tried to eliminate opportunities for an expert to perform as an advocate for a specific position rather than impartially for the court.

Concern has increased about the role of experts in recent years based on issues relating to:

1. The use of experts in every form of civil litigation.
2. Areas where the court has difficulty in understanding abstruse or obscure areas of expertise.
3. Perceptions that expert witnesses are hired guns and opinions can be bought.

There is a great opportunity, and with that goes responsibility, for surveyors to play this role as an expert witness in many areas that are now the subject of legal action.

2 HOW DO YOU GET AN IMPARTIAL OPINION?

Opinions expressed by the expert in a tendered report must be the opinion of the expert and not of the engaging lawyers or client. This does not mean that the lawyer and/or client have no role to play, and in complex cases, advice from both of these people is fundamental to understanding the extent of the problem. Note, however, that a meeting with a client should always include the advising lawyer.

The advice and assistance that a lawyer provides includes:

1. Identification of the issues to which expert evidence is required. In complex cases, the client is often mandatory as they have the detailed working knowledge of the issues.
2. Identification of one or more experts who are qualified to express opinions on these issues. Here the lawyer needs to ask a simple question, "*do we need an expert to give us this sort of answer/advice?"*
3. Clarification and limiting the issues on which an expert can express an opinion. Note that here the expert may help redefine the issues to provide clarity.
4. Clearly specify and detail the assumptions of fact that an expert is to make.
5. Supplement the assumptions with primary factual material that the expert is to consider.
6. Assisting the expert in drafting a report to ensure that, whilst the opinions remain those of the expert, the report meets the relevant levels of formal admissibility and persuasive value. The potential for influence to be bought to bear in this final stage of a report needs to be understood and resisted. This review process ensures that the report does not allow the expert into areas outside their expertise, and in the end the report will **only** express opinions that are fully justifiable and prepared by the expert.

The outcome that the court requires is that the purpose of expert evidence is to persuade the tribunal of fact and to resolve a particular matter. A court, tribunal or judge will hardly reject an expert report that clearly sets out:

1. The expert's qualifications on the subject before the court.
2. The issues.
3. The relevance of expertise used to assess and provide an opinion.
4. The facts, including assumptions of fact on which the opinion is based.
5. The expert's considerations of relevant facts.
6. The analysis of facts in relation to the expert's expertise or relevant literature or materials that support the opinion.
7. The conclusions that are logically reached.

In technical issues that are considered before the Land and Environment Court it is often a matter that a meeting of experts is scheduled prior to the hearing, so that the real areas of dispute can be identified and the respective arguments can be put forward against each dispute item. This meeting is referred to as a conference and whilst lawyers do not usually attend (a technical conference), there is a clear understanding of the role of the conference to define real areas of dispute and to resolve, where possible, all areas including those matters that are often considered to be peripheral to the main arguments. Note that in this conference all issues are considered in an endeavour to have them resolved. A joint report will then be prepared which will then specify matters that are agreed, matters that are not agreed and the reasons for the disagreement. A successful conference will save time at the hearing and will lead to earlier resolutions.

3 RULES FOR THE BEHAVIOUR OF EXPERTS

The courts have rules for the use of experts, the use and admissibility of their reports, the way in which the court wants to receive the expert's report and the way that the court wants an expert to behave, i.e. an effective code of conduct for experts.

The list of legal advice on the relevant behavioural codes of conduct includes:

1. Uniform Civil Procedure Rules 2005 (New South Wales). Generally provisions from rule 31.18 to 31.54 are relevant. These rules give direction for conferences, the way that an expert can be appointed as a court expert, a joint expert (for both sides before the court). Specifically rule 31.23 requires that the expert **works with the court impartially... and with other court witnesses** and that the expert witness must exercise independent professional judgement in relation to any conference and joint report**.** There is also advice that an **expert must not act on any instruction or request to withhold or avoid agreement**.
2. Uniform Civil Procedure Rules 1999 (Supreme Court of Queensland Act 1991).
3. Evidence Act 1995, part 3.3. Clause 79 permits evidence in the form of an opinion from a person having "***specialised knowledge***" provided that the opinion is "***wholly or substantially based on that knowledge***". The emphasis here is that the expressed opinion that is being admitted must be shown to be within the "*expert's*" own field of specialisation.
4. Supreme Court (General Civil Procedure) Rules 2005, S.R. No 148/2005 – Order 44.
5. Federal Court Rules – Order 34 Court expert, Order 34A Evidence of expert witnesses and Order 34B Expert assistant. The Federal Court has also prepared "*Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia*" and in this guideline the requirement is clearly stated that the expert witness is **not to be an advocate** for a party.
6. Land and Environment Court – Practice Direction: Expert witnesses – No 22. Schedule 1 relates to the expert witness code of conduct, duty of care to the court and the content of a report. Schedule 2 clarifies the requirements for joint conferences of expert witnesses. The court has considered having a single expert on specific areas that include noise, traffic, parking, overshadowing, engineering, hydrology and contamination, heritage, urban design and general planning. Mutual agreement between all parties before the court is usually obtained for the appointment of these single experts.

On other occasions, the L&EC requires that a full conference will result in a better result and accordingly in these cases, joint reports with details of agreements and disagreements are prepared and lodged.

4 PREPARING A REPORT

The content of a report is to include:

1. Executive summary.
2. Introduction that includes the person preparing the report, CV, case, parties involved, briefing party, general scope and header/footer.
3. Copy of original and any amended brief/clarifications.
4. Compliance with the Expert Witness Code of Conduct.
5. Facts, matters of assumptions on what your opinion relied on.
6. Documents and literature that was used in your assessment.
7. Description/chronology – this is to be short, precise with dates and plans in order.
8. Opinion.
9. Summary – usually bullet points and kept short.
10. Signage of the report.
11. Attachments or annexure that includes detailed CV, calculations and any documents referred to in the report.

Additional training for expert witnesses can be obtained from the Institute of Arbitrators and Mediators Australia (IAMA), Level 9, 52 Philip Street, Sydney NSW 2000, ph. (02) 9241 1188, fax (02) 9252 2911, or email nsw.chapter@iama.org.au.

5 CASE STUDY: ISSUES RAISED FOR RESOLUTION AT L&EC

This section gives an example based on a case study, i.e. the Land and Environment Court matter no. 10634/2008 – 52 Cove Boulevarde, North Arm Cove. In this case, the Council refused the development application on the basis of three (3) fairly simple reasons that were generally based on the disposal of waste water and the character of the surrounding development.

The legal team for the Council then proceeded to expand the matters for which they sought the Court's endorsement for refusal. These reasons included some 50 individual items that needed to be reconsidered and in part engaged multiple government agencies to also lodge objections on specific matters that came under their jurisdiction.

In the end, the matters before the Court became extremely complex, interrelated and needed the use of experts to sort it out.

Figures 1-4 provide some background information in regards to this case study.

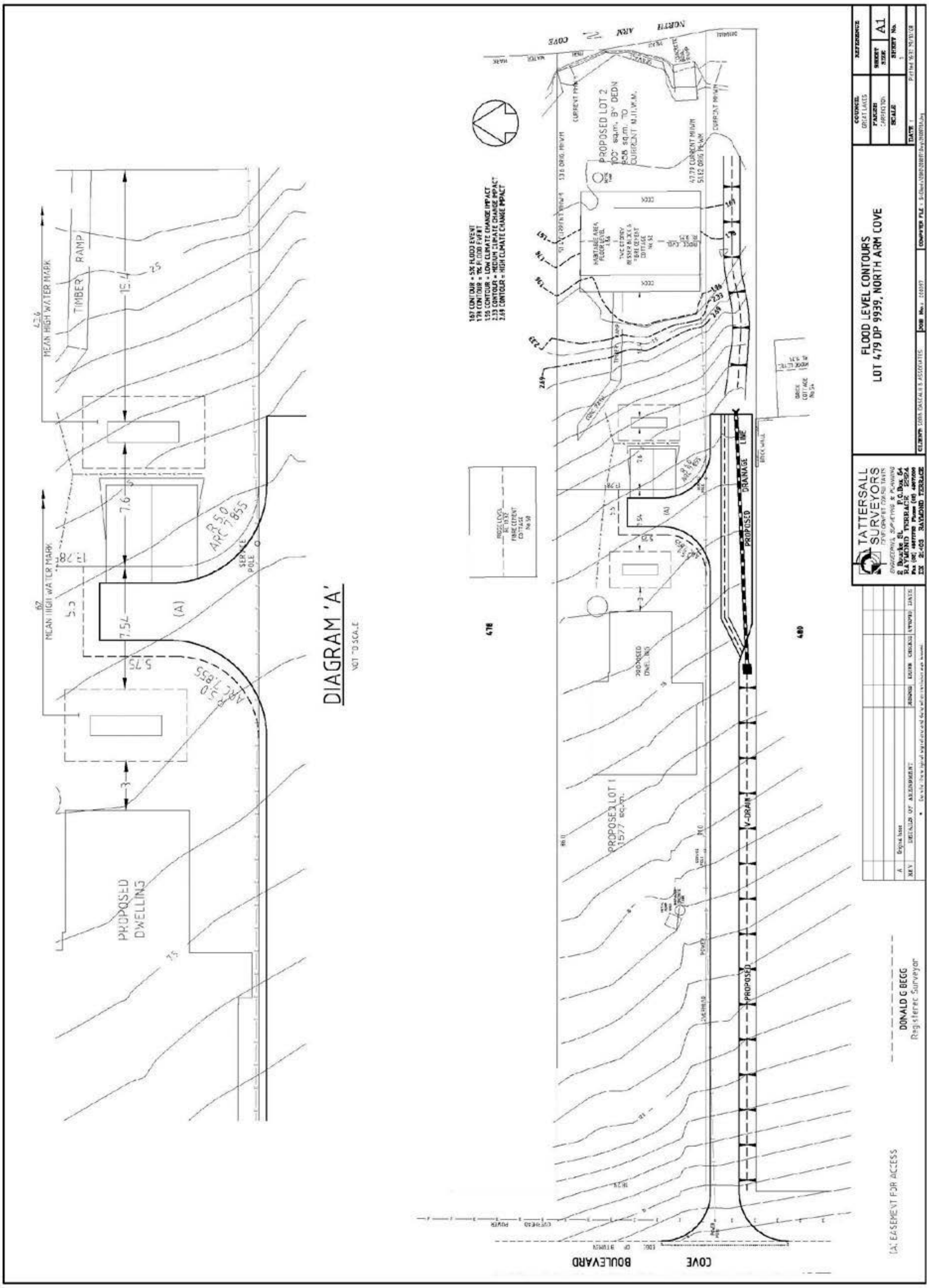

Figure 1: Plan showing flood level contours.

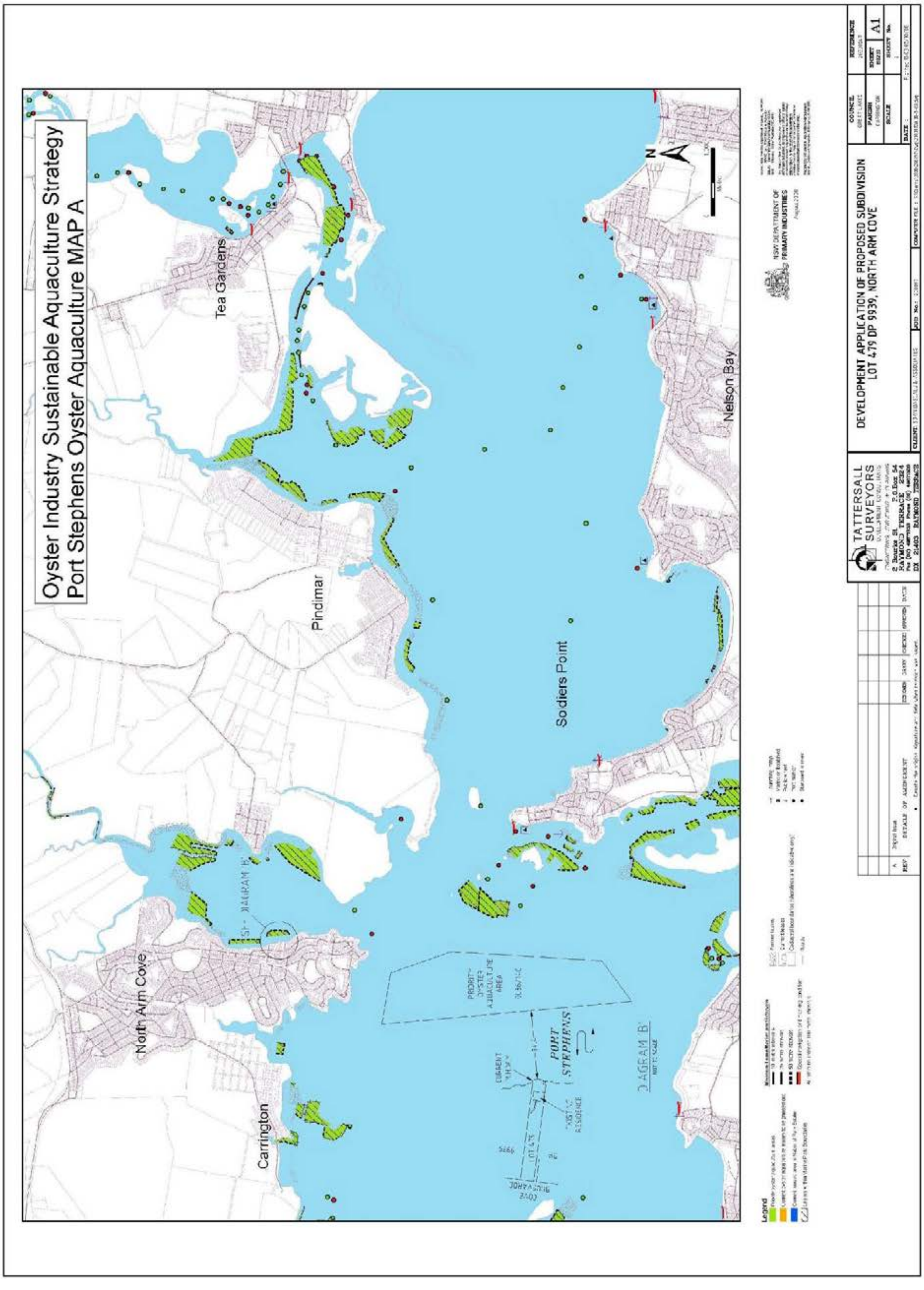

Figure 2: Plan showing oyster aquaculture areas.

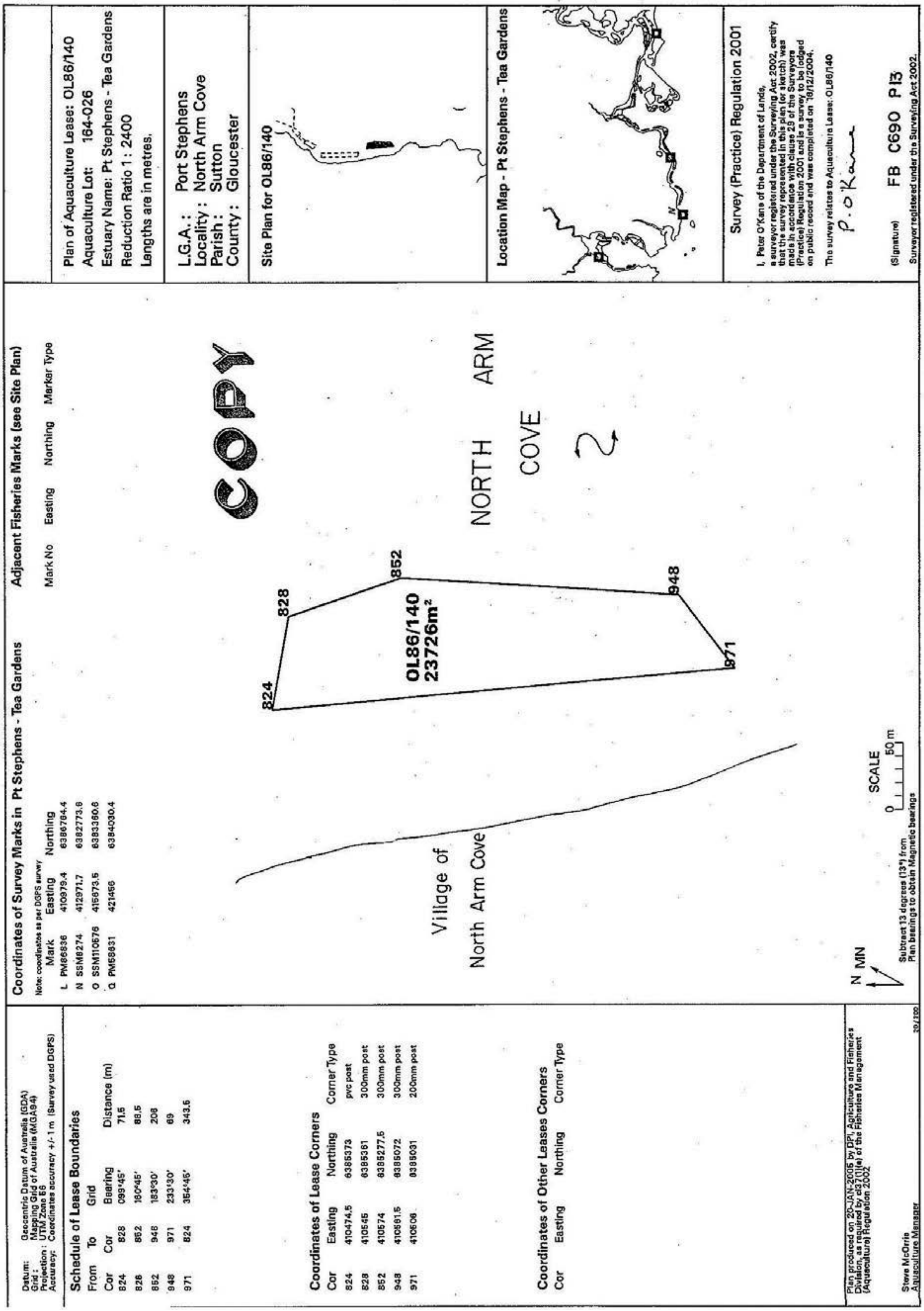

Figure 3: Plan showing aquaculture lease.

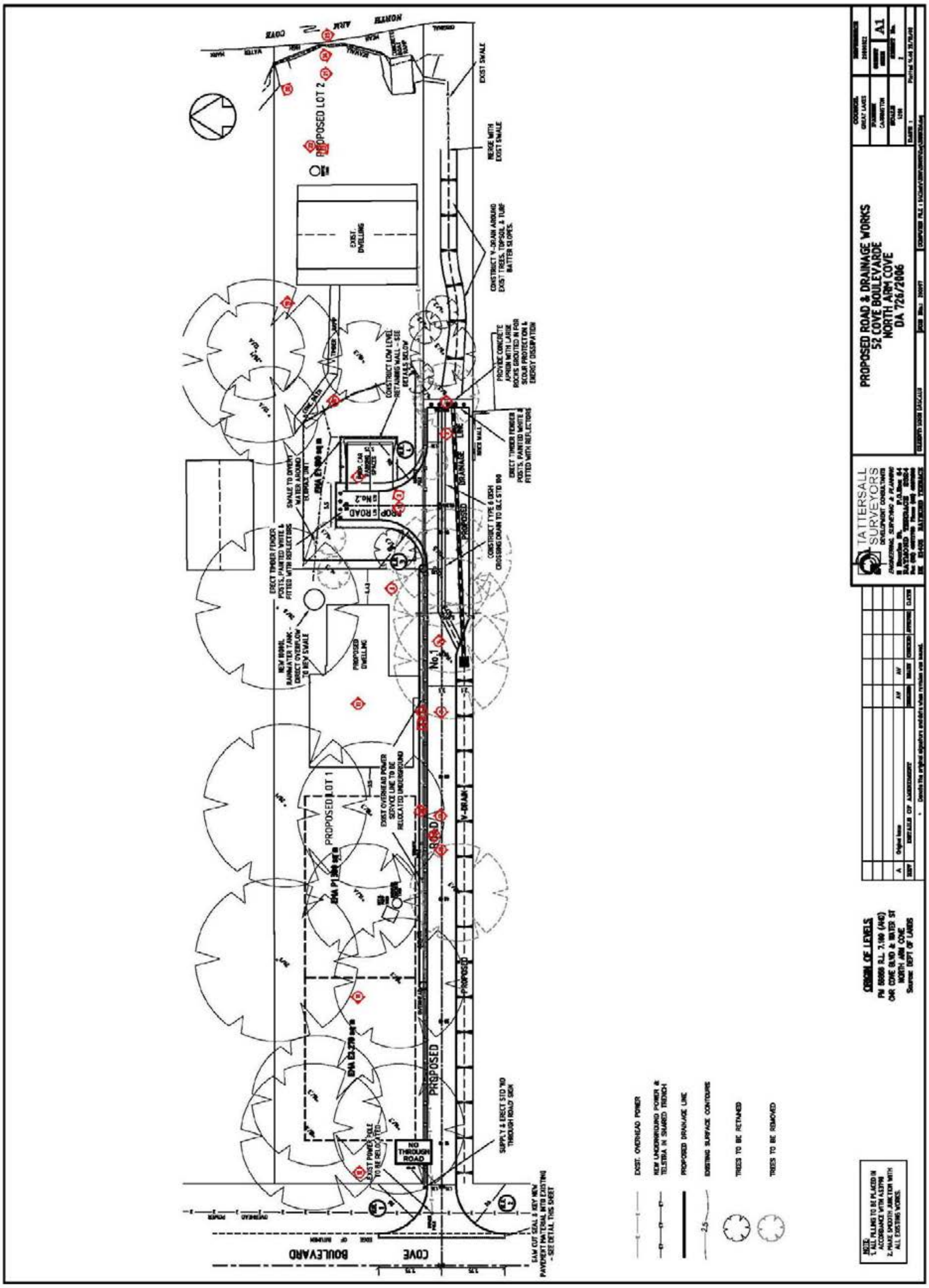

Figure 4: Plan showing proposed road and drainage works.

5.1 Original Reasons for Refusal by Council

1. Non compliance with clause 8(3) Great Lakes LEP 1996.
2. Non compliance with 8(m) and (p) of SEPP 71.
3. Non compliance with Council's On-site Sewer Management Policy.

5.2 Contentions raised by Council's Legal Advisors for Resolution at L&EC

Great Lakes Council

1. The applicant has not made any arrangement with the respondent pursuant to clause 12(b) of the Great Lakes LEP 1996 (GLLEP), for the provision of an adequate water supply and for facilities for the removal of sewage from and the drainage of the land.

   Particulars: To satisfy clause 12 of GLLEP 1996, the applicant in this instance, because of the absence of a reticulated water supply and sewerage services in the locality, has to satisfy the respondent in respect of compliance with Council's rainwater tanks domestic policy and Council's OSM strategy. The applicant must also obtain approval under Item 5 in Part C of the Table to S.68 Local Government Act 1993.

2.1 The development is unlikely to meet the zone objective of compatibility with the general character of the North Arm Cove village area because of the extensive removal of trees for the development (GLLEP cl (8) and Zoning Table).

2.2 The development is inconsistent with Aim cl 2(1)(b) GLLEP being:

(b) to protect and enhance the environmental qualities of the area;

because of the extensive removal of trees and the effects of the on-site sewerage management system set out in the following paragraphs.

3. The development does not have adequate facilities for the removal of sewage and drainage from the land (cl.12).

4. The on-site sewerage management system (OSMS) proposed for the development is unsatisfactory for the following reasons:

   (a) <u>SEPP 71 – Coastal Protection</u>
   The use of the proposed OSMS:
   (i) Is unlikely to meet aims of the SEPP in clause 2, namely its uses will not result in appropriate management of the coastal zone in accordance with the principles of ecologically sustainable development within the meaning of section 6(2) of the Protection of the Environment Administration Act 1991; and is unlikely to protect and preserve the marine environment of the State (cls 8 (a) and 2 (h) and (j)),
   (ii) is likely to pose an unacceptable risk to the water quality of Port Stephens, a coastal waterbody by the entry of inadequately treated domestic effluent into that waterbody (cl 8 (m)),
   (iii) is likely to have a cumulative impact on the marine environment of Port Stephens by increasing the density of OSMS's in the village zone of North

Arm Cove (cl 8 (p)(i)) and thereby increasing the total pollutant loading to the detriment of the sensitive waterway of Port Stephens.

(b) Marine Parks Act 1997
The proposed development, involving the use of a type of OSMS, is likely to have an effect on the plants or animals within the marine park because there may be discharge of inadequately treated effluent into the Port Stephens – Great Lakes Marine Park (s.20).

(c) SEPP 62
The proposed development, involving the use of a type of OSMS is likely, because of its nature and location, to have an adverse effect on oyster aquaculture development and a priority oyster aquaculture are in North Arm Cove (cls 15B and 15C).

(d) Hunter Region Environmental Plan
The impact of the proposed development on the amenity of the waterway is likely to be adverse to the water quality of Port Stephens by reason of the operation of the proposed OSMS (cl 6).

(e) NSW Coastal Policy and Coastal Design Guidelines
The use of the OSMS will not protect the natural values of the coastline, specifically, water quality and therefore the development is not in-keeping with the principle of ecologically sustainable development (Part A 2.1 Ecologically Sustainable Coast).

(f) Great Lakes Subdivision Development Control Plan 31
The proposed development does not have adequate sewerage service and that the proposed OSMS is non-complying with the DCP principal aim to protect and enhance the environment (s1.1.2).
The DCP requires "Subdivision in unsewered areas may be permitted only where allotment sizes and layouts are adequate to allow on site disposal of effluent. A report from a suitably qualified geotechnical engineer is required to verify that the land (and proposed allotment sizes and topography) is suitable for the on-site disposal of effluent" (s1.3.4).
The DCP further states "Council may reject an application requiring on site disposal of sewerage effluent where it considers there may be an impact on ground water quality or adjacent waterways" (s2.9.2).
The OSMS is likely to have an adverse impact on groundwater quality and the adjacent water of Port Stephens.

(g) Great Lakes On-Site Sewerage Management Strategy
The proposed OSMS is unsuitable and cannot provide a satisfactory on-site sewerage management service because of soil types, slope, ***and*** aspect combined with insufficiently treated ground and surface waters being likely to enter Port Stephens.
The proposed subdivision will limit the ***opportunity*** for the ***existing*** OSM system on proposed lot 2 to be up-graded to meet Council's OSM policy.

(h) Department of Local Government: Environment and Health Protection Guidelines On-Site Sewage Management for Single Households January 1998
The OSMS proposed for lot 1 will not meet the required buffer of 100 m from Port

Stephens, and that buffer, being a minimum, should likely be of greater dimension given the sensitive of the Port Stephens waterway and the nearby oyster farms.

The proposed lot 2 is of insufficient dimensions to provide a satisfactory site for an on-site sewerage management system when the existing system servicing the dwelling house has to be replaced. The current system on the land is septic tank and a disposal trench, approximately 15 m from the Port Stephens waterway and is classified as high risk. The system was licensed by the respondent, but on 31 July 2008 an inspection of that system by the respondent showed that it was not operating properly. An application under s68 Local Government Act 1993 to replace the system is likely to be refused as it will not meet the required minimum buffer distances in respect of the waterway, thereby rendering the habitation of the proposed waterfront lot 2 impossible.

The respondent's policy does not allow pump out systems for 'new' lots created by subdivision and pump out systems should only be used as a last resort for existing allotments.

(i) Generally

The dwelling proposed to be constructed on the subdivided allotment lot 1 will utilise and OSMS 'equal to' an 'Ecomax' system. However, although the Ecomax system claims to be a contained system, the system still utilises absorption trenches for effluent disposal and the cells will eventually fill up and then overflow into trenches surrounding the cells. This is likely to result in potential adverse impacts on the water quality of the receiving waters of Port Stephens, particularly in time of saturation of soils on the lot.

The Ecomax system uses ***blast furnace*** tailings. Their effect on the effluent as to pH is not known to the respondent and may adversely affect the waters in Port Stephens.

The specifications for the proposed OSMS are based on rainfall readings form Cessnock, well inland from the coastal strip, and the specifications are therefore unreliable given the propensity for the location to receive far greater rainfall over a period than Cessnock.

5. Precedent and effect on water quality of Port Stephens

The proposed development may set a precedent for owners of properties remaining in DP 9939 and capable of subdivision into similar sized allotments as proposed within North Arm Cove. An increase in the density of on-site disposal systems within the North Arm Cove area can potentially have health impacts and a detrimental effect on the quality of the receiving waters of Port Stephens. The Murray Darling Commission found in 1993 that significant levels of bacterial and nitrate contamination in groundwater were due to high density of on-site disposal systems. It concluded that areas with densities greater than 15 tanks/km^2, groundwater is considered to be vulnerable to nitrate and microbial contamination.

A study conducted by Whitehead and Associates in 2001 concluded that elevated nitrate concentrations (exceeding ANZECC water quality guidelines for protection of estuarine waters of 0.1mg/l) of surface waters sampled at North Arm Cove were most likely attributed to on-site sewage management systems. The study also concluded that the clay rich soils of North Arm Cove have "*low hydraulic conductivity so readily become waterlogged... they have... little capacity to absorb nitrates. The slopes are steep and distances to the shoreline are short, runoff is rapid and in particular after rain, with*

saturated soils, absorption trenches will readily contribute at best only partially treated effluent to the waters of Port Stephens." (p18)

The proposed subdivision is out of character with the predominant subdivision pattern in this part of North Arm Cove and may set an undesirable precedent for subdivision in a like manner.

6. Public interest

The proposal is not in the public interest as there is uncertainty as to the effect of the proposed OSMS, both on its own and cumulatively with other OSMS's at North Arm Cove upon the adjoining waters of Port Stephens and the oyster farms in that waterbody.

7. Suitability of the site

(a) The site is unsuitable for subdivision as no reticulated sewerage services are available and the proximity of the Port Stephens waterway to any on-site sewerage system on the land is unlikely to be of risk to the water quality of that waterway by reason of the likelihood of discharge of ***partially treated*** effluent, into that waterway.

(b) More than half the area of proposed lot 2 is within the 1% flood prone area and the subdivision, if approved, will result in the creation of a lot that will be significantly affected by the effects of climate change, namely sea level rise and increased rainfall intensities. The effectiveness of an OSMS and its relationship to water quality would be adverse, particularly on proposed lot 2. The entire area of footprint of the existing building is below RL 2.1 m and the lower floor level is not habitable given its relationship to High Water.

(c) The proposed dwelling house on lot 1 encroaches onto the narrow public road between Cove Boulevarde and the waterway.

(d) The development does not propose access in accordance with the Rural Fire Service's authority conditional S100B Bushfire Safety Authority, specifically section 4.3.2(a) "Planning for Bushfire Protection 2001".

(e) ***Future improvement and retro-fitting of the existing OSM system on lot 2 will not be able to achieve the buffer distances required by Council's OSM strategy being 100 metres from receiving waters.***

8. Cumulative impact

The respondent says that without appropriate studies on the potential cumulative impact by subdivision of the foreshore allotments at North Arm Cove for residential development, the future water, vegetation, biodiversity and scenic qualities of the locality may be adversely compromised. The respondent contends that no further consents for subdivision development should be granted until the respondent has considered a risk assessment report on the likely hazards and cumulative impacts of the use of OSMS's in the locality.

9. Public submissions

   Public objections to the proposal, specifically to site sewerage disposal and water quality; its effect on the waterway; perceived loss of access to the waterway by use of the public road for the purpose of the development; and the loss of coastal amenity. The submissions also raise precedent and the cumulative impacts that may be generated by any approval to this proposal.

10. Further information

    The respondent requires:
    (a) A plan of proposed subdivision showing clearly and simply all dimensions and proposed lots,
    (b) the finished floor level of lower floor of the existing building on proposed lot 2,
    (c) as the site is within 50 m of MHW and falls within Category A of the Port Stephens Foreshore (Floodplain) Management Plan, the submission of a Flood Planning Level Study.

NSW Food Authority

11. SEPP-71: Page 10 of the development application states that the development "*will not create potential conflict between land and water-based coastal activities*". This statement is incorrect; the increase of housing densities in proximity to oyster harvest areas has the potential to create conflict between oyster farmers and residents.

12. The incremental increase in the density of on-site disposal systems within close proximity to shellfish harvest areas creates public health risks that must be managed. To ensure adequate public health outcomes appropriate controls need to be implemented to effectively manage these risks including:
    (a) A vegetated buffer from any water course or drain of at least 100 m from on-site disposal systems,
    (b) sufficient lot size to facilitate on-site disposal,
    (c) disposal system design commensurate with site limitations, particularly soil type and water table level.

13. The 2001 study by Whitehead and Associates highlighted particular issues with the on-site disposal of sewage in North Arm Cove. The application does not address the issues raised in this report.

14. There does not appear to have been an assessment of the impact that the proposed development will have on the hydrology of the site, in particular:
    (a) The application proposes the installation of a drain to channel storm water down the side of the property. The effect of this drain on the transport of pollutants to the waterway needs to be considered.
    (b) The impact that any changes to the hydrology of the site have on the performance of the existing on-site disposal system (in proposed lot 2d).
    (c) The impact that any changes to the hydrology of the site will have on the performance of on-site disposal systems of neighbouring properties.

Department of Primary Industry

15. A detailed plan showing: the proposed lots and dwelling; the location and dimensions of the proposed disposal area and all other wastewater system components in relation to the high water mark; adjacent POAAs, the 1:100 and 1:20 flood contours.

16. The above plan should show the new high water mark. This is discussed on page 5 of *Development Application for Proposed Subdivision of Lot 479 in DP 9939, Cove Boulevard, North Arm Cove*. The *Development Application Plan* attached to this document only identifies the “Original Mean High Water Mark”.

17. The plan should also show the location and design of necessary soil berms, uphill diversion drains, and upslope subsoil drains (refer to page 8 of the *Effluent Disposal Investigation Report*).

18. More information about the preferred wastewater system Ecomax, how it works, and an analysis of the potential impact on water quality in the adjacent POAAs (with reference to the OISAS water quality objectives). For example, is disinfection included in the proposed system? If not, the exclusion of disinfection should be justified given the extreme sensitivity of the adjacent waterway to faecal coliform pollution.

19. The dimensions of the proposed disposal area. While a number of effluent disposal calculation methods have been utilised in the *Effluent Disposal Investigation Report*, the report does not specify which of the calculations will be utilised.

20. Specifications of actual buffer distances, not just recommended buffer distances (as provided on page 7 of the *Effluent Disposal Investigation Report*). Although not clearly marked on the plans provided, it would appear that the proposed disposal area is significantly less than 100 metres from permanent water, the minimum buffer distance in *On-Site Sewage Management for Single Households*.

21. Proposed mitigation methods to prevent any adverse or cumulative impacts to the sanitary water quality of POAAs.

22. The proponent has failed to provide sufficient information to demonstrate that the proposed use of Alumina Bauxite tailings in the proposed on-site wastewater management system would not have adverse impacts on the waters of Port Stephens.

23. Riparian Buffer Zone: NSW DPI recommends the maintenance of a riparian buffer zone for developments directly adjacent to estuaries. The buffer zone should be composed of native vegetation and be at least 50 metres in width. While there is insufficient area for a 50 metre zone on the subject lot, the proponent should be encouraged to establish a riparian buffer zone that is as wide as possible.

24. Stormwater Management: The applicant has not demonstrated that the proposed development will have a neutral or beneficial impact on the quality of stormwater runoff and ensure the protection of the adjacent oyster aquaculture industry. A detailed plan of the requirements of the drainage systems and design specifications of the system should be prepared. The OISAS water quality objectives should be referenced in demonstrating that there will be no adverse impact on water quality in the adjacent POAAs.

25. Erosion and Sediment Control: The applicant has not demonstrated that the proposed development will result in no significant impact on water quality in the adjacent POAAs as a result of construction activities. A comprehensive erosion and sediment control plan for the construction period should be prepared prior to the commencement of any works that disturb the ground. This plan should include a detailed site and soil assessment of the proposed development area. It should also reference the OISAS sanitary water quality objectives.

26. Visual Issues: The proponent should be made aware that the oyster aquaculture leased directly adjacent to the proposed development have existing use rights and will not be removed or altered as a result of subsequent residential development.

27. Consultation with Local Oyster Farmers and the NSW Food Authority: NSW DPI notifies the potentially affected sector of the oyster industry for all applicants referred to NSW DPI under SEPP 62. In this case the relevant oyster industry sector is the Port Stephens (Zone 2) Local Shellfish Program. The proponent should consider direct consultation with the Port Stephens oyster industry to ensure that all relevant issues are identified and addressed. The Local Shellfish Program also has water quality monitoring data (faecal coliform and salinity) for North Arm Cove and other areas in Port Stephens that may be relevant to the assessment of this application. The proponent should also contact the NSW Food Authority (NSW Shellfish Program) for advice regarding potential impacts to the classification of the North Arm Cove oyster harvest area.

6 CASE STUDY: THE CONFERENCE OF EXPERTS

A compulsory conference was ordered by the L&EC Commissioner to have the matters significantly reduced and tabulated. This conference was attended by representatives of all objecting Agencies on the day of the on-site hearing with an agreed position to attempt to resolve all matters.

The Appellant had provided additional information prior to the conference:
- Plans of proposed subdivision.
- Engineering plans.
- Water quality report.
- Flood level contour plan and report.
- Plan of POAA and location of development.
- Letter from Whitehead & Associates addressing NSW Food Authority issues.
- Letter from Whitehead & Associates addressing NSW DPI–Fisheries issues.

During the conference conclave the issue of time constraints limited the ability of the experts to resolve all issues. This meant that only marginal issues were able to be agreed with a general statement that attempted to resolve the main on-site sewer management systems. The report that was handed to the Commissioner ended with the following paragraphs.

Points of Agreement

Note that these points are the only fully discussed and agreed matters from the Experts Conference. As part of a final report to the court, these agreed matters only receive a cursory

review from the Court to ensure that their agreement is in accordance with the overall Court ruling. The final paragraph however, does indicate that agreement on the waste water management issues (the main contention) could be achieved and from this position the Court considered its position on the Appeal.

7. Suitability of the site
   (c) The proposed dwelling house on lot 1 encroaches onto the narrow public road between Cove Boulevarde and the waterway.

10. Further information
    The respondent requires:
    (a) A plan of proposed subdivision showing clearly and simply all dimensions and proposed lots,
    (b) the finished floor level of lower floor of the existing building on proposed lot 2,
    (c) as the site is within 50 m of MHW and falls within Category A of the Port Stephens Foreshore (Floodplain) Management Plan, the submission of a Flood Planning Level Study.

16. The above plan should show the new high water mark. This is discussed on page 5 of *Development Application for Proposed Subdivision of Lot 479 in DP 9939, Cove Boulevard, North Arm Cove*. The *Development Application Plan* attached to this document only identifies the "Original Mean High Water Mark".

22. The proponent has failed to provide sufficient information to demonstrate that the proposed use of Alumina Bauxite tailings in the proposed on-site wastewater management system would not have adverse impacts on the waters of Port Stephens.

23. Riparian Buffer Zone: NSW DPI recommends the maintenance of a riparian buffer zone for developments directly adjacent to estuaries. The buffer zone should be composed of native vegetation and be at least 50 metres in width. While there is insufficient area for a 50 metre zone on the subject lot, the proponent should be encouraged to establish a riparian buffer zone that is as wide as possible.

25. Erosion and Sediment Control: The applicant has not demonstrated that the proposed development will result in no significant impact on water quality in the adjacent POAAs as a result of construction activities. A comprehensive erosion and sediment control plan for the construction period should be prepared prior to the commencement of any works that disturb the ground. This plan should include a detailed site and soil assessment of the proposed development area. It should also reference the OISAS sanitary water quality objectives.

26. Visual Issues: The proponent should be made aware that the oyster aquaculture leased directly adjacent to the proposed development have existing use rights and will not be removed or altered as a result of subsequent residential development.

27. Consultation with Local Oyster Farmers and the NSW Food Authority: NSW DPI notifies the potentially affected sector of the oyster industry for all applicants referred to NSW DPI under SEPP 62. In this case the relevant oyster industry sector is the Port Stephens (Zone 2) Local Shellfish Program. The proponent should consider direct consultation with the Port Stephens oyster industry to ensure that all relevant issues are

identified and addressed. The Local Shellfish Program also has water quality monitoring data (faecal coliform and salinity) for North Arm Cove and other areas in Port Stephens that may be relevant to the assessment of this application. The proponent should also contact the NSW Food Authority (NSW Shellfish Program) for advice regarding potential impacts to the classification of the North Arm Cove oyster harvest area.

On matters of water quality and waste water management subject to any of the contentions in matter 10634 of 2008, it is agreed that a solution in terms of an alternative treatment and disposal approach which meets Government Department requirements in terms of waste water quality and potential for environmental and public health impact is achievable.

Outcome of the Hearing

(a) Joint Experts Conference: 50 matters considered in 2 hours, general agreement that all issues could be resolved but time became a constraint.
(b) Site Inspection by the Commissioner and Hearing on Site: Commissioner requested that the Court receive draft Conditions of Consent and the Court would determine the relevance of the matters raised and not resolved.

Decision of the Court

The Appeal be allowed.

7 CONCLUDING REMARKS

This paper has presented a case study that clearly indicates the role that a surveyor can play as a land professional in providing a professional service to a client. The role as an expert witness is an extension of the professional skills that training and experience have provided. The ability of a surveyor to be able to handle, discuss, interpret and present concepts involving coordinates, areas, contours, engineering designs, flood levels and logical land development processes together with an understanding of the roles of arborists, waste water engineers and planners ensured that the outcome in the Court was in favour of the Appellant. In fact, the surveyor in this case was the only expert inside the Conference that could get across all of the issues and untangle the interrelated matters to the satisfaction of the other experts.

The experts in this Conference were all intending to adopt their Agency's position as contained in the contentions as being absolute, but when the directions encompassed within the Code of Conduct were distributed, the flexibility to negotiate a reasonable position was then accepted by the Agency representatives. In all, this Conference was a very successful apparatus for the resolution of nearly all of the matters that the Court needed advice on. The Court then only had to consider the merits of the Appeal knowing that the technical matters had been generally resolved.

Surveyors' professional development can, with some additional training as provided by the Institute of Arbitrators and Mediators Australia, be extended to include acting as an expert witness. The ability of surveyors to understand coordinates, distances, areas, contours and land matters generally makes them an ideal candidate to assist the Court in the resolution of

complex development matters. The guidance provided by the Institute on what the Court expects allows the surveyor to improve their professionalism.

The skills of surveyors are enhanced by the avenues to which we seek to increase our involvement and the opportunities offered by the current processes in the Land and Environment Court are an ideal area that should not be ignored by the wider profession.

ACKNOWLEDGEMENTS

This paper could not have been prepared without the course notes that were provided by the Institute of Arbitrators and Mediators Australia (IAMA), NSW Chapter.

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Relevant legislation is available in NSW at www.legislation.nsw.gov.au (accessed Jan 2012).

Likely Impact of the Approaching Solar Maximum on GNSS Surveys: Be Alert but Not Alarmed

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ABSTRACT

Global Navigation Satellite System (GNSS) signals travel about 20,000 km from the satellite to a receiver on the surface of the Earth. At the end of this journey, which only takes about 60-70 milliseconds, the GNSS signal must travel through the Earth's atmosphere. Particularly the ionosphere, located at a height of between about 50 and 1,000 km above the surface, has a significant effect on the propagation of GNSS signals due to its high spatial and temporal variability. Most of the ionosphere is electrically neutral, but when solar radiation strikes it becomes an electrical conductor and supports the flow of electric currents. The effect of the ionosphere on GNSS signal propagation is a function of the Total Electron Content (TEC) along the signal path and the frequency of the signal. The TEC varies with time, season and geographic location. When travelling through the ionosphere, the speed of the GNSS signal deviates from the speed of light, causing measured pseudoranges to be 'too long' compared to the geometric distance between satellite and receiver, while carrier-phase observations are 'too short'. The condition of the ionosphere is strongly related to the solar cycle, which shows a maximum approximately every 11 years. This paper discusses the likely effects of the maximum of the current solar cycle (cycle 24), predicted to occur in early 2013, on GNSS users. Although it is anticipated to be a smaller solar maximum than the previous peak encountered in 2000-2001, GNSS users can at times expect reduced positioning, navigation and timing performance. Particularly during enhanced ionospheric or geomagnetic storm activity caused by sudden eruptions of the Sun, increased ionospheric variability can be expected. This will also cause increased scintillation effects (i.e. rapid changes in the phase and amplitude of the transmitted signals), which adversely affects ambiguity resolution and may cause GNSS receivers to lose lock in some instances.

KEYWORDS: *Solar cycle, ionospheric delay, TEC, scintillations, GNSS.*

1 INTRODUCTION

Global Navigation Satellite System (GNSS) signals travel about 20,000 km from the satellite to a receiver on the surface of the Earth. This journey only takes about 60-70 milliseconds (0.06-0.07 seconds) and requires the GNSS signal to travel through the Earth's atmosphere. The ionosphere is part of the Earth's upper atmosphere and stretches from a height of about 50 km to more than 1,000 km above the surface. Its high spatial and temporal variability has a significant effect on GNSS signals. Moreover, the condition of the ionosphere is strongly related to the solar cycle, which shows a maximum approximately every 11 years.

The effects of the ionosphere can be breathtakingly beautiful, i.e. the aurora australis/borealis (the southern/northern lights) are dancing curtains of light that occur when charged particles

enter the Earth's atmosphere at high latitudes. On the other hand, the effects can also be devastating, i.e. solar storms can cause widespread power blackouts, disrupt navigation systems and radio communication, and destroy the payloads on commercial satellites.

The ionosphere is the largest individual systematic error in the GNSS error budget, accounting for as much as 80% or more (Kunches and Klobuchar, 2001). The ionospheric range error on the GPS L1 frequency in the zenith direction can reach 30 metres or more, and near the horizon this effect is amplified by a factor of about three (Teunissen and Kleusberg, 1998). The ionosphere may also cause intermittent signal fading, in severe cases causing losses of availability. Travelling ionospheric disturbances can move at speeds of up to 1,000 m/s, causing sudden changes in electron density. In addition, ionospheric scintillations, which manifest themselves as rapid phase and amplitude variations of the received signal, can cause GNSS receivers to lose lock, thereby interrupting the reception of one or more satellites (ESA, 2005).

At present we are approaching another solar maximum, which is currently predicted to occur in early 2013. This has led to increased interest regarding the possible effects on GNSS users (e.g. Kintner et al., 2009; Jensen and Mitchell, 2011). This paper briefly explains how the occurrence of sunspots and the solar cycle influence the behaviour of the ionosphere. Related phenomena such as scintillations, travelling ionospheric disturbances and ionospheric storms are described, and recent advances in modelling the ionosphere are outlined. Finally, the likely effects of the maximum of the current solar cycle (cycle 24) on GNSS users are discussed, with an emphasis on Australia.

2 SUNSPOTS AND THE SOLAR CYCLE

Sunspots are the physical expression of complex processes within the Sun and are seen as dark areas on the solar disk that wax (become stronger) and wane (become weaker) (Figure 1). Sunspots are darker than their surrounding area because they are cooler than the average temperature of the solar surface and can therefore easily be observed. The appearance and disappearance of sunspots is due to underlying changes in the magnetic fields that exist throughout the Sun. For an extensive review on sunspots, the reader is referred to Solanki (2003).

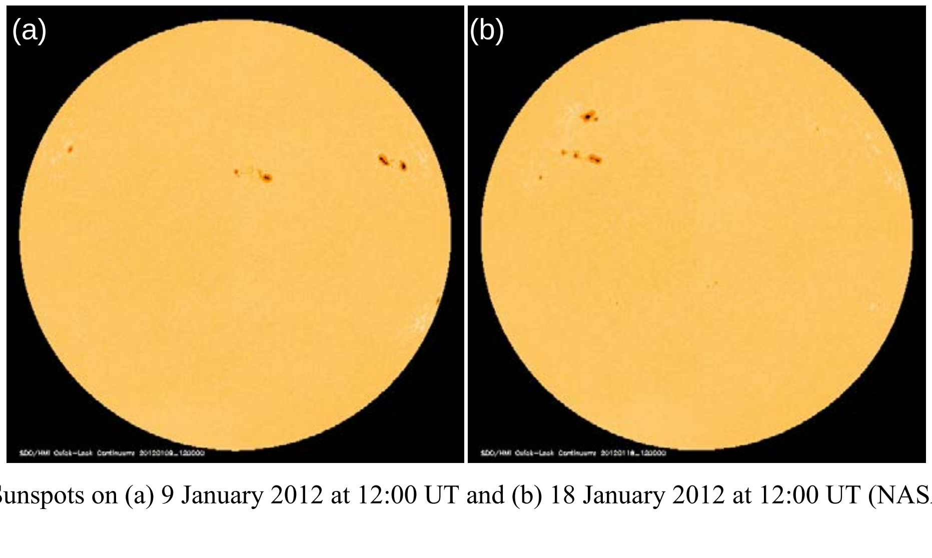

Figure 1: Sunspots on (a) 9 January 2012 at 12:00 UT and (b) 18 January 2012 at 12:00 UT (NASA, 2012a).

The pattern of sunspots on the Sun varies on timescales from a few hours to many years. In order to quantify the abundance of spots, an index called the *sunspot number* was introduced about 400 years ago and has been used to consistently and continuously monitor sunspots for the last 260 years. The sunspot number is calculated from the number of individual sunspots and sunspot groups visible on the Sun, under consideration of differences between observers and observatories.

In this context it is necessary to clarify a few terms associated with solar activity. As explained by Knight (2000), sudden increases in the intensity of solar radiation associated with sunspot activity are known as *solar flares*. The *solar wind* is composed of particles charged with high energy that are emitted from the Sun. *Coronal holes* are low density regions of the solar corona (region around the Sun, extending more than one million kilometres from its surface) and the primary source of the solar wind.

The solar cycle has an average length of 11 years. However, cycles vary considerably in length from as short as 9 years up to almost 14 years. Due to its large day-to-day variability, the sunspot number is usually averaged over a month. If smoothed over a 13-month period, it effectively charts the progress of the solar cycle. The daily and monthly averages exhibit considerable variation with respect to the smoothed curve due to bursts of rapid solar region growth often associated with events like solar flares. Figure 2 shows the smoothed sunspot numbers for the entire 260-year historical record, i.e. solar cycles 1-23.

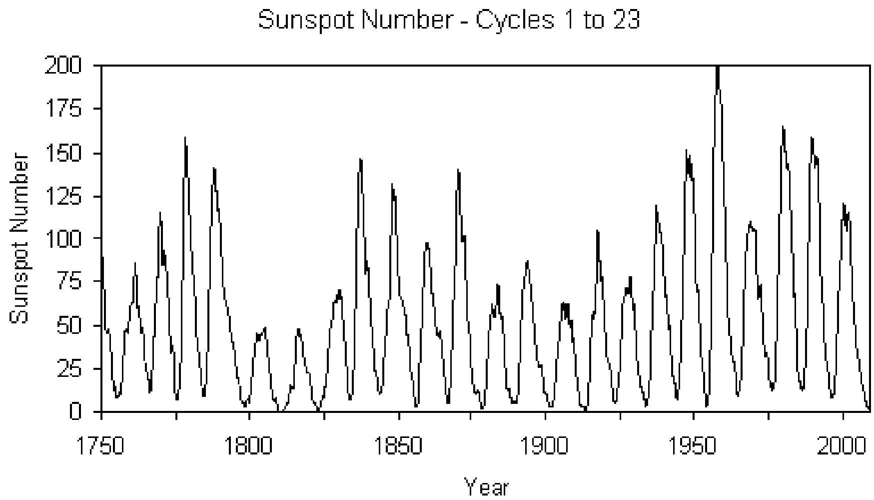

Figure 2: General variation of the solar cycles (1-23), illustrated by the smoothed sunspot number (IPS, 2012a).

At present, we are more than three years into the current solar cycle (cycle 24). Increased activity in the last few months has raised the predicted maximum and moved it to occur earlier than first expected. The solar maximum is now predicted to occur in early 2013, although this may still be revised by several months. It should be noted that ionospheric activity tends to remain high for several years around the solar maximum. However, the currently predicted size (smoothed sunspot number maximum of about 59) still makes this the smallest solar cycle in about 100 years. Figure 3 illustrates the monthly sunspot numbers for the previous solar cycle 23 (with its maximum in 2000-2001) and the current solar cycle 24, including a prediction for the remainder of the cycle.

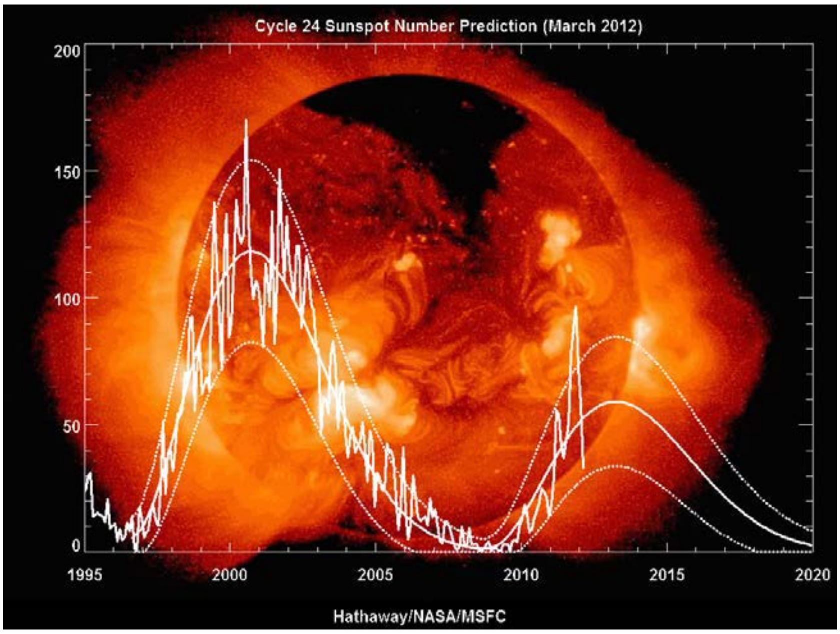

Figure 3: Monthly sunspot numbers for solar cycles 23 and 24, including prediction (NASA, 2012b).

3 THE IONOSPHERE

The ionosphere is a band of the atmosphere located about 50-1,000 km above the Earth's surface, thinning into the plasmasphere (or protonosphere) and eventually into the interplanetary plasma at greater heights. Most of the ionosphere is electrically neutral, but ionisation (i.e. adding or subtracting electrons from atoms by strong electric fields in a gas) results when solar radiation strikes the ionosphere. The upper atmosphere then becomes an electrical conductor, which supports the flow of electric currents, and hence affects the propagation of radio waves.

Free, negatively charged, electrons are produced when solar radiation collides with uncharged atoms and molecules, leaving behind positively charged atoms (i.e. ions). This process only occurs in the daylight hemisphere of the ionosphere because it relies on solar radiation. On the other hand, a loss of free electrons in the ionosphere occurs when a free electron combines with an ion to form a neutral particle. Loss of electrons occurs continually, both day and night (Figure 4).

The ionosphere is traditionally divided into several regions (D, E and F) and layers, based on the level of ionisation within a region. Figure 5 illustrates these ionospheric layers and the principle ions that compose each region; the electron density is also included (in units of electrons/cm^3). The F2 layer is particularly important for GNSS users because here the electron concentrations reach their highest values.

The free electrons present in the ionosphere affect the propagation of radio waves. At frequencies of up to about 30 MHz the ionosphere acts almost like a mirror, bending the path travelled by a radio wave back towards the Earth, thereby allowing long-distance radio communication (e.g. 'over the horizon' via 'skips and hops'). At higher frequencies, such as those used by GNSS, radio waves pass right through the ionosphere. However, the speed of the GNSS signal deviates from the speed of light when travelling through the ionosphere. This causes measured pseudoranges to be 'too long' compared to the geometric distance

between satellite and receiver, while carrier-phase observations are 'too short'. The terms *group delay* and *phase advance* are also used in this context (Teunissen and Kleusberg, 1998).

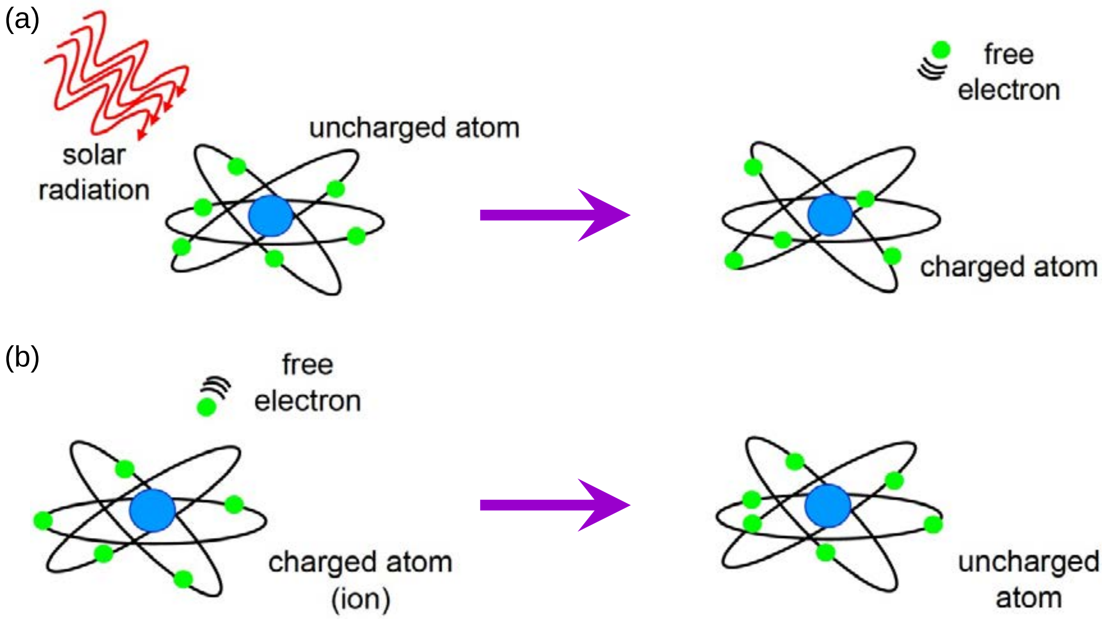

Figure 4: (a) Production and (b) loss of free electrons in the ionosphere (IPS, 2012b).

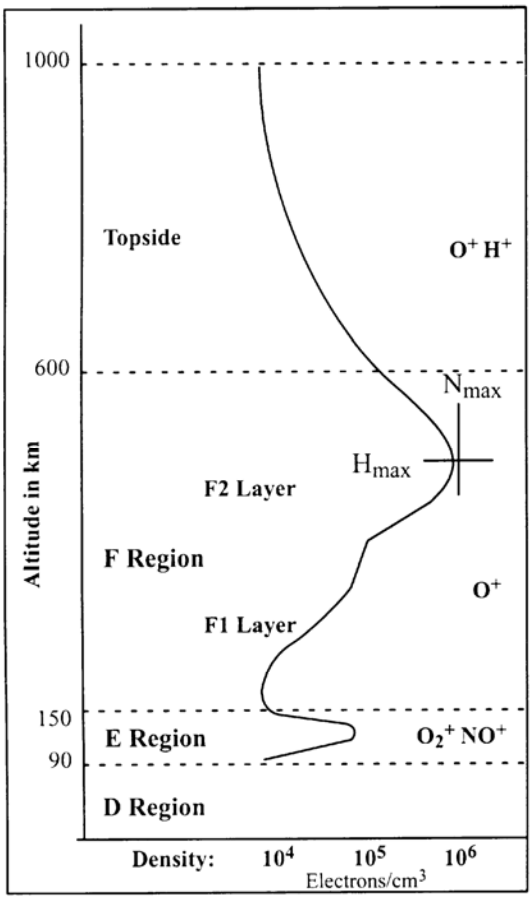

Figure 5: Regions and layers of the ionosphere, their predominant ion populations and electron density (Anderson and Fuller-Rowell, 1999).

The ionosphere is a dispersive medium for microwaves, i.e. the refractivity depends on the frequency of the propagating signal (e.g. Langley, 2000). Hence, measurements on multiple frequencies can be used to account for the ionospheric effect on GNSS observations, e.g. by forming the so-called ionosphere-free linear combination of the L1 and L2 signals. For short baselines the ionospheric effect is considered to be the same for both receivers, and therefore assumed to be eliminated by differencing the measurements taken at both ends. However, this assumption is not always true, particularly in periods of high solar activity. Experiments in Hong Kong have clearly shown that the ionospheric gradient in the region and the ionospheric delay effects could not be removed by double-differenced observables, even over baselines less than 10 km (Chen et al., 2001).

3.1 TEC

The effect of the ionosphere on GNSS signal propagation is a function of the Total Electron Content (TEC) along the signal path and the frequency of the signal. TEC is a measure of the integrated (i.e. summated or total) free electron density in a $1m^2$ column along the signal path between satellite and receiver, expressed in TEC units with 1 TECU = 1016 electrons/m^2. The TEC is highly variable with time, season and geographic location, with the main influences on signal propagation being solar activity and the Earth's magnetic field. Other factors influencing the ionospheric refraction are geographic location, the period in the solar cycle and the time of day. The largest TEC values are generally observed in the early afternoon local time, when the effect of solar radiation has reached a maximum. Consequently, the lowest activity is experienced late at night, just before sunrise (Jensen and Mitchell, 2011).

3.2 Scintillations

The ionosphere is most active in a band extending up to approximately 20° on either side of the geomagnetic equator (Figure 6). This is also one of the two regions where small-scale ionospheric disturbances (scintillations) mainly occur, the other being the high-latitude (auroral) regions close to the poles.

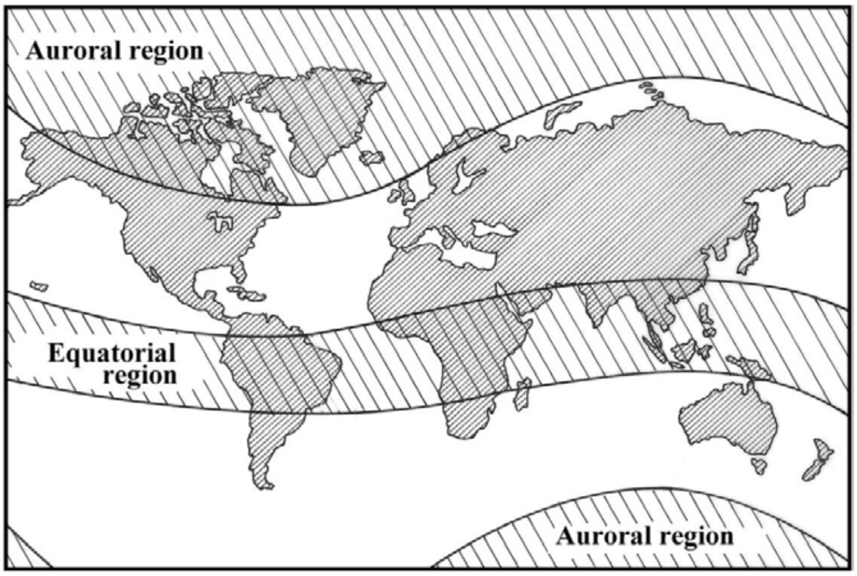

Figure 6: Regions of the world with high ionospheric activity (Seeber, 2003).

Scintillations are rapid, short-term variations in the amplitude and phase of radio signals travelling through the ionosphere, thereby causing rapid changes in signal power. Auroral and

polar scintillations are mainly the result of geomagnetic storms that are associated with solar flares and coronal holes. Equatorial scintillations, on the other hand, are caused by irregularities in the F-layer of the ionosphere following the passage of the *evening terminator*, the boundary that divides day from night (Knight, 2000). Equatorial scintillations generally occur from about one hour after sunset until midnight and should have disappeared by 03:00 local time (Klobuchar, 1996).

Figure 7 illustrates the maximum L-band signal fading depths (i.e. fading signal strength) due to ionospheric scintillation that can be expected during the peak of the solar cycle (left) and under solar minimum conditions (right). It can clearly be seen that scintillation effects are much more severe during solar maximum conditions. It should also be noted that the main anomaly region located at ±15° of the geomagnetic equator experiences the deepest signal fades of up to 20 dB below the mean signal level. Less intense fading is experienced at the geomagnetic equator and in regions surrounding the main anomaly region. The primary diurnal maximum of this *equatorial anomaly* is also known as the *fountain effect* because it is characterised by high electron concentration observed on either side of the geomagnetic equator.

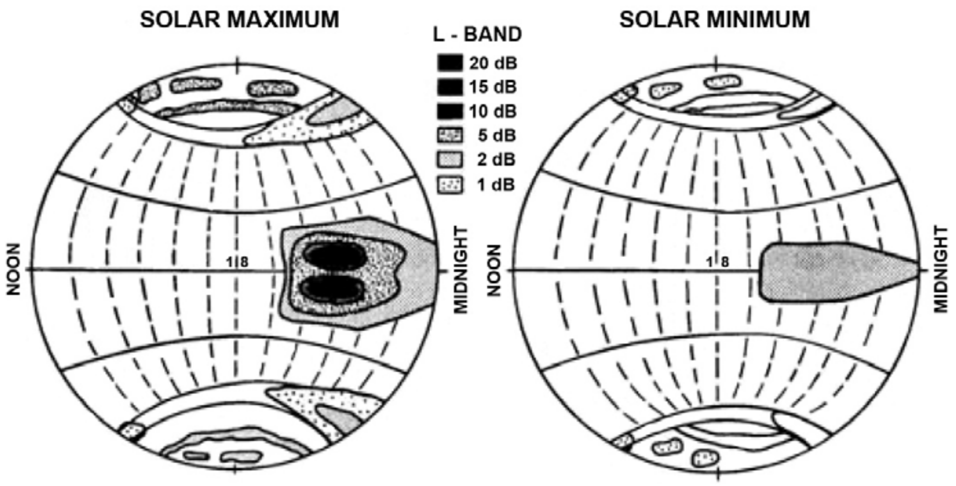

Figure 7: Ionospheric scintillations during high and low solar activity (Goodman and Aarons, 1990).

The occurrence of scintillations also varies with the seasons. Between April and August they are less severe in the American, African and Indian longitude regions, but are at a maximum in the Pacific region, while the situation is reversed from September to March (e.g. Seeber, 2003). It has also been shown that scintillation effects tend to peak in the equinox seasons, i.e. around 20-21 March and 22-23 September each year (Doherty et al., 2000).

3.3 Travelling Ionospheric Disturbances

Travelling ionospheric disturbances (TIDs) are wave-like density fluctuations that propagate through the ionosphere at various horizontal velocities and wavelengths of several hundred kilometres (Hocke and Schlegel, 1996). Generally, the distinction is made between large-scale TIDs (LSTIDs) and medium-scale TIDs (MSTIDs). LSTIDs are related to geomagnetic disturbances (e.g. caused by the aurora effect or ionospheric storms) and can travel large distances. They last for more than 1 hour and move faster than sound (i.e. in excess of 300 m/s or 1,080 km/h). On the other hand, MSTIDs are more related to lower atmospheric weather disturbances (e.g. severe weather fronts or volcanic eruptions). They last for shorter time periods (from 10 minutes to 1 hour) and move at slower speeds of about 50-300 m/s (e.g.

Hernández-Pajares et al., 2006; Wang et al., 2007). MSTIDs frequently occur in mid-latitudes, mainly during daytime in the winter months, during periods of high solar activity (e.g. Wanninger, 2004; Kotake et al., 2007).

3.4 Ionospheric Storms

Ionospheric storms result from large energy input to the upper atmosphere associated with geomagnetic storms. The latter are large variations in the strength and direction of the Earth's magnetic field caused by eruptions on the Sun that eject a mixture of electrons, protons and ions into the solar wind (Knight, 2000). Since the geomagnetic field and the ionosphere are linked in complex ways, a disturbance in the geomagnetic field often causes a disturbance in the ionosphere through fluctuations in electron density. This process can cause strong scintillation effects and large rapid changes in the ionospheric delay for GNSS signals, within time periods of about one minute. These ionospheric storms may last a number of days, and higher latitudes are generally affected more than low latitudes (IPS, 2012b).

4 MODELLING THE IONOSPHERE

Many different methods for estimating and modelling the ionospheric signal delay have been developed (e.g. Allain and Mitchell, 2009; Burrell et al., 2009). The ionosphere is usually approximated by a very thin shell at a certain altitude (generally between 300 and 400 km) above the Earth's surface. The slant TEC (STEC, along the line-of-sight to the satellite) is often converted to an equivalent vertical TEC (VTEC), allowing convenient comparison between different datasets and spatial mapping of the ionosphere (Figure 8). The point where the line of sight between a GNSS receiver and a satellite passes through this shell is known as the ionospheric pierce point (IPP).

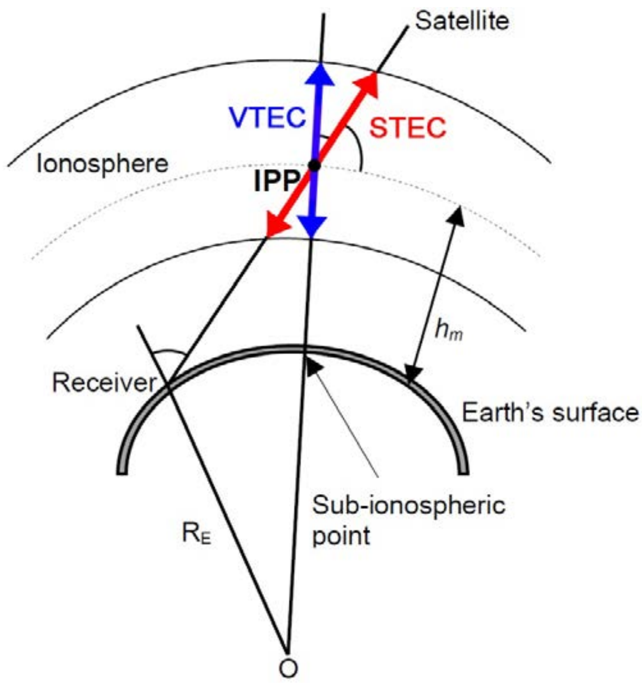

Figure 8: Geometry of a single-layer ionospheric shell model at altitude h_m, adapted from Ya'acob et al. (2008).

This single-layer approach is feasible because the majority of free electrons in the ionosphere are distributed at these altitudes. However, such a 2-dimensional model is not ideal because it

is unable to provide a vertical profile of the ionosphere. Alternatively, tomographic imaging (a medical imaging technique to create images of a parameter from integrated measurements) can be used (Bust and Mitchell, 2008). A tomographic model can describe the ionosphere in a 3-dimensional frame, allowing more precise exploration of the ionospheric characteristics and subsequently better modelling accuracy (Gao and Liu, 2002).

In practice, these two approaches for ionospheric modelling can be applied in two ways. The first option is to use a model *predicting* the ionospheric delay, e.g. the Klobuchar (1987) model or the International Reference Ionosphere (IRI) model (Bilitza, 2006). The coefficients for the Klobuchar (1987) model are determined by the GPS control segment and broadcast to users as part of the GPS navigation message. The second option is to implement *real-time mapping* and to transmit this information to the GNSS user in the field, e.g. via a geostationary satellite broadcasting on GNSS frequencies or the internet. Real-time mapping generally provides greater accuracy over prediction models. However, it does require a sufficiently dense GNSS Continuously Operating Reference Station (CORS) network infrastructure over the area of interest.

Considerable progress has been made in regards to improve modelling by accounting for second-order (i.e. non-linear) ionospheric terms (e.g. Hernández-Pajares et al., 2007; Hoque and Jakowski, 2008), which is particularly useful in periods of high solar activity. In addition, the ability to estimate ionospheric delay parameters quickly and precisely is expected to improve significantly when GPS observations can be combined with measurements using other GNSS such as GLONASS, Beidou and Galileo (Richert and El-Sheimy, 2005).

The introduction of new GNSS frequencies is expected to provide better ionospheric modelling over longer baselines. For example, the new dual-frequency GPS L1/L5 signal combination has a larger frequency separation than the original GPS L1/L2 combination, thereby promoting better correction of ionospheric effects (Roberts, 2011). Similarly, triple-frequency observations based on a single GNSS will allow instantaneous ambiguity resolution over longer distances. Traditional dual-frequency combinations must either compute a baseline solution whilst ignoring the ionosphere or vice versa. Triple-frequency combinations, on the other hand, will allow multiple combinations to compute the baseline and account for the ionosphere, thereby providing instantaneous positioning over longer baselines (Rizos, 2008).

The growing number of operational GNSS constellations also has the potential to generate new alternatives for GNSS positioning. For example, single-frequency code-plus-carrier positioning could become an interesting application of a future Galileo E5 receiver, due to the exclusive properties of this broadband signal. Simulated results featuring high ionospheric variations have indicated a positioning performance which is at least three times better than that of a GPS L1 receiver (Schüler et al., 2011).

4.1 Global Ionosphere Maps

The Center for Orbit Determination in Europe (CODE), located at the University of Bern in Switzerland, generates daily global ionosphere maps (GIMs) based on data collected at global International GNSS Service (IGS) sites (Schaer et al., 1998). An example of such a GIM is shown in Figure 9, dark blue indicating low TEC and red indicating high TEC. The dotted line corresponds to the geomagnetic equator. The equatorial anomaly (see section 3.2) is clearly visible north of Australia.

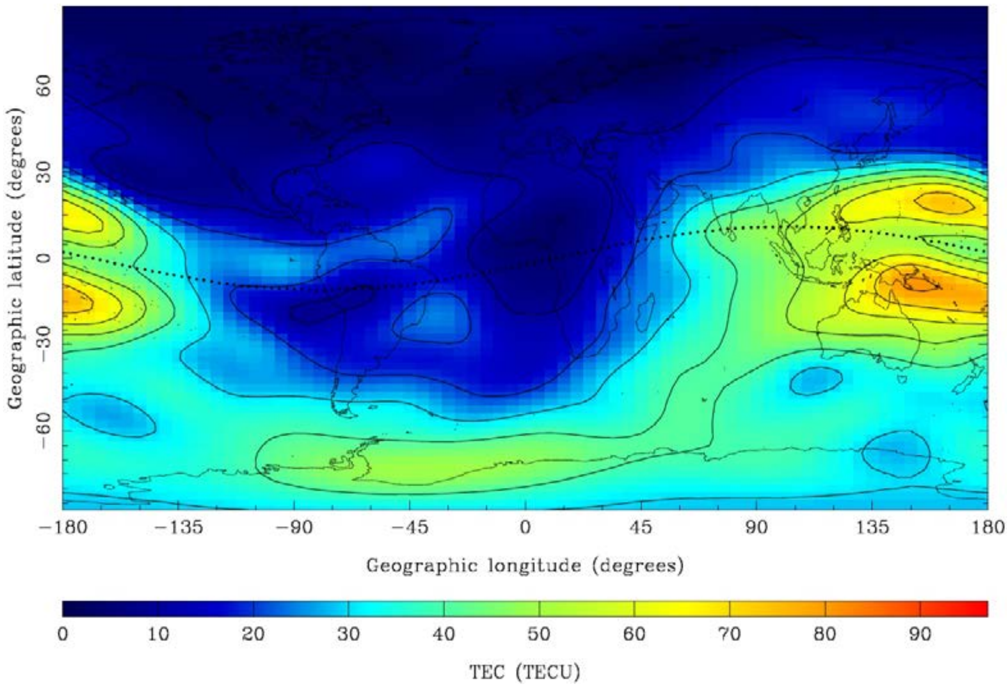

Figure 9: Global Ionosphere Map (GIM) for day 361, 2011 at 04:00 UT (AIUB, 2012).

While freely available on the internet, these global maps are not very effective in modelling the ionospheric conditions in local or regional GNSS networks for short observation periods because they cannot reproduce local, short-lasting processes in the ionosphere. Moreover, even though there are a large number of IGS sites, they are unevenly distributed, with most of the GNSS stations being situated in the mid-latitude region of the northern hemisphere. The smaller number of GNSS receivers in the equatorial region and the southern hemisphere, and consequently the reduced number of available TEC measurements, results in the ionospheric modelling to be less accurate for these regions. However, GIMs are invaluable for tracking the behaviour of the global ionosphere over time.

4.2 Regional Ionosphere Maps

The temporal and spatial TEC variations over a local or regional area are very complex, making it a challenging task to precisely represent the varying behaviour of the ionosphere (Wu et al., 2006). Nevertheless, many methods have been developed and evaluated to model the regional ionosphere based on GNSS observations (e.g. Gao and Liu, 2002; Janssen and Rizos, 2003; Wielgosz et al., 2003; Liu et al., 2011).

The Ionospheric Prediction Service (IPS), located in Sydney, Australia, produces near real-time regional ionospheric TEC maps for the Australasian region. These maps are determined by combining GPS data from a range of CORS with the IRI-2007 ionospheric model driven by real-time observations from IPS ionosondes. A brief description of ionosode operation can be found in IPS (2012b). An example of an IPS TEC map is shown in Figure 10, dark blue again representing low TEC while red indicates high TEC. It can clearly be seen that Australia is affected by the equatorial anomaly (04:30 UT is equivalent to 15:30 AEDST).

Time sequences of such TEC maps based on GNSS CORS network observations can also be used to investigate the spatial structure and temporal evolution of TIDs, geomagnetic storms and other ionospheric phenomena (e.g. Tsugawa et al., 2007; Wang et al., 2007).

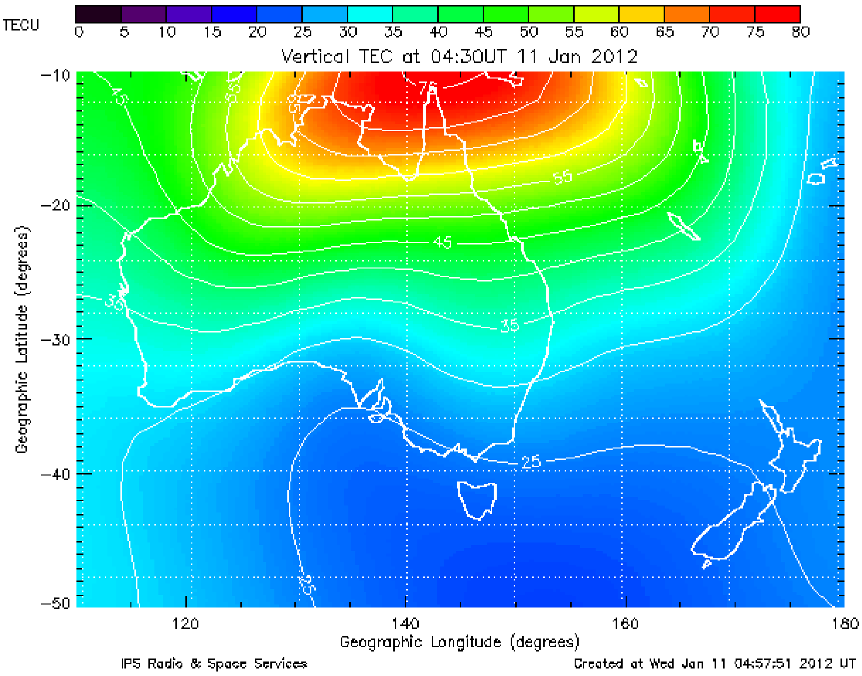

Figure 10: Regional Ionosphere Map for Australia for day 011, 2012 at 04:30 UT (IPS, 2012c).

5 LIKELY EFFECTS OF THE SOLAR MAXIMUM ON GNSS SURVEYS

Although the approaching maximum of solar cycle 24 is anticipated to be much smaller than the previous peak (see Figure 3), GNSS users can at times expect reduced positioning, navigation and timing performance. Particularly during enhanced ionospheric storm activity, increased TEC variability can be expected. The increased occurrence of scintillations, TIDs and ionospheric storms can lead to more cycle slips and (partial or complete) loss-of-lock for GNSS receivers as they track the signal, thereby limiting the availability of carrier-phase measurements and negatively affecting ambiguity resolution (e.g. longer time to fix ambiguities and lower success rate). In addition, the noise level of solutions is expected to rise for both pseudorange and carrier-phase observations during the solar maximum period. This may be noticeable, for example, through poorer standard deviations, reference variances, Root Mean Square (RMS) values, Quality Control (QC) or Coordinate Quality (CQ) values, and ratio tests.

5.1 Indications from International Studies

Scintillation effects mainly occur in the equatorial region (including Northern Australia) and at high latitudes, and are significantly more severe under solar maximum conditions (e.g. Datta-Barua et al., 2003; Seo et al., 2007). Analysing three years of GPS observations in Hong Kong during the previous solar maximum, Chen et al. (2008) showed that the number of loss-of-lock occurrences increased dramatically during strong disturbance periods (from less than 50 to 500 per day), with most losses occurring on the (weaker) L2 frequency. In addition, both the pseudorange and carrier-phase measurement noise level increased significantly. For the ionosphere-free combination, the carrier-phase measurement noise level increased by more than a third compared to ‘normal’ conditions. It was also shown that different types of GPS receivers behave differently during the disturbances, which is related to the receiver hardware and firmware employed.

Travelling ionospheric disturbances frequently occur in mid-latitudes and are more severe during periods of high solar activity. Australia is located mainly in the mid-latitude region. Consequently, MSTIDs have the biggest effect on Real Time Kinematic (RTK) and Network RTK (NRTK) performance for Australian GNSS users, due mainly to their wavelength and amplitude. Despite the small amplitude of MSTIDs (typically tenths of a TECU), these ionospheric disturbances can cause a (sometimes dramatic) decrease in the performance of GNSS positioning (e.g. Wanninger, 2004; Wu et al., 2006). TIDs can also introduce biases in the ionospheric interpolation process applied within CORS networks with baselines from tens to hundreds of kilometres, due to the inability of routinely used models to account for these short-term fluctuations (Hernández-Pajares et al., 2006).

An increased number of ionospheric storms can be expected to occur during the upcoming solar maximum (Valladares et al., 2009). These storms are able to significantly degrade GNSS positioning accuracy, particularly during high solar activity (Skone, 2001). During an ionospheric storm in northern Europe, kinematic analysis of GNSS position repeatability has been shown to degrade by one order of magnitude, from better than 1 cm in the horizontal and about 2.5 cm in the vertical position to 12 cm in the horizontal and 26 cm in the vertical (Bergeot et al., 2011). This was attributed mainly to second-order ionospheric delays on GNSS signals which are currently not accounted for in routine GNSS data processing. It was also noted that this degradation was less severe for stations located in central Europe, again highlighting the strong latitude dependency of ionospheric effects.

5.2 Indications from Australian Studies

It is very difficult to quantify the effects of the approaching solar maximum on GNSS positioning users in Australia, mainly due to the complexity of the ionosphere and the lack of studies conducted in this region. In a rare example, Wu et al. (2006) investigated the temporal and spatial variations of the ionosphere over Victoria using GPS CORS data collected over a period of two years (2003 and 2004). It was found that maximum TEC values generally occur at about 14:00 local time, while minimum values are observed at about 03:00 local time. As expected, daytime TEC values were larger than night-time values. However, significant diurnal and seasonal ionospheric TEC variations were evident. In spring (September to November) and autumn (March to May), daytime TEC values were generally greater than in the other two seasons, i.e. summer (December to February) and winter (June to August). The study also revealed spatial correlations, in principle allowing ionosphere modelling across the entire state. However, the existence of TEC gradients causes difficulties in establishing an appropriate model that sufficiently describes the complex nature of ionospheric effects over such a wide area for high-precision, real-time GNSS positioning.

By using a regional CORS network, such as CORSnet-NSW (Janssen et al., 2011) or GPSnet (Hale et al., 2008), a large portion of the differential ionospheric biases can be modelled and removed. However, in the presence of small-scale or medium-scale ionospheric disturbances large ionospheric residuals can remain, even with NRTK. The advantage of NRTK over single-base RTK lies in the mitigation of the ionospheric biases affecting ambiguity resolution and positioning accuracy. The ionospheric correction models of NRTK successfully remove (at least) the linear part of the differential ionospheric biases (Wanninger, 2004). Connecting to a regional CORS network is therefore the preferred option in regards to minimising the effects of the approaching solar maximum on real-time GNSS surveys in Australia. However, it should be emphasised that ionospheric disturbances are also prone to affect the

communication links required to transfer data between the CORS network (or a local base station) and the GNSS user. As a result, radio links and mobile phone connections can suffer, at times leading to the need for more frequent reinitialisation of the GNSS receiver.

5.3 What Does the Future Hold?

Based on the findings of these recent studies, it is appropriate to speculate about how GNSS users and CORS network operators may be able to minimise the effects on GNSS positioning performance during solar maximum conditions in the near future.

GNSS users may be required to pay more attention to their rover and its real-time performance indicators over the next few years. It is well known that coordinate quality indicators are generally overly optimistic (e.g. Edwards et al., 2010; Janssen and Haasdyk, 2011). This discrepancy is likely to be more pronounced during heightened solar activity, leading to an increased number of outlier positions not identified by the rover's quality indicators.

The effect of ionospheric disturbances on GNSS positioning performance at the user end may differ between receiver brands and receiver types due to variations in receiver hardware, firmware and the algorithms employed (see section 5.1). This is likely to continue, as each manufacturer continues to develop improved ways of accounting for the ionospheric delay, e.g. via long-range RTK algorithms. As a result, the performance gap between legacy (GPS-only) equipment and modern GNSS rovers will grow considerably. In any case, it may be beneficial to increase observation times to obtain additional measurements if possible.

New algorithms for sparse CORS networks, allowing station separations of about 100 km or more, are now commercially available to CORS network providers. Applying these across existing, denser CORS networks may help to counter-balance at least some of the expected reduction in positioning quality due to the solar maximum, possibly resulting in current user performance to be maintained in some areas. In general, connecting to a CORS network using NRTK is recommended to help minimise the effects of ionospheric disturbances on real-time GNSS applications. The continuing expansion of regional CORS networks, paired with the introduction of new GNSS signals (see section 4), will significantly improve ionospheric modelling in the near future. This, in turn, will minimise the effects of the solar maximum on modern GNSS equipment.

6 CONCLUDING REMARKS

This paper has briefly reviewed how the solar cycle influences the behaviour of the ionosphere and described related phenomena such as scintillations, travelling ionospheric disturbances and ionospheric storms. Recent advances in modelling the ionosphere have been outlined, and the likely effects of the approaching solar maximum of cycle 24 (currently predicted to occur in early 2013) on GNSS users have been discussed.

GNSS users should be alert but not alarmed. GNSS positioning is expected to continue to perform at current levels most of the time, with the occasional larger and more frequent glitches encountered in the field. Australia is located mainly in the mid-latitude region and therefore generally spared from the most severe ionospheric disturbances. In addition, the approaching solar maximum is predicted to be significantly smaller than the previous peak in

2000-2001. However, it should be noted that many of the most intense solar outbursts have occurred during below-average solar cycles. During the solar maximum period, which may last for up to two years or so (i.e. until about 2015), intermittent degradation of positioning performance (particularly for real-time surveys) should be anticipated across Australia. An increased number of cycle slips and periods of frequent loss-of-lock to multiple satellites are expected to occur at times. In addition, drop-outs in the communication links required for real-time applications (i.e. radio link or connection to mobile internet) should be anticipated. GNSS users in Northern Australia can expect more severe scintillation effects to occur more frequently. Consequently, GNSS users should pay particular attention to GNSS best practice and be a little more cautious over the next few years.

The gap of about 11 years between solar maxima marks only one iteration of the solar cycle, but it represents several generations in regards to GNSS infrastructure and receiver design. The number and density of GNSS CORS networks in operation has increased considerably since the previous solar maximum, both at global and regional scales. In addition, significant progress has been made in ionospheric modelling. As a result, the GNSS community is well prepared for the approaching solar maximum. This also provides an unprecedented opportunity to further enhance our understanding of the complex nature of the ionosphere and to develop and test improved ionospheric models (e.g. higher resolution and lower latency) using the CORS data collected over the next few years.

Efficient real-time modelling of the ionospheric effects on GNSS observations is getting close to becoming a reality. The growing number of operational GNSS constellations will not only contribute to this process, but also help generate new alternatives for GNSS positioning which may be less affected by variations in the ionosphere.

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Post-Processed Precise Point Positioning: A Viable Alternative?

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ABSTRACT

The concept of Precise Point Positioning (PPP) using Global Navigation Satellite System (GNSS) technology was first introduced in 1976. However, it took until the 1990s for PPP to generate interest amongst the greater GNSS community. Over the last two decades, dual-frequency PPP has been extensively researched, and several PPP online services and software packages have been developed. This research has shown that centimetre-level point positioning is achievable in post-processed static mode. However, several limitations still remain, primarily the long convergence times needed to resolve ambiguities, currently restricting the use of PPP for high-accuracy survey applications. With the advent of cost-effective and accurate post-processing PPP services provided by organisations such as the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL), the International GNSS Service (IGS) and Natural Resources Canada (NRCan), PPP now offers centimetre-level point positioning from much smaller observation datasets. This study compares PPP results from 1-hour, 2-hour, 4-hour, 12-hour and 24-hour observation datasets using NRCan's PPP online service against the official, Regulation 13-certified coordinates of twenty CORSnet-NSW sites across New South Wales. It is shown that post-processed PPP can provide a viable alternative to differential techniques for survey accuracy, static survey applications for observation spans of at least 4 hours.

KEYWORDS: *Precise Point Positioning, GNSS, post processing, static, CORSnet-NSW.*

1 INTRODUCTION

For three decades the differential Global Positioning System (GPS) technique, and subsequently the differential Global Navigation Satellite System (GNSS) technique, has been the dominant operational mode for precise positioning in the geospatial community. All differential GNSS techniques perform positioning relative to one or more reference GNSS receivers located at points of known coordinates. Depending upon the type of GNSS measurement, user equipment, reference receiver infrastructure, data processing algorithm, ancillary products or services, and operational requirements (e.g. real-time or post-processed, moving or static user equipment, good or poor satellite and reference receiver geometry), different levels of performance are obtained. For example, the basic differential GNSS technique using single-frequency, pseudo-range measurements can deliver few-metre to sub-metre positioning accuracy. The processing of carrier phase data enables sub-decimetre-level

accuracy, with the highest operational accuracy being possible (at the few centimetre-level) using the most sophisticated receiver equipment and algorithms, even in real-time and with the user equipment in motion.

Precise Point Positioning (PPP) is an alternative positioning method that employs widely and readily available GNSS orbit and clock correction products, e.g. obtained via the International GNSS Service (IGS), to perform point positioning using a single GNSS receiver (Kouba, 2009). This provides PPP with an advantage over differential techniques in that only a single receiver is necessary (at the user's end), removing the need for the user to establish a local base station or access data from surrounding Continuously Operating Reference Station (CORS) networks. Consequently, the spatial operating range limit of differential techniques is negated, as well as the need for simultaneous observations at both rover and reference station. This, in turn, can reduce labour and equipment costs and simplify operational logistics (Gao, 2006). It should be noted, however, that an international CORS network is required to calculate the GNSS orbit and clock correction products essential for PPP. Since this international CORS network is so far removed and hidden from the user, PPP is assumed to provide stand-alone point positioning.

The use of a single GNSS receiver for PPP also invokes major disadvantages. The most significant disadvantage is the long convergence time necessary (> 20 minutes) for the float solution to converge to centimetre accuracy, thus limiting its use in real-time applications. PPP requires a number of corrections to limit the effects of centimetre-level variations to un-differenced code and phase observations. Phase wind-up corrections, satellite antenna phase centre corrections, solid earth tide corrections and ocean loading corrections are all necessary for accurate PPP solutions, but not considered for standard differential positioning techniques (i.e. short/medium-length static baselines, kinematic and real-time techniques). For a review of recent developments in PPP, the reader is referred to Grinter and Roberts (2011).

At present, post-processed PPP offers the most comparable accuracies to differential positioning techniques. PPP post-processing services such as Auto-GIPSY from the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory (JPL) (JPL, 2012) and Natural Resources Canada's (NRCan's) CSRS-PPP (NRCan, 2010) provide converged float solutions at the centimetre-level. This has allowed PPP to offer a viable alternative to post-processed differential GNSS solutions for some applications.

CSRS-PPP provides converged GPS & GLONASS float solutions utilising IGS satellite orbits and clock corrections, satellite/receiver antenna phase offsets, tropospheric models including hydrostatic and wet delay and mapping functions. It should be noted that it also allows ocean loading coefficients to be input by the user. However, this was deemed unnecessary in this study because the average user will generally not have access to these coefficients.

Ebner and Featherstone (2008) investigated a geodetic network solution across a 550 km by 440 km area in Western Australia composed of 46 points with 5-day GNSS occupations. It was found that CSRS-PPP solutions were generally not significantly different from the scientific Bernese 5.0 solution (Dach et al., 2007) used as 'ground truth'. Whilst it was acknowledged that PPP is inherently less accurate than network-processed GNSS due to the inability to fix carrier-phase integer ambiguities, this was balanced against the cost-effective advantages of PPP. As PPP requires only a single dual-frequency GNSS receiver, this significantly reduced the equipment and personnel needed, as well as the pre-planning and logistics involved in a conventional network-based static GNSS geodetic survey.

Furthermore, the processing time and skills needed to process conventional GNSS baselines (even via commercial off-the-shelf software) is greater compared to post-processed PPP, which involves sending the observed data to a third party for position determination. It was concluded that PPP yields a "slightly lower accuracy" but is a more cost-effective alternative to establishing geodetic control, particularly applicable in remote areas or developing countries. Ebner and Featherstone (2008) also noted that at least two continuous days of observations were required to achieve reliable results, in this case interpreted as a PPP solution within 20 mm of the Bernese solution.

This paper employs NRCan's CSRS-PPP online service (NRCan, 2010) to investigate what accuracies can be expected when using a PPP-only approach to geodetic control at twenty CORS sites across NSW, based on observation periods of different lengths (between 1 and 24 hours). The accuracy is determined by comparison to the official coordinates of these CORS, which were obtained from a differential GPS network solution performed by Geoscience Australia during the Regulation 13 process (see section 2). It is shown that survey accurate PPP solutions (here defined as 25 mm in Easting and Northing, and 35 mm in Ellipsoidal Height) can be obtained for observation windows of at least 4 hours.

2 STUDY AREA: CORSnet-NSW

CORSnet-NSW is a rapidly growing network of GNSS CORS providing fundamental positioning infrastructure for New South Wales that is accurate, reliable and easy to use (Janssen et al., 2011; LPI, 2012). The network also provides stimulus for innovative spatial applications and research using satellite positioning technology. It is built, owned and operated by Land and Property Information (LPI), a division of the NSW Department of Finance & Services. CORSnet-NSW currently (February 2012) consists of more than 80 CORS tracking multiple satellite constellations, and efforts are underway to expand the network to over 120 stations by the end of 2013.

In order to distinguish GNSS CORS networks in regards to their purpose, the concept of a tiered hierarchy of permanent GNSS reference stations was proposed by Rizos (2007) and has since been widely accepted across Australia (Burns and Sarib, 2010). Tier 1 stations contribute to international or global geodesy initiatives, Tier 2 stations provide primary national geodetic infrastructure for datum definition, and Tier 3 stations are secondary state or private GNSS networks, often established for real-time precise positioning services. While Tier 1 and Tier 2 sites generally require solid pillar monuments firmly anchored to bedrock, Tier 3 sites are often mounted on buildings. This original hierarchy has been adopted and expanded by CORSnet-NSW (LPI, 2011).

Initially, seven Tier 2 CORSnet-NSW sites were selected for this study, as these provide the most stable CORS sites with the clearest skyview and the most advanced GNSS antennas. A further 13 Tier 3 sites were added to increase the size of the dataset and provide a more even distribution across NSW. Extensive and continuous scientific processing by LPI and Geoscience Australia has proven the long-term stability of Tier 3 sites (data not shown).

The selected CORS and their distribution across NSW are shown in Figure 1. Tier 2 sites are represented by orange triangles, and Tier 3 sites are illustrated by blue triangles.

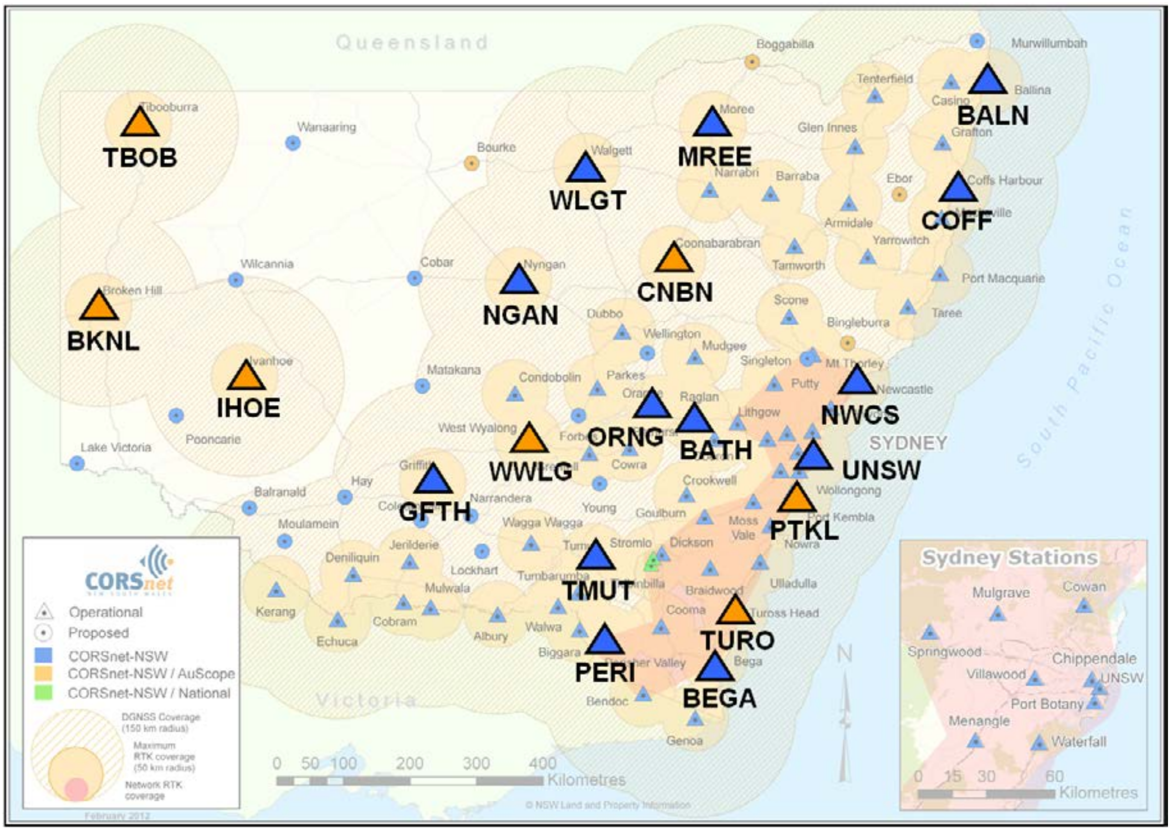

Figure 1: CORSnet-NSW coverage map (current at February 2012), including the 20 CORS sites investigated. Tier 2 sites are shown in orange, Tier 3 sites in blue.

The Geocentric Datum of Australia (GDA94) is the basis for geodetic infrastructure in Australia (ICSM, 2006). For a review of coordinate systems, datums and associated transformations the reader is referred to Janssen (2009). All CORSnet-NSW sites are coordinated via Regulation 13 certification, which provides coordinates in the GDA94(2010) realisation of the national datum (Janssen and McElroy, 2010). The so-called 'Reg 13' certificates are issued by Geoscience Australia, a facility accredited by the National Association of Testing Authorities (NATA). Geoscience Australia determines 3-dimensional site coordinates, which are stated on these certificates, based on a differential GPS network solution using one complete week of 30-second GPS data (in RINEX format) and highly traceable, standardised, scientific processing using the Bernese 5.0 software (Dach et al., 2007). These certificates are valid for five years (assuming that no equipment change occurs) and provide a Recognised Value Standard for positioning infrastructure with respect to the national datum. Through this facility the site coordinates are linked to a standard of measurement in accordance with the National Measurement Regulations 1999 and the National Measurement Act 1960.

Consequently, Regulation 13 certification assists users in establishing some legal traceability of GNSS positions when CORS data are used. GDA94(2010) coordinates also provide interoperability between existing CORS networks and Geoscience Australia's online GPS processing service, AUSPOS (GA, 2011). These GDA94(2010) coordinates were used as the 'true' coordinates of each CORS in this study, the only exception being CNBN which had to use a 24-hour AUSPOS solution because Regulation 13 certification is still pending in this case. Internal LPI testing has revealed that the provisional coordinates based on a 24-hour AUSPOS solution (using rapid IGS orbits) generally agree with the final Regulation 13

coordinates to better than 10 mm in horizontal position and 15 mm in ellipsoidal height (data not shown).

3 TESTING METHODOLOGY AND DATA USED

The PPP solutions investigated in this study were obtained by NRCan's CSRS-PPP online processing service (NRCan, 2010). It is important to note that CSRS-PPP results are referred to the International Terrestrial Reference Frame (ITRF, see Altamimi et al., 2011) and not GDA94. In order to enable coordinate comparisons to the official CORSnet-NSW coordinates (determined via Regulation 13 certification), the ITRF2005 or ITRF2008 precise position estimates had to be transformed to GDA94. It should be noted that this extra step in the process can lead to the propagation of further errors in the final coordinates (Haasdyk and Janssen, 2011, 2012a). Following GNSS best practice, a 14-parameter similarity transformation between ITRF and GDA94 was applied utilising the parameters stated in Dawson and Woods (2010).

For each of the twenty CORSnet-NSW sites investigated, a subset of the 7-day GNSS dataset used to determine the Regulation 13 certified coordinates was utilised, i.e. day four (middle day). In the case of CNBN, a 24-hour AUSPOS solution was used instead. Each 24-hour file was then divided into separate 1-hour, 2-hour, 4-hour and 12-hour files centred on 12:00 UT. This ensured that all PPP coordinate solutions obtained at a site referred to the same ITRF epoch (i.e. 12:00 UT on the selected day), as well as referring to the same epoch used for Regulation 13 certification. These files were then submitted to the CSRS-PPP service for processing.

The resulting PPP coordinates, obtained from observation windows of varying length, were then transformed to GDA94 and compared against their official Regulation 13 values. An initial analysis was based on the seven Tier 2 CORSnet-NSW sites currently in operation. This sample was then extended by a further 13 Tier 3 sites to provide a more even distribution across NSW.

4 RESULTS AND DISCUSSION

4.1 Post-Processed PPP Performance for Longer Observation Windows

It is recognised that a longer observation window generally provides a better coordinate solution for static GNSS applications, simply because more data can be used in processing. In practice, the observation window chosen is usually a compromise between the requirement to collect enough data to meet accuracy specifications on one hand and the logistics and cost of the fieldwork on the other. In an initial analysis, it was investigated how well the 12-hour and 24-hour PPP solutions agree with the official Regulation 13 values (here assumed to be the 'true' coordinates). The aim was to determine whether there is a significant difference in coordinate quality between these two solutions. This analysis was limited to the seven Tier 2 sites currently operating in CORSnet-NSW (see Figure 1).

It was found that the 12-hour PPP solutions provide very similar results to the 24-hour solutions. Table 1 lists the minimum and maximum differences from the official Regulation 13 coordinates across the seven Tier 2 sites, as well as the Root Mean Square (RMS) which

can be interpreted as the average accuracy at the 1-sigma level. While there is a slight improvement (a few millimetres) in positioning quality when using 24 hours of data, this improvement is generally negligible for static positioning at the 2-centimetre level required for most survey practice. Based on these findings, the remaining analysis was limited to observation windows up to 12 hours.

Table 1: CSRS-PPP vs. Regulation 13 coordinate comparison across seven Tier 2 sites for 12-hour and 24-hour observation windows. All values in metres.

12-Hour	Easting	Northing	Ell. Height
Min	-0.010	-0.005	-0.031
Max	0.013	0.012	0.008
RMS	0.007	0.008	0.014

24-Hour	Easting	Northing	Ell. Height
Min	-0.007	-0.005	-0.030
Max	0.008	0.009	0.006
RMS	0.005	0.006	0.012

4.2 Post-Processed PPP Performance for Shorter Observation Windows

In practice, the GNSS observation window is selected to be as short as possible but long enough to provide a reliable position that meets accuracy requirements. In order to investigate how long it takes for the CSRS-PPP solutions to converge to an acceptable level, PPP solutions were obtained for 1-hour, 2-hour, 4-hour and 12-hour files centred around 12:00 UT, and compared to their official Regulation 13 values (or, for CNBN, the 24-hour AUSPOS solution). This analysis was performed for all Tier 2 and Tier 3 sites investigated (i.e. 20 CORS in total) to provide an even distribution across NSW.

For each observation window length, Table 2 lists the minimum and maximum differences from the official Regulation 13 coordinates across all sites, as well as the RMS. Figure 2 graphically illustrates the RMS values obtained for each coordinate component to allow easy, visual comparison.

Table 2: CSRS-PPP vs. Regulation 13 coordinate comparison across 20 sites for 1-hour, 2-hour, 4-hour and 12-hour observation windows. All values in metres.

1-Hour	Easting	Northing	Ell. Height
Min	-0.058	-0.013	-0.066
Max	0.091	0.041	0.092
RMS	0.033	0.013	0.033

2-Hour	Easting	Northing	Ell. Height
Min	-0.049	-0.009	-0.041
Max	0.042	0.027	0.033
RMS	0.021	0.009	0.015

4-Hour	Easting	Northing	Ell. Height
Min	-0.015	-0.005	-0.042
Max	0.021	0.027	0.025
RMS	0.009	0.009	0.020

12-Hour	Easting	Northing	Ell. Height
Min	-0.010	-0.005	-0.031
Max	0.017	0.027	0.017
RMS	0.007	0.008	0.012

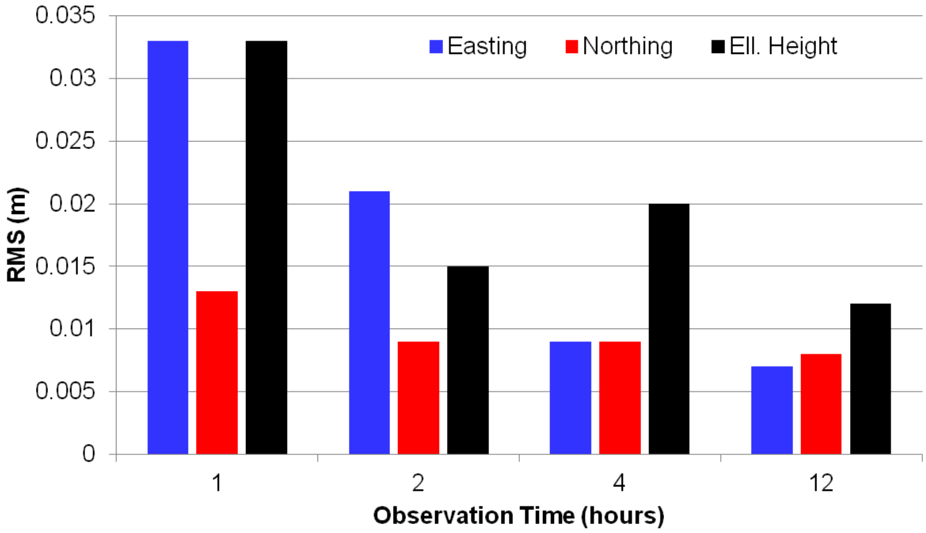

Figure 2: Average agreement of CSRS-PPP solutions to Regulation 13 across 20 sites for different observation windows.

From Table 2 and Figure 2 it can be seen that, as expected, PPP solutions based on shorter observation windows (i.e. 1 and 2 hours) produce larger differences to the official coordinates than those based on longer observation windows (i.e. 4 and 12 hours). This is apparent for both the RMS (i.e. the average agreement) and the minimum/maximum values (i.e. the largest disagreement across the twenty sites). In regards to the RMS, this behaviour is particularly evident in the Easting coordinates, with coordinate differences converging for the longer observation spans. It should be noted that the overall height quality of the 2-hour PPP solutions was better than expected, in this case outperforming agreement in the Easting component.

The improvement between the 4-hour and the 12-hour solutions is only minor, both in terms of RMS and the minimum/maximum values. This shows that a 4-hour dataset can generally provide very similar results to the much longer 12-hour dataset, assuming typical survey requirements.

An outlier in the 1-hour PPP solution for ORNG accounts for the second largest difference in the Easting (-58 mm), and the largest difference in the Northing (41 mm) and Ellipsoidal Height (92 mm) components across all sites. This site is known to exhibit less than favourable multipath conditions. Removing ORNG from the 1-hour analysis reduced the RMS values from 33, 13 and 33 mm to 30, 10 and 26 mm in Easting, Northing and Ellipsoidal Height respectively. The PPP solution for ORNG improved significantly when using two hours of data, showing much better agreement to the Regulation 13 coordinates (-4 mm, 27 mm and 22 mm in Easting, Northing and Ellipsoidal Height).

WLGT is another example of a site that is more prone to multipath than usual. Since the effect of multipath can generally be cancelled out (at least to some degree) over time, the agreement to the Regulation 13 coordinates improves considerably with increasing observation length (Table 3).

In the 2-hour PPP solution dataset, BKNL accounts for the largest difference in the Easting coordinate (-49 mm) across all sites. Removing BKNL from the 2-hour analysis slightly reduced the RMS values from 21, 9 and 15 mm to 18, 7 and 15 mm in Easting, Northing and Ellipsoidal Height respectively.

Table 3: CSRS-PPP vs. Regulation 13 coordinate comparison at WLGT for 1-hour, 2-hour, 4-hour and 12-hour observation windows. All values in metres.

	Easting	Northing	Ell. Height
1-Hour	0.091	0.002	0.044
2-Hour	0.042	0.003	0.033
4-Hour	0.018	0.000	0.025
12-Hour	-0.001	0.003	-0.002

These examples show the effect that larger-than-normal differences from the 'true' Regulation 13 coordinates can have on the average agreement determined from the relatively limited sample size of twenty CORS investigated in this study. It is well known that shorter observation windows are more likely to be affected by multipath than longer observation spans.

Let us assume typical survey requirements of obtaining accuracies at the 25 mm level for Easting and Northing, and 35 mm in Ellipsoidal Height. Out of the twenty 1-hour PPP solutions investigated, 11 fell outside these specifications in at least one coordinate component (i.e. 55% failed). Using a 2-hour observation window improved the results, but still left 6 (30%) solutions outside specifications. The 4-hour dataset only showed 2 (10%) solutions that did not meet specifications. All 12-hour solutions met specifications, with the small exception of one solution in Northing slightly outside specifications (i.e. 27 mm).

Figure 3 illustrates these findings visually. It should be noted that ORNG contributes heavily to the instances outside specifications in all datasets, i.e. in Easting, Northing and Ellipsoidal Height (1-hour dataset), as well as Northing (2-hour, 4-hour and 12-hour datasets).

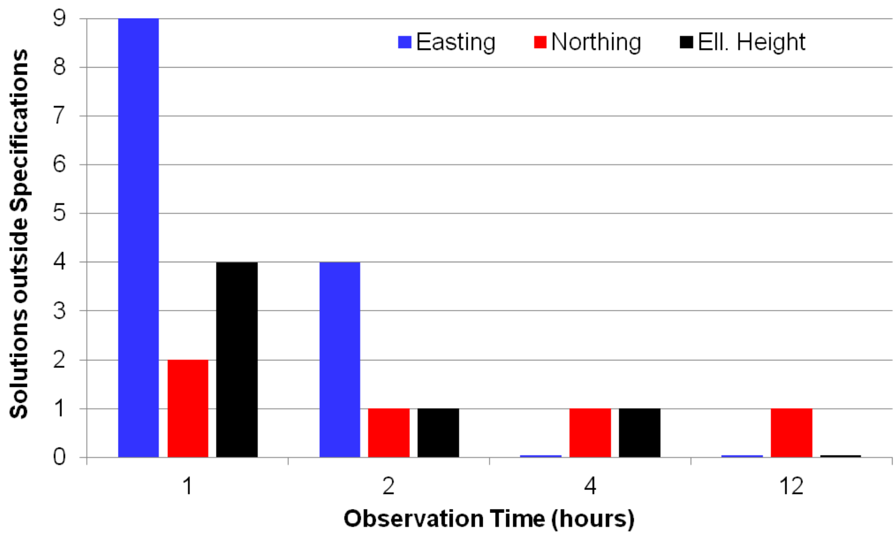

Figure 3: Number of PPP coordinate component solutions outside specifications (25 mm in Easting/Northing and 35 mm in Ellipsoidal Height) across 20 sites, for different observation windows.

This analysis shows that, for the datasets investigated, a 4-hour post-processed PPP solution can provide survey accurate coordinates (within 25 mm horizontally and 35 mm vertically) for static applications. However, it should be noted that outliers can always occur, so double occupations are strongly recommended (and GNSS best practice). The risk of outliers can be further reduced by utilising a longer observation window.

This result provides a significant improvement on findings reported by Ebner and Featherstone (2008) who noted that at least two continuous days of observations were required to achieve results within 20 mm of a Bernese network solution. While it is recognised that the focus of the present study is different from the Ebner and Featherstone (2008) study, and is based on a small sample size, it is clear that PPP has evolved significantly over the last five years or so. Post-processed PPP can provide a viable alternative to differential GNSS processing for static applications, even with observation spans as short as 4 hours, provided that the vital step of transforming between ITRF and GDA94(2010) is performed using GNSS best practice (Haasdyk and Janssen, 2011, 2012a). If a connection to the local survey control network in NSW is required, a site transformation must be performed (Haasdyk and Janssen, 2012b). However, it should be remembered that differential GNSS positioning will continue to provide superior results (accuracy and reliability), simply due to the processing strategy employed. PPP is evolving, and its potential and developments should be closely monitored. It is up to the spatial professional to decide which tool is the most suitable for a given job.

5 CONCLUDING REMARKS

Cost-effective and accurate online post-processing PPP services are now able to offer centimetre-level point positioning for static applications in Australia, provided the resulting positions (generally given in a global datum such as ITRF2008) are transformed to GDA94. If a connection to the local survey control network in NSW is required, a site transformation must be performed.

This study has compared PPP results from 1-hour, 2-hour, 4-hour, 12-hour and 24-hour observation datasets using the CSRS-PPP online service against the official, Regulation 13-certified coordinates of twenty CORSnet-NSW sites across the state. It was shown that post-processed PPP can provide a viable alternative to differential GNSS techniques for survey-accuracy, static applications using observation spans of 4 hours. The risk of outliers can be minimised by utilising a longer observation window, while excessive 12-24 hour occupations do not appear to provide any further improvements in meeting the specifications assumed in this study (within 25 mm in Easting/Northing and 35 mm in Ellipsoidal Height). However, it should be emphasised that outliers can always occur, so double occupations are strongly recommended (and continue to be GNSS best practice). Post-processed PPP can be potentially useful in regional areas that are currently not covered by a sufficiently dense CORS infrastructure.

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Pipe Deformation Survey Using 3D Laser Scanning

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ABSTRACT

The SKM spatial team, in association with the Roads and Traffic Authority - Southern Region (now Roads and Maritime Services, RMS) found a unique solution to measuring the deformation of a water drainage pipe along Kelly's Creek under the Princess Highway (located around 65 km south of Sydney), incorporating innovative field collection techniques combined with innovative calculation and presentation methods. The 140-metre long and 1.46-metre diameter stormwater pipe is being deformed by a combination of the pressure exerted on it by highway fill above and subsidence from underground mining below. A custom-built tripod and specialised target supports were constructed to overcome the tight space conditions in the pipe and 3D laser scanning was used to give the most comprehensive result. Ingenious methods were developed to process and present the data to clients in a simple and easily comprehendible format, in addition to highly detailed production plans for design.

KEYWORDS: *Static, scanning, deformation, pipe, subsidence, modelling.*

1 INTRODUCTION

Subsidence and the monitoring of subsidence due to mining is a big issue in the New South Wales. Many thousands of dollars are spent monitoring and repairing infrastructure damaged by subsidence from both coal and mineral underground mines.

The discipline of surveying contributes in a major way to the monitoring of subsidence, and it has been an area of innovation where traditional surveying technologies may not always be the appropriate tool for the job. While most subsidence monitoring is based on the absolute change in a structure, e.g. the change in height of a bridge or building, a previously unexplored field of subsidence is the deformation of structures relative to themselves.

The SKM spatial team, in association with the NSW Roads and Traffic Authority - Southern Region found a unique solution to measuring the deformation of a water drainage pipe along Kelly's Creek under the Princess Highway, incorporating innovative field collection techniques combined with ingenious calculation and presentation methods.

2 HISTORY

The NSW Roads and Maritime Services (RMS), formally the Roads and Traffic Authority (RTA), has a firm commitment to monitoring its assets including all culverts and drainage structures across the state. After the collapse of a culvert structure near Bega and another collapse near Gosford claimed the lives of 5 people, RMS put in place procedures to monitor

and asses the condition of its culverts and drainage assets. One of the issues arising from this monitoring process is how best to determine the condition of these assets in both a quantitative and qualitative manner.

In this instance, the asset manager required information on the extent of damage to the pipe to support the claim the damage was caused by mine subsidence as well as to provide a precise measure/assessment of the smallest pipe that could be used to replace the existing pipe. This would in turn determine the method of replacing the pipe. Given the need to locate small transverse cracks, changes in shape, grade and extents of damage, ground survey was deemed the most appropriate solution. Issues associated with access, occupational health and safety, time and cost lead to the use of laser scanning technology.

3 LOCATION

Located around 65 km south of Sydney in the district of Stanwell Park, the crossing of the Kelly Creek by the F6 Motorway (Princes Highway) was completed in 1975 as part of the Waterfall to Bulli Tops upgrade. Kelly Creek runs from the Old Princes Highway to Stanwell Park where it runs into the ocean. Approximately 1.5 km from the project site the creek runs over the escarpment and creates a waterfall known as Kelly's Waterfall, which is a feature of an old walking trail, established in the 1930s.

The 1.46 m diameter pipe runs from west to east for approximately 140 m, and is 25 m below the F6 carriageways. It is surrounded by heavy bush and is in a steep valley, which creates logistical problems in access and egress. It is around a 1-hour round trip by foot to get to the pipe.

Figure 1: Location of the Pipe in Kelly Creek Valley.

4 SCOPE

The scope given to the RMS by the Mine Subsidence Board included the requirement for the presentation of:

a) Dimensional changes to the pipe diameter – measured at regular intervals along the pipe (e.g. vertical and horizontal axis).
b) The horizontal angle where the pipe diameter is narrowest – measured at regular intervals along the pipe.
c) Any changes to the pipe joints – provide description / sketches.
d) Any evidence of shear failure at the pipe joints or lateral movement – measured at intervals along the pipe.

Based on this and on consultation with RMS, SKM surveyors decided that the best course of action would be to complete a laser scan of the pipe, to ensure that the deformation of the pipe could be measured over its entire length, leaving no possibility of important information being missed.

The pipe is being deformed by a combination of the pressure exerted on it by the highway fill above and the subsidence from the underground mining below (Figure 2). At the time of building, the pipes were covered with straw bales to allow for the compaction soil not to have an effect on the pipe, but this straw has since been fully compacted.

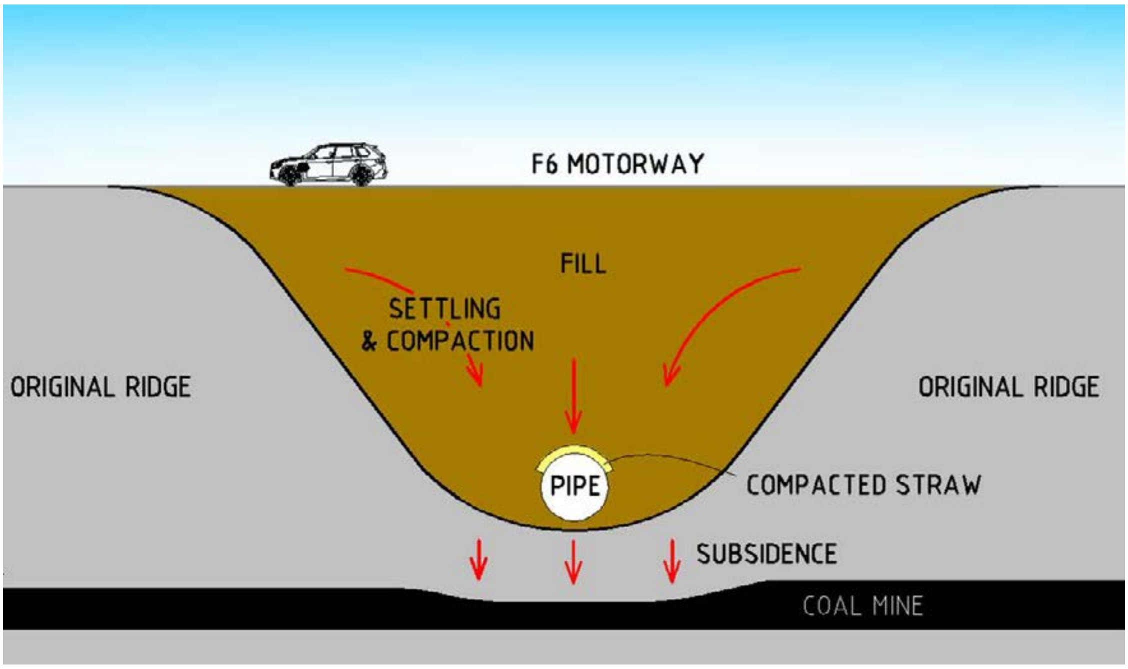

Figure 2: Profile showing pressures exerted on pipe.

5 METHODOLOGY

Based on correspondence with RMS, a proposal and techniques were formulated for the project, and after tender agreement, surveyors were dispatched from the SKM offices in St Leonards, Sydney.

5.1 Safety

The number one priority on any project is safety. A full examination of the possible risks for the project were identified before heading out into the field, and control measures were formulated and put in place. Some of the risks on this job included:

- Confined spaces. Gas detecting gear was used inside the pipe, with a spotter and extraction plan drawn up, and all personnel were confined space trained.
- Wildlife, snakes and spiders were a real risk on this job, as dark pipes and bush land are common habitats of these creatures. Controls such as snakebite kits and full length clothing were used.
- Slips Trips and Falls (STF) were also another major source of potential harm on this site. Due to its location and structural type, water, rocks and steep banks all made this a high risk site. Controlling STF involves instructing personnel on steady walking techniques, keeping eyes on the path, and maintaining three points of contact where possible.

5.2 Control

While the main areas of measurement are relative in nature, as with all RMS projects, a state based datum was used. In this case, the Map Grid of Australia (MGA94) and Australian Height Datum (AHD71) were adopted. Three marks were placed at the bottom of the creek using static Global Navigation Satellite System (GNSS) positioning methods, with extended duration times due to canopy and elevation constraints. These three marks were then connected through the pipe using a closed traverse and reciprocal trigonometric heighting (Figure 3).

Figure 3: Running control through the pipe.

5.3 Laser Scanning

Laser scanning is an established survey methodology which has been in use for around ten years. The basic concept of a laser scanner is to take reflectorless measurements, similar to a reflectorless total station, but with large amounts of measurements in a very short timeframe. For example, a Leica 1200 series total station can take a reflectorless measurement once every 1-2 seconds, where a phase-based laser scanner can take 500,000 measurements in one second.

The laser scanner used on this job was a Leica HDS6000, which is a phase-based measuring system. The difference between "phase" and a "time of flight" scanner is that the measurements are taken based on a change in wavelength, instead of measuring how long it takes a signal to return.

At each scanner location, the laser scanner will pick up measurements in a 360° horizontal and 270° vertical field of view. However, the distance between each location is limited by what is visible and the angle of incidence of the laser. The angle of incidence is the angle with which a laser hits a surface. The more acute the angle, the less chance there is of getting a return signal. In a road-based situation the angle of incidence is increased by setting the instrument up higher, which increases the setup spacing to 20-30 metres. Inside a pipe there is no way to increase the angle of incidence (Figure 4), so the scanner was required to be setup at 5-metre intervals to collect the necessary amount of data.

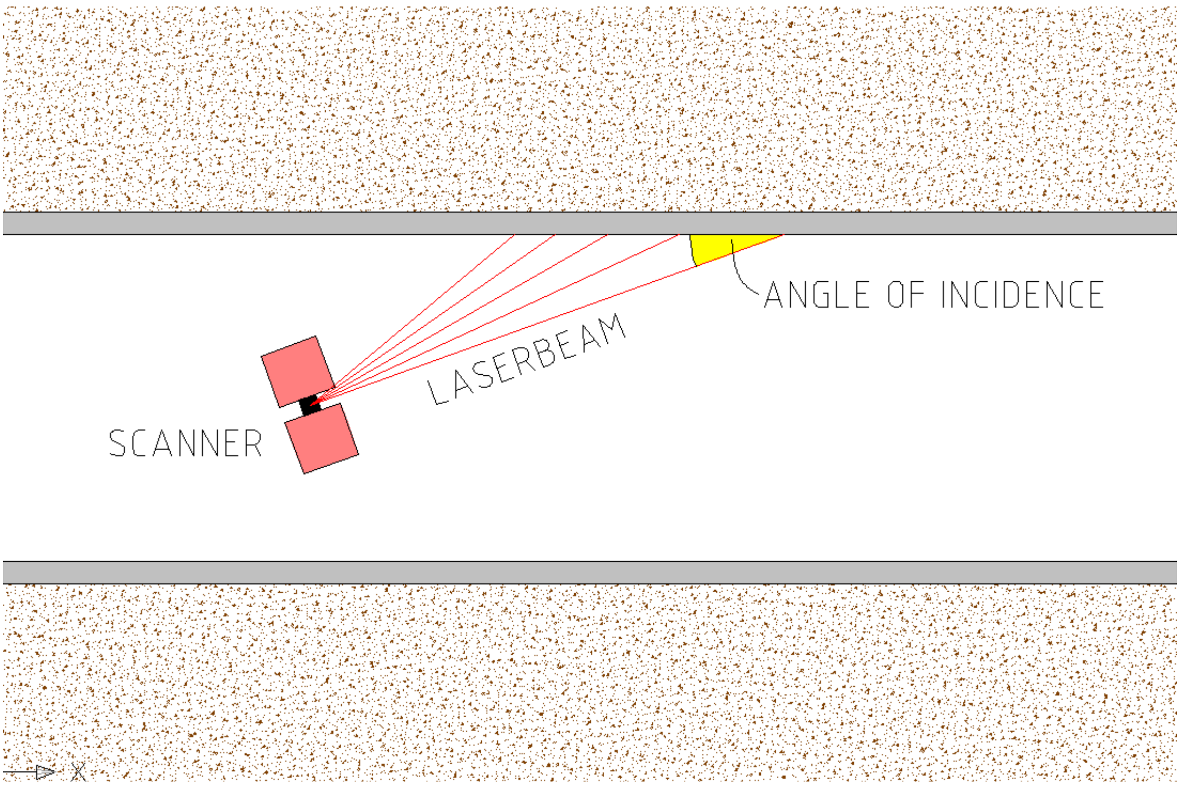

Figure 4: Angle of incidence inside a pipe.

The normal process of scanning involves placing targets around the area to be scanned, coordinating the targets using a total station and using the scanner to collect a point cloud that includes the targets (Figure 5).

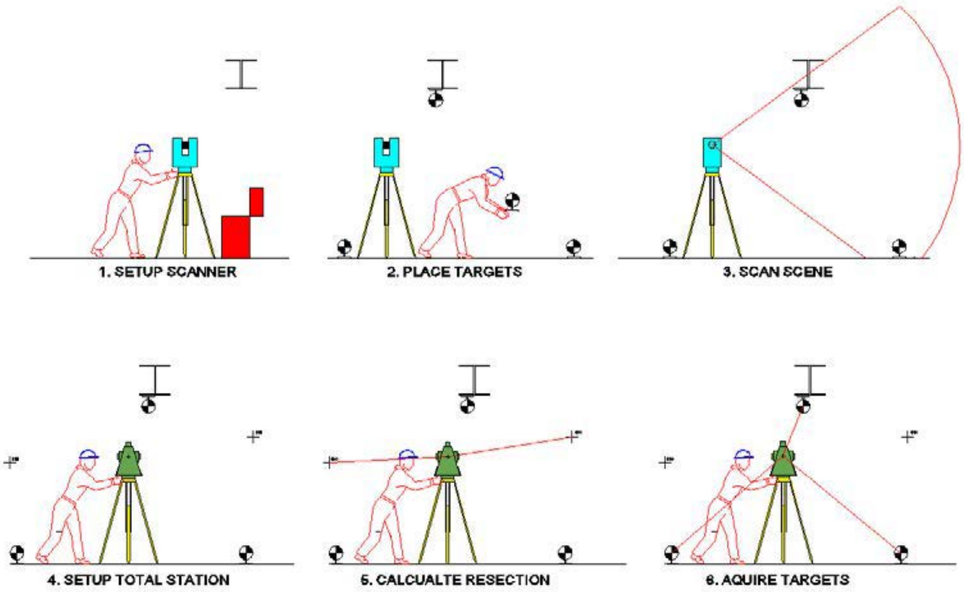

Figure 5: Normal field procedure for laser scanning.

Working inside a pipe with restricted headroom creates and number of equipment based problems. A standard survey tripod has a minimum height of approximately 1.3 m, which when the scanner was placed on top of the tripod would have been projecting up through the top of the pipe. To overcome this problem, two methods were used to set the scanner up at the lower height:

1) The "spider" – The "spider" is a purpose built mini tripod, based on a pillar plate, with the legs replaced by threaded rods, allowing for levelling (Figure 6).
2) The "trolley" – The "trolley" is a piece of ply board, with a 5/8th thread coming up through the centre. The board is placed in the pipe creating a bridge across the bottom (Figure 7).

Figure 6: The "spider".

Figure 7: The "trolley".

To speed up scanning time the spider and trolley were alternated, so while one tripod was used for scanning the other was being setup for the next scan.

The next problem was the targets. The HDS6000 laser scanner uses black and white swivel targets, which are acquired in the scan data due to the cross formed by the alternating colours (Figure 8). These can be either stuck to metal objects using magnetic bases or mounted on tripods. Inside a concrete pipe neither of these methods could be used, so an alternative was found.

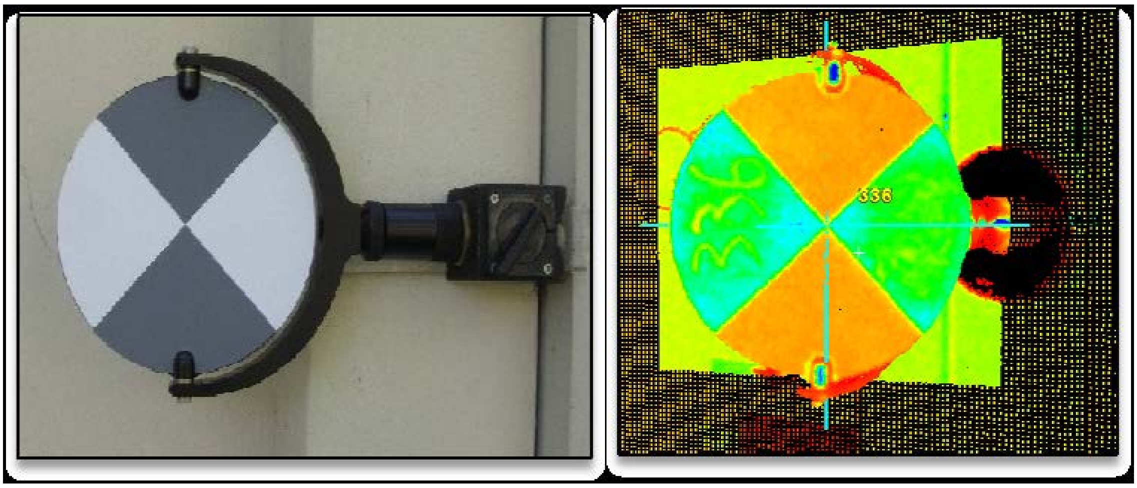

Figure 8: Magnetic black-and-white swivel target.

Holes were drilled in either end of a 1.3-metre wooden beam, and through these was inserted a 5/8th bolt. The black and white targets were then affixed to these bolts. Three of these beams were constructed, creating the six required targets to register the scans together. The beams were then wedged into the pipe until stable, and the scanning and target acquisition could begin (Figure 9).

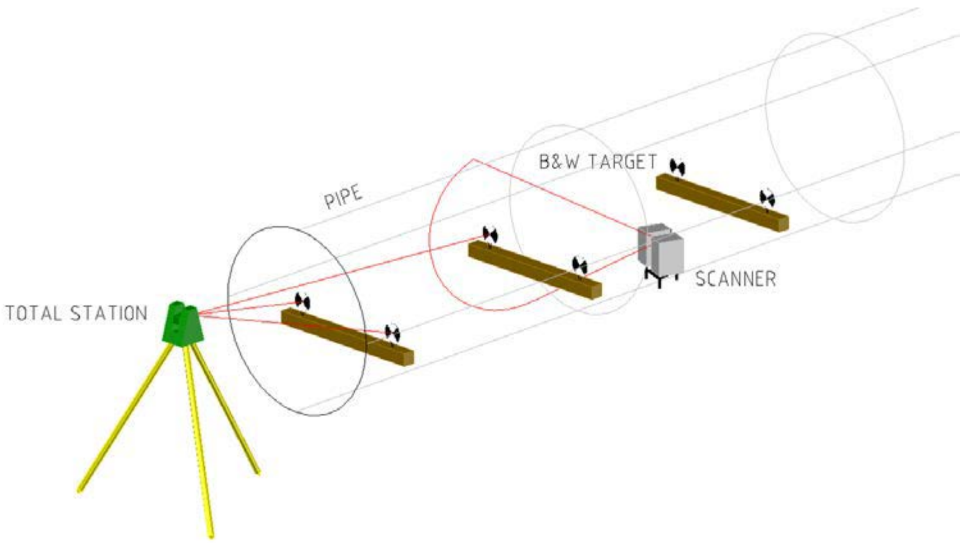

Figure 9: Scanning field procedure.

A total of 28 scans were competed along the length of the tunnel (Figure 10). At each scan the scanner acquired six targets which were then coordinated using a total station located at the ends of the tunnel. While the minimum number of targets required to control each scan is 3, SKM surveyors use 6 to ensure there is redundancy even if targets are obscured or bumped. The scan data was stored on board the scanner and downloaded and uncompressed in the office.

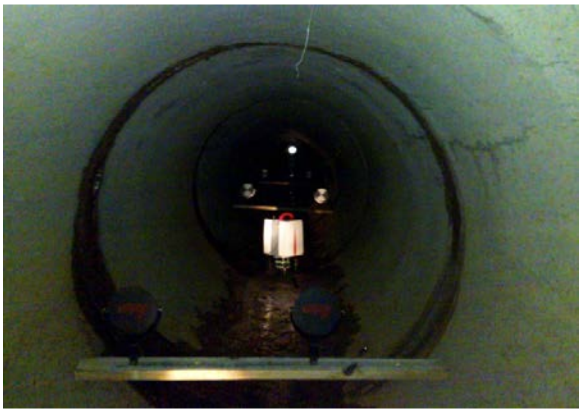

Figure 10: Laser scanning inside the pipe.

5.4 Registration of the Point Clouds

Each cloud is an independent setup, and straight from the raw data, has no absolute orientation or position values. In order to transfer each cloud into real world coordinates, the black-and-white targets are identified within the cloud using an advanced detection algorithm. These black-and-white targets were surveyed in the field using a traditional total station, so their coordinates were known.

Once all the targets have been identified in the scan data they were registered together using least squares techniques. The diagnostics from this registration give an indication of targets that may have been bumped in the field, or improperly fitted in the cloud acquisition process. They can then be corrected or removed from the calculations.

Once the registration is complete, the separate scans are unified into a single point cloud. The unification process ties all the scans together into one big cloud, while at the same time reducing the density of the cloud. This density reduction is required due to the fact that more information is recorded close to the scanner, due to the angle of acquirement (Figure 11). For the Kelly Creek project a reduction to the cloud of 3 mm was used.

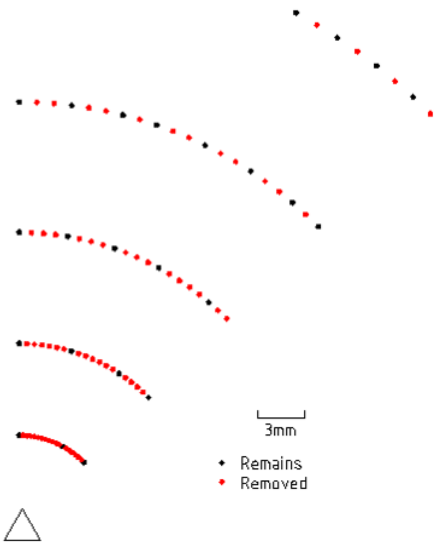

Figure 11: Point reduction during unification.

5.5 Quality Control Checking

For this particular project it was difficult to find a method of quality control based on RMS's G73 specification, which outlines standard methods for quality checking work. The calibration of the scanner and instruments were up to date, but to ensure the results obtained were accurate, a number of methods were used to check the work performed in the field:

1) Control checking and traverse closing. This involves examining the results of the closed traverse and ensuring they meet the minimum requirements.
2) While scanning. Each scan covers a horizontal rotation of 182°, capturing data in the overlap on both faces. The extra 2° is to ensure that the scanner's vertical circle is in calibration. If this was out of calibration, there would be a step and overlap in the data inside this 2° overlap.
3) Scanner Registration. Each time a scan is registered, it is also performing a simple calibration check on itself. If the scanner was out of calibration, there would either be abnormalities in the registration, due to either a scale factor in the distance measurement, or errors in the horizontal and vertical circle. The 3 redundant control points from each scan ensure that this is not the case.
4) Quality control string. A quality control string down the middle of the pipe, commonly known as a QQ string, was acquired using a total station. These points were then compared with results from the scan data to ensure conformity.

5.6 Processing and Calibration

The processing of the cloud to a deliverable was perhaps the most important section of project. Not many clients have the ability to use a point cloud directly from the registration software, so it is the job of spatial professionals to extract the required data from the cloud. Since no project like this had ever been completed before, the processes to present the data needed to be developed from scratch:

1) The first step was to find the nominal size of pipe. The pipe segments are a precast concrete, but due to concrete mould wearing they may not be the exact size as specified by the drainage specifications. By taking a segment of pipe and using the 'fit to cloud' algorithm, a least-squares fit of the pipe was executed over a single segment of pipe, using in excess of 40,000 points to find the nominal size of the pipe. The nominal pipe size was found to be 1.46 m with a standard deviation to the cloud of 3 mm.

2) Using this size, a series of sections were taken along the pipe, the ends and midsection of each segment, using a fit of the nominal pipe diameter.

3) The end segments gave a good indication of the deflection of the pipe along its length, and an alignment was formed from the centres of these sections. From there a long section of the pipe was generated. This showed a dip in the middle of the pipe (Figure 12).

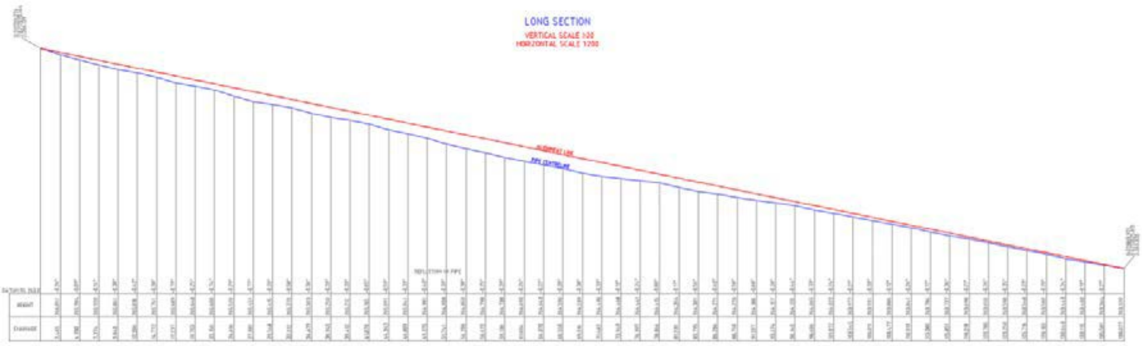

Figure 12: Long section of pipe.

4) The next stage was to extract a contour map from the cloud that would show the pipe's deviation from its nominal shape. To do this, a technique used for doing as-builts of tank structures was employed. Special software known as 'Unfurl' was developed in-house by the SKM spatial team. Unfurl is typically used to show deviations from design inside tank structures. Circular structures are always difficult to present on paper, so to simplify the presentation, the tank is unrolled based on the design radius into a flat surface (Figure 13). The difference in the distance along the centre of the pipe is used as the new y coordinate, the arc distance around the circle becomes the x coordinate and the z coordinate reflects the radius. By then turning the new plane on its side and contouring the results, a contour map of the deviations can be shown.

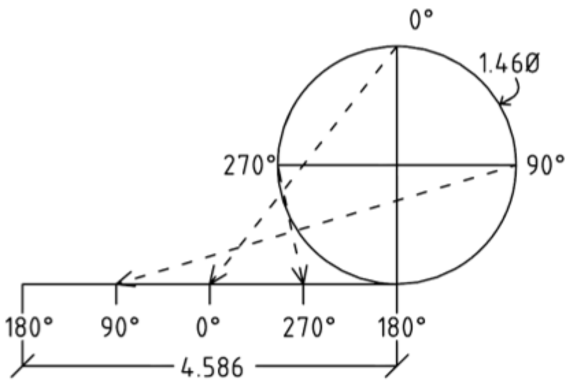

Figure 13: Unfurling.

The problem in this case was the pipe was not suitable for using the tank method, as the axis of the pipe was changing along each segment. The unfurl program was re-written to use the alignment developed in step 3, and each point was calculated to the nearest segment on the alignment. As a result the pipe was unfurled segment by segment (Figure 14).

This flattened section also became useful for the mapping of the cracking along the pipe. The cracks became visible when the laser return intensity values were plotted in grey scale (Figure 15).

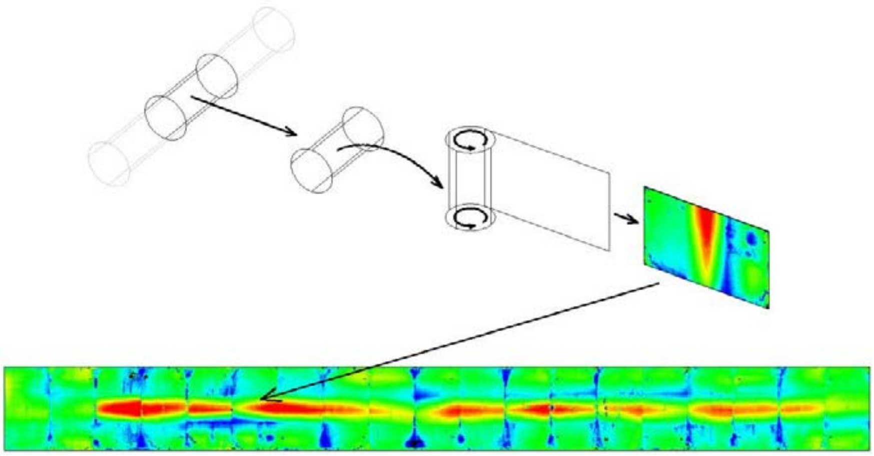

Figure 14: Using Unfurl to map deviations along each pipe segment.

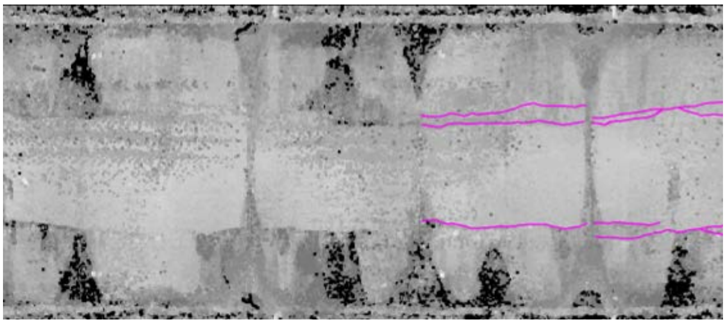

Figure 15: Crack mapping on unfurled cloud map.

5) The next step was to find the maximum and minimum cross sectional distance inside each segment of pipe. After a number of attempts to do this by eye and trial and error, the SKM spatial team came up with the solution of using the point cloud processing package to create a cross sectional polyline, and then analysing the polyline to find the maximum and minimum deviations from the centre. On the first attempt it was found that overspray and outliers, that are common in laser scan data, were giving false readings, and the routine was rewritten to take an average of the vertexes over a 6° slice of the section. This also allowed for deviation calculations, in the form of a numerical value to be show in a series of sections (Figure 16).

Figure 16: Section of segment of pipe showing deviation numerical values and max/min deviations.

6) The final processing step was to calculate the maximum deviation of the pipe along the alignment. This was required because the next step in the project may involve the insertion of a liner inside the pipe. The different types of liners available on the market have different amounts that they can distort before they will stop feeding into the pipe. This maximum value is a combination of the vertical and horizontal deviation of the alignment (Figure 17). A routine was written to transform the segment lines to a horizontal plane and then calculate the deviation from these values. This was done using a z-axis transformation. These values were then added to the long section for clarity purposes.

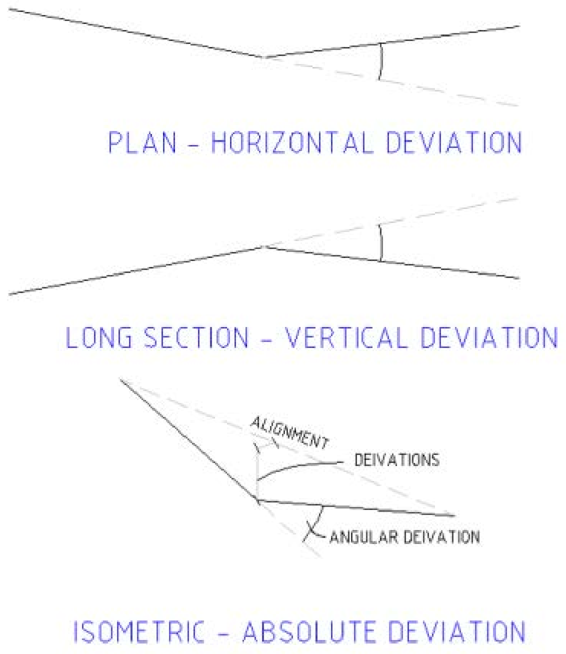

Figure 17: Deviation of the alignment.

Although crack mapping was performed, only the most significant cracks were plotted from the point intensity values. This gives an overview of the cracks, but the scope specified that the client wished to identify areas where the cracking was extensive, especially at joints.

As a by-product of the scanning process, panoramic images known as Truviews are created (Figure 18). From these Truviews engineers, project managers and other stakeholders can carry out a ‘virtual visit’ of the pipe from the office, without the need for extensive safety procedures, and examine parts of the pipe that may not have been visible, even with the use of artificial lighting. The other additional benefit of the Truviews is that as well as being able to view the inside of the pipe, they can also take measurements and positions at any stage, giving the panoramic photos a fourth dimension.

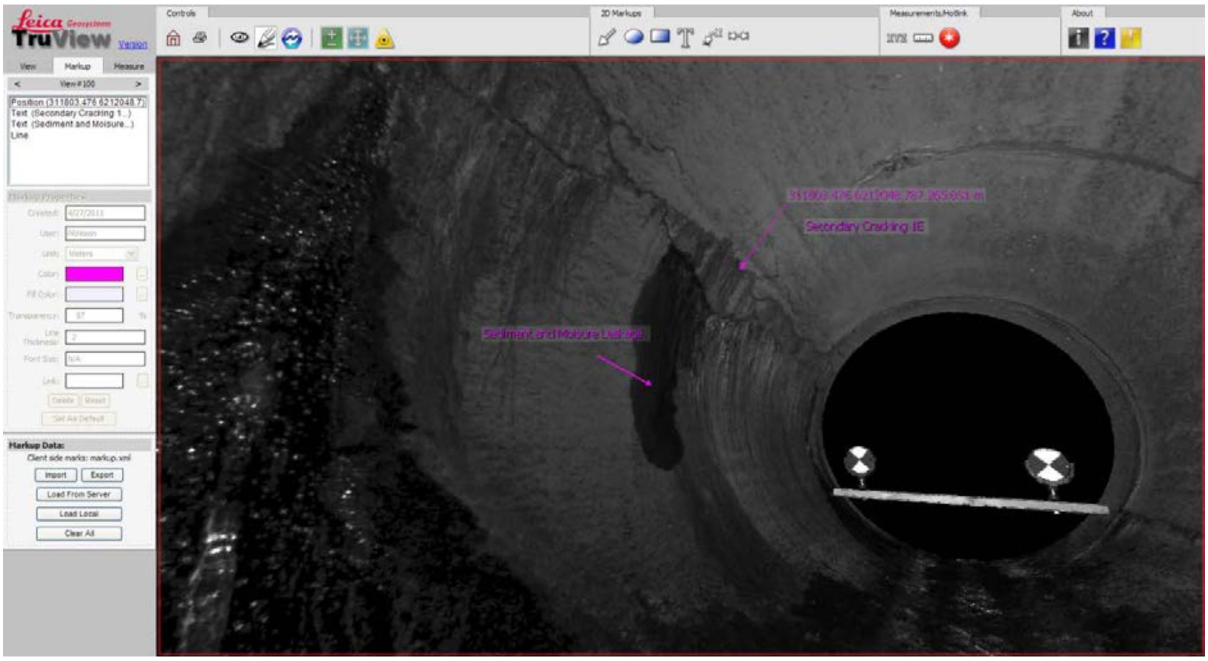

Figure 18: Truviews inside the pipe.

6 RESULTS

A meeting between the SKM survey team and RMS mechanical engineers was organised to present the results of the survey. The results were primarily supplied as a series of sections and contours maps. These were analysed by the mechanical engineers to interpret the structural deformities of the pipe. The analysis determined that the bottom of the pipe appeared to have no or minimal deflection, while the top of the pipe had visibly split at 45° and 315° (Figure 19). This is consistent with the stresses being placed on the pipe based on theoretical forces.

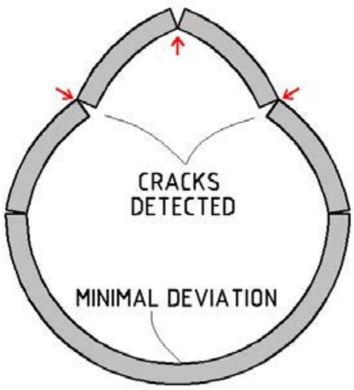

Figure 19: Simplified deformation of the pipe based on the results.

7 CONCLUDING REMARKS

Deformation of structures due to mining remains a real threat to infrastructure in New South Wales, and the monitoring of these structures will continue to be required over the coming decades. This project has seen a new way of monitoring these structures, by not using the

conventional single point observation, but by looking at the entire structure, to deliver a more comprehensive deformation analysis. There are hundreds of pipes that are affected by mine deformation and other stress factors across NSW, giving this new process the potential to be adopted throughout the spatial industry on multiple projects.

The project delivered above and beyond the original scope, conveying information that may not have been realised using traditional methods. Although the project may not have been large in terms of expenditure, the potential ramifications of this technique could contribute huge benefits to the surveying industry as a whole.

ACKNOWLEDGEMENTS

SKM would like to acknowledge the input of the RMS in the preparation of this paper.

ePlan and Land XML

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ABSTRACT

Land and Property Information (LPI) is undertaking a major development program known as the Digital Plan Processing System (DPPS) that incorporates the development of ePlan systems to process digital cadastral plans in Land XML format. The program seeks to introduce the capability for data collected in the field to be 'created once, yet used by many'. This initiative is based on the practical application of an Australasian standard in Land XML format enhanced by the Intergovernmental Committee on Surveying and Mapping (ICSM) ePlan Working Group. LPI has established the Spatial Information eXchange (SIX) platform as a collaborative working space for use by government, business and the community. The SIX gateway provides a single entry point for searching, accessing and utilising the wealth of geospatial services and data managed by LPI. It also provides opportunities for users to contribute to this state-wide resource. The ePlan system will develop the capability for professionals involved in the land development processes to source and lodge digital survey and spatial data through the SIX gateway. The digital lodgement service will provide automated validation and reporting on data formats, survey geometry, and LPI business rules prior to lodgement. Electronic plan examination, automated cadastral update and electronic dissemination of plan datasets to businesses, the industry and clients are key features of the system. The adoption of the national standard by all states and territories is critical to the success of ePlan across all jurisdictions. LPI has developed a prototype lodgement validation service and examination environment to demonstrate the benefits of adopting this approach. Through ICSM and the national forum it is timely to drive the survey software vendors and surveying industry engagement process to ensure that the industry develops the capability to create and transfer appropriately structured, accurate and reliable survey and cadastral data. This presentation will provide information on the development of a new digital plan processing system that is being developed which will have significant impact and benefit both within LPI and externally on land development stakeholders, particularly the surveying profession. The presentation will include a practical demonstration on the creation of survey plans in Land XML format and the online digital plan validation service that has been developed within SIX.

KEYWORDS: *Digital cadastral plans, ePlan, Land XML, SIX, online validation.*

Re-Development of the WIN Stadium Western Grandstand, Wollongong

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ABSTRACT

The WIN Stadium and WIN Entertainment Centre precinct in Wollongong occupies Crown Land and is administered by the Illawarra Venues Authority, a state government authority under the portfolio of Education and Communities NSW. This project commenced in late 2009, with NSW Public Works, Project Management Group, being engaged by the Illawarra Venues Authority to manage the overall western grandstand re-development project after a significant grant was secured from the state government. This project valued at $29 million involved the complete demolition of the existing inadequate and dilapidated 1960s grandstand and replacing it with a new stand with over 6,000 seating capacity. NSW Public Works Project Management Group then engaged Surveying and Spatial Information Services to undertake an assortment of different surveys to assist with architectural and engineering design and land matters issues. This paper sets out to describe some of the various surveys undertaken by our local survey team to achieve the project objectives. The surveys included establishment of a control survey, initial detail surveys and utility service locations, creation of an accurate cadastral model, detail survey extension to include more areas of the stadium undergoing upgrades, a terrestrial laser scan survey of the whole stadium, setout and location off geotech boreholes, conformance checks and volumes, construction setout, land matters surveys including title consolidation, electrical padmount substation and underground cable easements, stratum subdivision for lease purposes, and road closure for lease purposes. Not all of these types of surveys are discussed in this paper, however some of the more interesting components are examined. The roof of the new stadium was completed in early August 2011 with much excitement generated in the local media regarding the recommencement of St George-Illawarra Dragons games at WIN Stadium. However, on 20 September 2011 a strong wind event caused the failure of two roofing bolts, resulting in major damage to the roof structure and sheeting. This paper provides some insight into how and why this may have happened, but the paper mainly describes the surveys and processes undertaken by NSW Public Works, Surveying and Spatial Information Services.

KEYWORDS: *Detail, land matters, re-development, roof, easements, Illawarra Venues Authority*.

1 INTRODUCTION

WIN Stadium is located in Wollongong, NSW and is the premier sporting facility within the Illawarra region. The stadium is one of two home grounds used by the St George-Illawarra Dragons National Rugby League football club, and is currently operated by the Illawarra

Venues Authority (IVA). The IVA is an authority within the Office of Communities, under the Department of Education and Communities, within the portfolio of the Minister for Citizenship and Communities.

NSW Public Works were appointed project managers for the construction of the new western grandstand in early 2010. NSW Public Works, Surveying and Spatial Information Services (SASIS), have been involved with the WIN Stadium western grandstand re-development project since its inception. SASIS have undertaken numerous field surveys, prepared a variety of survey plans, and facilitated the land matters associated with the project.

1.1 History of the Venue

Rugby league football games began being played at the original Wollongong Showground in 1911. Up until that time the venue hosted mainly agricultural shows and greyhound racing. The Illawarra Steelers entered the NSW Rugby League competition in 1982, and a few years later the ground was converted into a more football-friendly rectangular shape. The facility was situated on Crown Land, and in 1986 the Wollongong Sportsground Act appointed the Sportsground Trust to administer and manage the venue.

The southern grandstand was built in 1992, with the WIN Corporation purchasing the naming rights in 1997 when the venue became WIN Stadium. In 1998, on the same Wollongong Sportsground land, and abutting WIN Stadium, the Wollongong Entertainment Centre was opened. In 2002 the new northern grandstand was opened, further increasing the stadium's seating capacity.

The Illawarra Venues Authority replaced the Sportsground Trust as the government-appointed management authority for the now WIN Sports and Entertainment Centre, Wollongong. In October 2009, the government announced nearly $29 million in funding for the construction of the new 6,170 seat capacity western grandstand, taking WIN Stadium's capacity to over 23,000 people.

Recently, the government announced that sporting venue authorities including the Illawarra Venues Authority, Hunter Region Sports Venues Authority, and the Parramatta Stadium Trust were to be abolished and replaced with a broader authority called Venues NSW.

1.2 Project Overview

The $28.9 million project involves:

- Demolition of the existing "Sid Hayes" western grandstand and other buildings including an electrical substation, old turnstiles, media broadcast boxes, workshops and physio rooms.
- Preparation of the site including new drainage works and major electrical works.
- Construction of a new 6,170 seat capacity covered grandstand and associated works including new ticketing and turnstile facilities, corporate facilities, improved player facilities, and upgrades to pedestrian and traffic movement areas outside the ground.

The main new grandstand (Figure 1) is designed to fit between the two existing lighting towers located on the western side of the ground. The grandstand's top levels of seating extend out over Harbour Street, with its supporting concrete pillars located within the current bitumen road formation.

Figure 1: Artist's impression of the new WIN Stadium western grandstand.

2 SURVEY COMPONENTS

2.1 Initial Control Establishment and Site Detail Survey

A well conditioned survey control network, external to the main demolition site, was established using total station traversing methods, utilising existing SCIMS permanent marks (LPI, 2012) located adjacent to the site. The control survey was carried out on an MGA94 (ICSM, 2006) origin and azimuth, based on a plane "flat earth" grid, and referred to the AHD71 height datum (Roelse et al., 1971).

A detail survey of the site ensued, locating all features relevant to the design and construction, including buildings, sheds, stairs, light towers, surface types, kerbs, fencing, spot levels, and utility services where possible. Heights of the light towers and the existing grandstand roof were determined for design, and the detail survey also included accurate location of the property boundary and any reference marks. Most of the detail survey was undertaken using a total station, with some fill-in by RTK GNSS methods.

The initial detail survey only included the western grandstand and its immediate surrounds. However, as the project developed, more and more of the stadium was required to be surveyed in detail. This resulted in extending the site further to the south which was to be used for new car parking facilities, and also further to the north where new turnstiles, gates and a substation where to be located. Some services location was carried out by SASIS, however the Dial Before You Dig (DBYD) search revealed a number of Sydney Water sewer and water mains, and high-pressure gas mains which needed to be defined, so a professional service locator was engaged to locate these. Of particular interest was the location of a large Sydney Water outfall main (750 mm diameter) which ran along Harbour Street. Location of these mains was critical because the footings of the supporting pillars of the grandstand were going to be located within the road formation, very close to the existing services.

Once the detail survey was plotted, a cadastral anomaly was discovered with the existing old electrical substation. The existing substation at the time consisted of a brick building approximately 8 by 6 metres in size, butting up against the Harbour Street boundary.

However, the small Crown portion that showed up on the LPI Cadastral Records Enquiry (CRE) search, and owned by the then Integral Energy, was located approximately 8 metres further south than it should have been. All that existed on the small portion was a concrete driveway.

2.2 Engineering Surveys during Demolition and Construction

As more utility services were discovered during the investigation and demolition phases, further detail survey works were undertaken to locate these and add them to the existing detail survey plan. Borehole locations were accurately marked out on the road pavement, so that geotechnical drilling could proceed safely without striking the abovementioned Sydney Water mains in Harbour Street.

A baseline survey for the earthworks was also undertaken, involving a survey along the construction gridlines which provided vertical profiles of the site in relation to the existing kerb levels. This small and seemingly insignificant exercise proved to be of great value when the first variation claim for additional earthworks from the contractor was received. NSW Public Works were able to prove from the baseline survey that the contractor's claim was invalid; therefore the variation was subsequently rejected, saving the client valuable money.

2.3 Terrestrial Laser Scan (TLS) Survey

Being a high-profile project amongst the local Illawarra community, and also being a piece of infrastructure that was going to be visually obvious, the new grandstand was always going to attract a lot of attention from the public and from local residents and businesses alike. One concern was that the occupants of the recently completed hotel and residential apartment blocks across the road in Harbour Street may object to the development if their views of the beach and ocean became obstructed by the new grandstand roof.

In order to address this potential risk to the project, it was proposed that a Terrestrial Laser Scan (TLS) survey be undertaken of the stadium and its immediate surrounds. NSW Public Works engaged the AAM Group, based in Wollongong, directly to undertake the TLS field survey, to register the data, and to produce a point cloud. By doing this survey, a spatial relationship could be established between the existing grandstand and any of the surrounding buildings. The TLS survey would produce a point cloud that is spatially referenced in MGA94 and AHD71 and could be used to augment the existing detail survey information. By merging the architectural design into the TLS point cloud, a digital product can be created that has much broader value-added applications than the engineering detail survey (Figure 2).

The TLS information combined with the 3-dimensional architectural model could be used for a variety of applications including:

- Assessment of sight lines from any viewpoint.
- Creation of shadow diagrams.
- Interference assessments between the new build and the existing light towers.
- Confirmation of the exact height and characteristics of the light towers.
- Development of public relations material, artist's impressions, etc.
- Assessment of the Development Application by Wollongong Council and the Joint Regional Planning Committee.

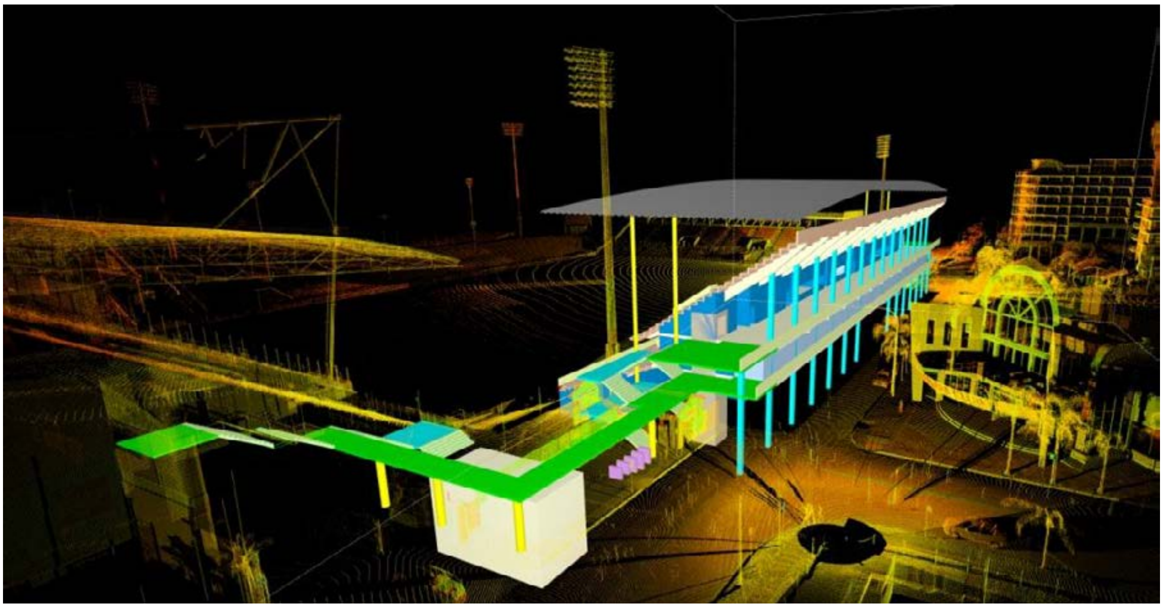

Figure 2: Architectural 3D model merged into TLS point cloud.

2.4 Cadastral Elements

2.4.1 Existing Electrical Substation

During the planning phase of the project, it became apparent that an existing electrical substation located on Harbour Street was not positioned within the original Crown portion that was created to accommodate the structure. The substation, owned and maintained by Endeavour Energy (formerly Integral Energy), was a 1960s brick building of 6 by 8 metres in size, incorrectly standing approximately 8 metres further north than the Crown portion.

As part of the new western grandstand design, it was proposed to demolish the existing substation and construct two new replacement padmount substations approximately 30 metres to the north of the present substation. Easements for the two new substations and underground cables were created by the lodgement of a Deposited Plan, accompanied by the supporting Section 88B instrument.

As the Crown portion was not serving any purpose, the decision was made to consolidate the portion with the existing lot which the stadium occupies, owned by IVA. The first step in the consolidation process was for IVA to purchase the Crown portion and consequently gain the Certificate of Title. After negotiations with Endeavour Energy, it was agreed upon to transfer the Certificate of Title to IVA for a token amount of $1. At this point in time the consolidation process has not progressed any further with the survey plan currently being in its draft stage.

2.4.2 Harbour Street Partial Road Closure

During the planning phase, it was outlined that the newly constructed western grandstand was to overhang the public road, Harbour Street, up to approximately 8 metres at roof level. Not only was the structure to overhang the road, it was also to be supported by 14 concrete columns. These columns were to be positioned 7.2 metres west of the stadium subject lot, therefore occupying the road at surface level.

The nature of this design created numerous land issues, firstly in regards to the land zoning. Harbour Street and land to the west was zoned as B4 (mixed-use) which prohibits major recreation facilities. Therefore, in order for the development application to be approved, the small strip of affected road had to be rezoned to SP3 (tourist zone) to coincide with the zoning that applies to WIN Stadium.

Another issue was to deal with the overhanging grandstand and columns encroaching onto public road (Figure 3). Following liaison between council representatives and Land and Property Information (LPI), it was decided to close the affected portion of the road. The part to be closed comprised of the surface area and stratum airspace occupied by the 14 columns and overhanging structure. The closed road portions were to be sold to Wollongong City Council and consequently leased to Illawarra Venues Authority for the annual rent of $1.

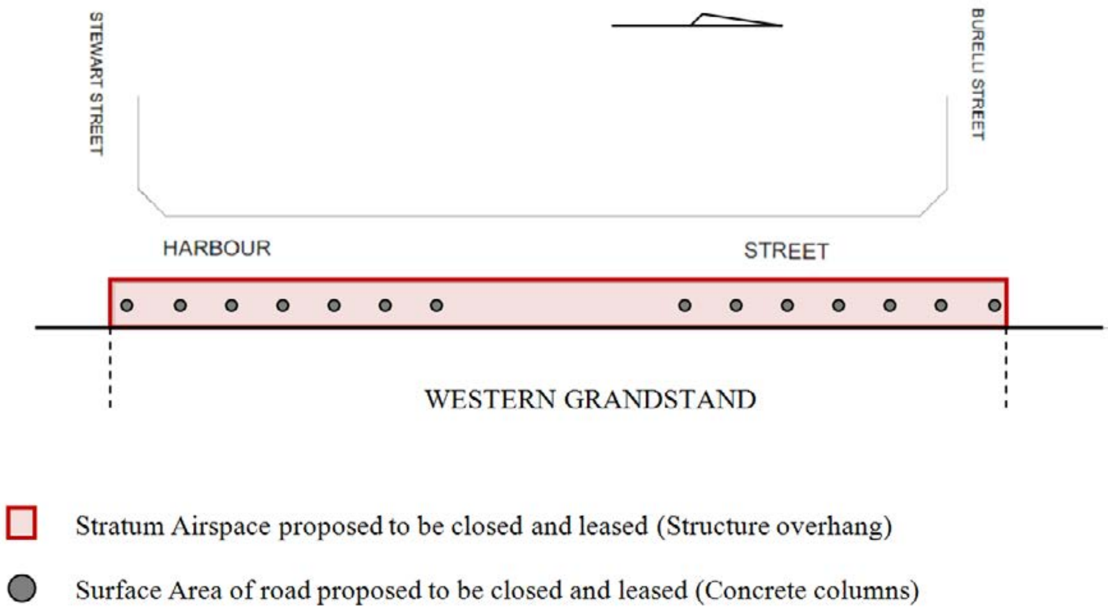

Figure 3: Property matter proposal within Harbour Street.

NSW Public Works survey services were called upon to carry out the survey plan to enable the abovementioned road closure. Due to the unusual nature of survey, discussions were held with LPI in regards to how the columns and stratum airspace were to be shown. It was settled upon to show the columns as part lots (being Lot 1) with surveyed connections shown in between each column. The limit in depth of Lot 1 was defined as two regular inclined planes, being the road surface of Harbour Street, shown by reduced levels related to AHD71 on the surface of the plan. Each column was given a part area with the total area of Lot 1 summating to 3.5 m^2. The limit in height of Lot 1 was defined as the horizontal plane at RL 9.82 m coinciding with the underside of the overhanging grandstand. Lot 2, being the stratum airspace of which the overhanging grandstand was occupying, was limited in depth by RL 9.82 m, abutting with the height limit of Lot 1 (columns). No height limit was placed upon Lot 2.

The survey plan has not been lodged due to the roof buckling under strong winds in September 2011. The entire recently constructed roof was disassembled in order for repairs to be undertaken. It is now expected that the stadium will be ready for use by June 2012.

3 CONCLUDING REMARKS

This paper has summarised NSW Public Works, Surveying and Spatial Information Services, involvement in the construction of the new western grandstand at WIN Stadium in Wollongong. During the planning phase of the project several control and detail surveys were carried out, providing the important framework for the design team. As the project matured, survey services were called upon for utility service location, borehole set-out and earthwork surveys. NSW Public Works had its first experience with Terrestrial Laser Scanning, and has since been able to deploy TLS for other projects which may be discussed in future papers. Several cadastral matters were encountered and successfully dealt with by effective communication between SASIS staff and other involved parties such as NSW Public Works project managers, council and utility authorities.

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Cadastral Survey for the Sea Cliff Bridge on Lawrence Hargrave Drive by the Roads and Maritime Services

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ABSTRACT

This paper describes the cadastral survey carried out by the Roads and Maritime Services (RMS) to define the new road boundaries to accommodate the Sea Cliff Bridge on Lawrence Hargrave Drive near Clifton, NSW. The survey had to contend with inhospitable terrain and the instability of the geological structure of the Illawarra Escarpment. It is shown how the application of traditional survey techniques, coupled with modern technology, under these difficult conditions, has produced a very comprehensive and rigorous cadastral survey. The paper describes how marks that were over 100 years old were located along the ocean rock shelf, as well as locating rare stone cubes placed as monuments along the old road alignment. The political urgency of reopening the road as quickly as possible meant that design of the property boundaries was left until after completion of the bridge. This required the survey team to liaise with land owners and other stakeholders to determine the optimal final boundaries and extent of the survey. Complicating this was the need to accommodate a bridge suspended over the sea bed, reclamation of the sea bed off the NSW coast and survey requirements to protect sensitive heritage items. The survey reinstated some of the most challenging boundaries faced by cadastral surveyors including railways, irregular roads, mean high water, as well as creation of stratum lots and boundaries. The paper touches on the unique rugged beauty of the site and the privilege of being entrusted with the survey of what has become an iconic structure. Corporations worldwide are currently using images of the Sea Cliff Bridge to promote their products. The survey commenced in December 2005, immediately after completion of the bridge, with plan registration completed in April 2009.

KEYWORDS: *Cadastral survey, Sea Cliff Bridge, mean high water, stratum, heritage items.*

1 INTRODUCTION

1.1 The Problem

The section of the Lawrence Hargrave Drive between Coalcliff and Clifton hugs the most unstable section of the Illawarra Escarpment between Wollongong and Sydney, NSW. The Illawarra Escarpment north of Thirroul is noted for its instability and the risks this poses to structures and the public. In August 2003, a major rock fall onto the road surface led to the closure of this section of road by the Roads and Maritime Services (RMS) until it could be made safe for traffic. The closure follows a long history of road failures and reconstruction due to rock falls and subsidence since its opening in the 1880s. This closure virtually spilt the villages along the coastal strip into two sections, requiring those on the northern side to

endure considerable extra travel time to Wollongong and those on the southern side extra travel time to Sydney. The resulting public unrest forced the NSW government to ask the RMS to seek a permanent solution; that solution was the construction of the Sea Cliff Bridge.

1.2 The Site

The high battlements of the escarpment and the vast openness of the Tasman Sea offer a vista of some of the most spectacular coastline in NSW for motorists (Figure 1). However, the geotechnical structure of the escarpment, steep cliff faces, thick vegetation covering the escarpment and the pounding sea make this area one of the most difficult for road/bridge construction and associated survey work.

Figure 1: View of the coastline from the top of the escarpment.

This is the environment that confronted the RMS survey team to carry out the cadastral survey to define the boundaries for the new Sea Cliff Bridge. It created significant logistical and Occupational Health & Safety (OHS) problems for the team that would make the survey physically very demanding, as well as adding to the timeframe and cost.

Two examples of the logistical and OHS problems that confronted the survey team on this site were as follows. Example 1: Permanent Mark 51440 was used with PM 17237 as orientation for the survey. Permanent Mark 51440 is located in the South Coast Railway reserve on the eastern side of the track and railway fence. To gain access to the mark, the survey team had to drive to the western side of the railway, seek permission to enter private property, then proceed along the old Clifton School right-of-way access track, then walk via a creek bed and through a concrete pipe culvert under the railway line back to the eastern side of the railway line, and finally cut a track through thick lantana to reach the mark. Example 2: All survey marks placed by this survey along the base of the cliff were reference marks set back from the cliff to minimise the hazard of falling rocks to this survey team and surveyors using the marks in the future (see lot 23 on sheet 3 of DP 1137408 included in the appendix of this paper). No survey marks were placed along boundary lines near the cliff face for safety reasons.

The survey team's first visit to the site was just prior to the bridge's opening in December 2005. This enabled them to consult with construction personnel to understand OHS risks associated with the site and develop a Safe Work Method Statement (SWMS) specific to the cadastral survey. The Safety Management Plan for construction identified the risk of rocks falling from the escarpment onto the old road formation as high and recommended avoiding work in that area where possible but if necessary then a lookout was required. Figure 2 shows a typical rock fall that led to the closure of the road in August 2003 and was still possible during the time of the survey.

Figure 2: Typical rock fall during 2003.

The survey team agreed that at least three staff were required whenever survey work was carried out on or near the old road formation at the base of the cliff or close to the water's edge.

The geology of the escarpment has seen many rock falls and slips throughout the existence of Lawrence Hargrave Drive along this section of road. Since 1980, the RMS has carried out significant restoration work in this area after road failures. This has involved removal of the existing road formation, sometimes to depths of 18 metres and rebuilding the road. Finding survey monuments along this section of the road corridor was considered very unlikely because of these road failures and restoration works. However, it was still incumbent on the survey team to search for these monuments to establish their existence or otherwise.

1.3 Project Alliance

Due to disruption to local traffic created by the road closure, the RMS developed an Alliance to deliver the Sea Cliff Bridge as quickly and efficiently as possible. Alliances are expected to reduce the planning and tendering phase as well as reduce friction during construction. There are also incentives to contractors based on any efficiency gains they may develop to reduce construction costs. The partners for the Alliance were the RMS to oversee and manage the project, Barclay-Mowlem to carry out construction, Maunsell to carry out the design and Coffey Geosciences for geotechnical services.

However, while there were efficiency gains and tight time and budget constraints were achieved, there were implications for the cadastral survey. The RMS did not carry out its

normal practice of planning and charting property boundaries during the planning phase of the project. The urgency of reopening the road to the public and the dynamic nature of the Alliance, where the design was carried out during construction, restricted the ability of the RMS to pre-plan and design the final cadastral boundaries. The Authority was not in a position to chart cadastral boundaries as the final size and position of the structures were still being finalised. They therefore made the decision to postpone work on property boundaries until after or near completion of the work. An email from the Alliance's Public Liaison Officer to the RMS Property Manager in September 2005, just three months prior to the opening of the bridge, states that they were then ready to determine the land required for the works.

This made the scope of the Survey Instruction for the cadastral survey open-ended and deliberately vague, leaving the survey team to liaise with stakeholders to determine the optimum position of the final boundaries. This was possible on this project as the affected land was owned by three other government agencies, apart from land owned by the Illawarra Coke Works. That part of the Illawarra Coke Company land affected was unused due to its physical terrain and, in addition, the proposed acquisition had no effect on their coke making operations. The affected government-owned property was basically unused due to its physical terrain.

Nevertheless, it was still necessary that the cadastral survey provided the RMS with sufficient land to maintain the road and that the road did not encroach onto land they did not own. There were also a number of heritage items identified in the Review of Environmental Factors (REF) that had to be protected from construction and future maintenance work. These items also had to have public access.

2 FIELD SURVEY

2.1 Survey Traverse

The work-as-executed plans for the bridge could not be located, so the original intention was to traverse along the bridge's footway to check that the bridge was constructed to design. This method would also enable radiations from the bridge deck to look for marks on the old road formation and on the 30.48-metre reserve from mean high water. However, RMS bridge engineers advised that the bridge could not be considered a stable structure and movements of up to 100 mm were possible. Another solution was required.

Traversing over the escarpment with its height, steep slopes and thick vegetation was not considered as an option. The next option was to use the rock shelf, which is uncovered for some distance from the shoreline at low tide. Geotechnical advice was that the shelf was much more stable than the escarpment and therefore suitable for placing survey marks. A suitably placed mark would enable a surveyor to sight both ends of the survey and to look for marks along the old road corridor and shoreline. These requirements determined the position of SS 141552 (see sheet 4 of DP 1137408 in the appendix).

However, as shown on DP 1137408, this mark is on the seaward side of mean high water but is nevertheless frequently uncovered. Therefore survey work occupying the mark had to be planned in advance, including consultation with the RMS Survey Manager to provide extra staff for OHS compliance. It also needed optimum predictions for rain, tide, wind direction

and strength, wave direction and height and, on one occasion, satellite availability for GNSS observations to ensure successful completion of survey tasks (Figure 3).

Figure 3: GNSS position fixing of SS 141552.

GNSS was used to establish the control network due to the rugged nature of the terrain, accessibility of marks and length of sight lines (sheet 8 of DP 1137408 contains the control survey: RMS Control Plan number 0185.497.CS.8243). However, as the bridge was designed on the Integrated Survey Grid (ISG), the survey was carried out on ISG orientation, which made it easier to compare the bridge's design position with its constructed position.

2.2 Survey for Stratum Lots

The RMS Property Manager originally expressed the view that the survey should create a stratum two metres below the soffit of the bridge and in plan view, two metres either side of the constructed bridge, to enable access to the road surface and, if needed, to the soffit of the bridge from equipment placed on its deck. The RMS has adopted this policy for bridges, particularly in residential areas, where the bridge is over private land or land in public use. It negates the need to resume land underneath bridges.

The Property Manager also felt that there should be easements of support over the batters of the road for maintenance purposes.

In order to define stratum lots to accommodate the bridge structure, the survey team traversed along the old road formation, placing traverse stations on the extended centreline of the piers that were to be included in the stratum. The extended centreline was determined by eyeing out either side of the pier with a plumb line and the traverse station placed equidistant between these two points. This enabled an XYZ check of the bridge at known cross section by reflectorless radiation to bridge components.

During construction, the Alliance surveyors established the survey control network for the bridge by fixing (gluing) survey control marks (reflectors) to the face of the cliff. These were still in place during the cadastral survey. These marks were also radiated to compare the design position of the bridge components to their constructed position. Generally, good

agreement was found with the constructed position of the bridge fitting with its design position within the order of one to two centimetres.

The survey team also spent some time radiating and coordinating extremities of gabion walls, that formed batters and other road structures that supported the road formation, to establish the extent of proposed easements of support.

However, after spending considerable time in the field, it became apparent that the stratum envisaged for the bridge was not the most efficient approach for this project. This was based on the fact that the bridge was over land in the control of the Crown Lands Division of the Department of Primary Industries (CLD of DPI) and the main use of the land was access to the shoreline. Land between Lawrence Hargrave Drive and the Tasman Sea contains a steep slope which has a high risk of slips and falls and a rock shelf, which only the hardy access for rock fishing.

It was then decided on resuming all of the land between the old road alignment and mean high water for the new road without creating a stratum for the bridge. This solution provided a far less complex cadastre of the affected land than that originally envisaged.

There are a number of precedents of bridges carrying traffic over waterways without the need to create a stratum for the bridge, e.g. the Sydney Harbour Bridge. However, where the bridge is suspended over a waterway and is part of a toll road, then creating stratum lots for the bridge would be required as the road is leased to the tollway consortium for the life of the tollway lease. The lease must include the physical structures of the road and allow access for maintenance of the road/bridge. However, the option of a toll for this section of road was not considered.

In addition, defining and marking easements for batter support for the road would be of little value given the unstable nature of the terrain in the vicinity of the road formation. Defining land outside the toe of batter for maintenance access was problematic given the steep slope on which the batters are built. Also, the nature of maintenance work on this road would, more than likely, destroy any survey marks if reconstruction of the batter was required. However, a stratum lot was created for the heritage items as outlined in section 2.3.

2.3 Heritage Items

The land in lot 6 of DP 1137408 is part of the 30.48-metre reserve (plan 3045-3000) and will remain in public ownership with the CLD of DPI. On sheet 2 of DP 1137408, Diagram B shows lot 18, which is a stratum lot above a stratum plane of 31.0 m AHD and above lot 6.

Lot 18 includes the bridge which after resumption will be dedicated as road and will be vested in Wollongong City Council. If the stratum lot was not created, then lot 18 would include the heritage items, which in turn would become the responsibility of the council; something the council did not want. To overcome this problem, for the land bound by the plan dimensions of lot 18, only that which is above RL 31.0 metres AHD is dedicated as road and that which is below 31.0 metres AHD remains part of lot 6 and as part of the 30.48-metre reserve.

The heritage items in lot 6 include:
1. Steel boiler used during the life of the closed Coalcliff mine.
2. Entrance to closed Coalcliff mine, which was sealed in 1992.

3. Some brickworks placed to stabilise the cliff near the mine entrance.
4. Entrance to an air vent tunnel for the mine.

The REF describes the boiler and the brickwork as having high significance. Figure 4 shows the sealed entrance to the mine and the brickworks.

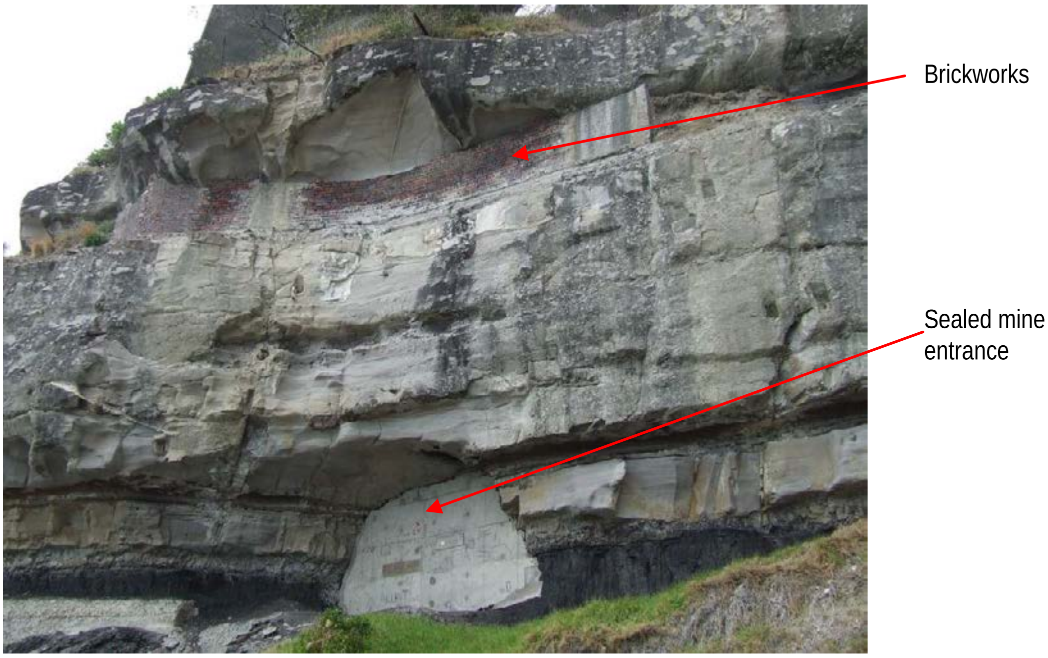


Figure 4: Sensitive heritage items.

All of the items listed above are under the bridge except for the air vent tunnel entrance and some of the brickworks. The shape of lot 6 north-west of lot 18, as shown on sheet 2 of DP 1173408, is to include the air vent tunnel entrance and the face of the cliff where some of the brickworks for stabilising the cliff face were placed. Figure 5 is a LISCAD screen dump showing the position of heritage items and other features which determined the shape of lot 18. It also shows other mine buildings and the jetty, the remains of which are no longer visible but were relocated by using measurements shown in Surveyor Hall's field book (FB 7612).

The significance of the old mine boiler was highlighted at the start of the project and caused a change in the bridge design when it became clear that a bridge pier was to be constructed over it. The bridge pier shown green in Figure 5 is in the final constructed position, not in the position originally intended.

The boundary of lot 6 north-west of lot 18 had to pass between the pier and the boiler to ensure that the pier is located in lot 19 (to be dedicated as road) and the boiler remained in lot 6. The two green rectangles shown in Figure 5 are the outlines of the pile cap and the pier itself.

The REF describes the boiler as 4 metres long and 0.6 metres in diameter (although Figure 6 suggests that it is a 0.6-metre radius, not diameter), consisting of seven cylindrical hoops riveted together.

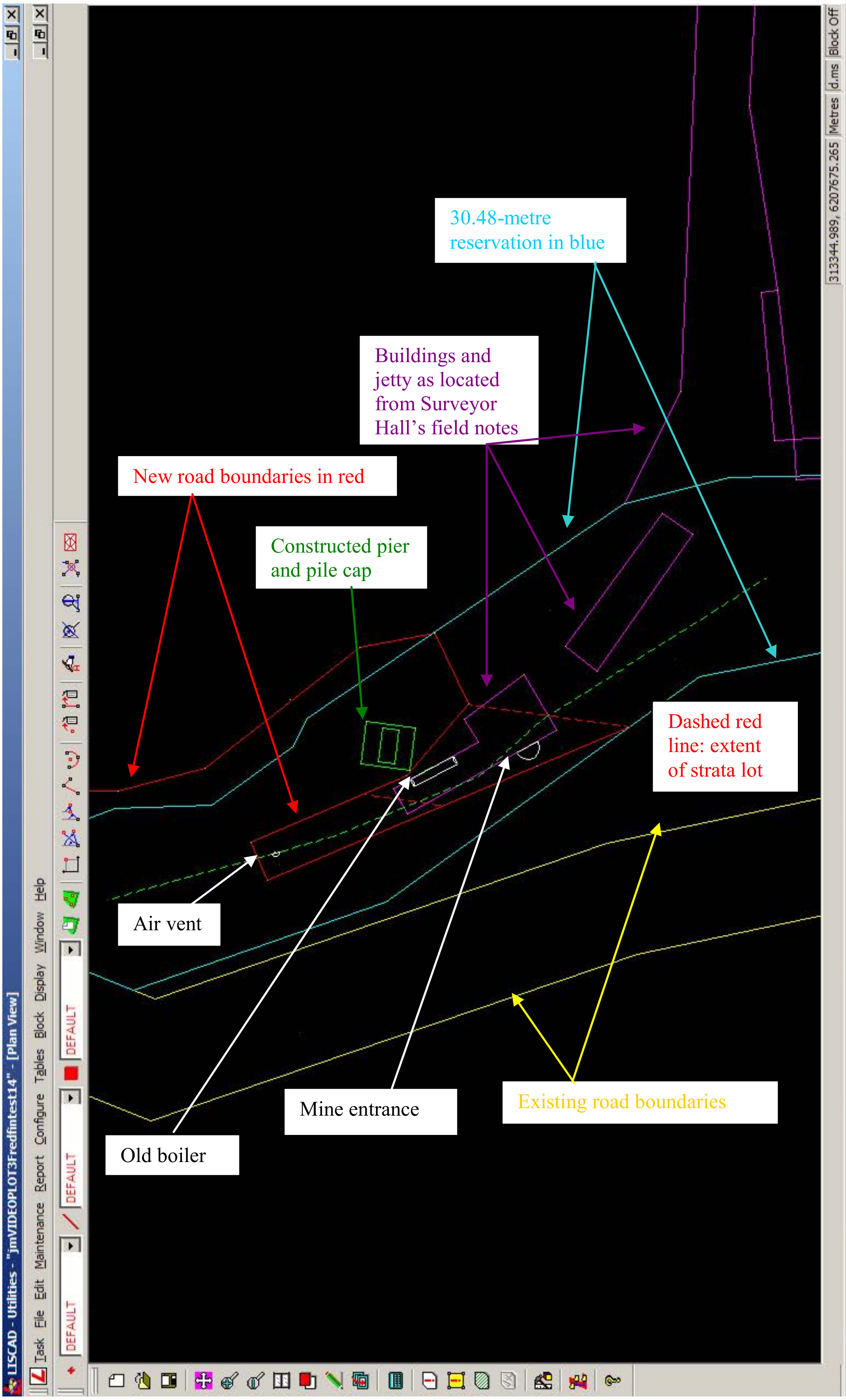


Figure 5: LISCAD screen dump of heritage items.

Figure 6: Land Surveyor Stephen Bennett with the exposed boiler.

2.4 Illawarra Coke Company Land

In order to protect Lawrence Hargrave Drive from future erosion and rock falls at the northern end of the site, the RMS required an easement over land owned by the Illawarra Coke Company, shown as lot 13 on sheet 6 of DP 1137408 (see appendix). They want to restrict access to land shown as [G] and establish an easement for stabilisation over the area for that purpose. Easement shown as [E] is for access to [G] should restoration work be required.

Clause 18 of the Surveying and Spatial Information Regulation 2006 (Lands, 2006) requires that the terminals of an easement must be connected to a monument. The survey team were able to locate survey marks for a connection to the northern end of the easement [E] from recent survey plans. However, finding a monument for connection to the southern end of [E] was much more problematic and difficult, particularly given the rugged terrain.

The decision was made to search for survey marks where the South Coast Railway land cuts the northern boundary of land survey by DP 397976 along the top of the escarpment. An initial trek through thick vegetation and bush to the top of the escarpment carried out a reconnaissance using a handheld Garmin GNSS receiver. However, this revealed that the likely positions of the marks were covered by thick ferns. The survey team made their first visit to the top of the escarpment without survey equipment as they were unsure of the terrain and undergrowth and of the likelihood of the existence of the survey marks. Before making the long trek back down, they placed a traverse station from which they could sight PM 17237 at the southern end of the survey and SS 141552 placed on the rock shelf outside the shoreline (see sheets 1 and 4 of DP 1137408 respectively).

The second trek to the top of the escarpment was much more difficult as it required hauling in the necessary survey equipment, which required extra staff. Before leaving on the trek, a new risk assessment of the proposed work on the escarpment was carried out with new safety controls implemented for the SWMS. The walk took about 45 minutes with the last 200 metres through waist high dense fern that covered a large number of fallen logs, creating the perfect situation for slips, trips and fall hazards.

However, the effort was rewarded when the reference mark, a galvanised iron pipe, on the eastern boundary of the South Coast Railway reserve was located with the aid of a metal detector. This was without the assistance of a calculated radiation from the traverse station placed by the first reconnaissance. It is believed that this exposure of the reference pipe is the first time in the 50 years since the original survey.

The determination of the position of the traverse station was by an eccentric station fix procedure by measuring distances to PM 17237 and SS 141552, as well as the included angle. Later, distances from those two marks back up to the traverse station, as well as the included angles, were also measured to give a more accurate fix of the traverse station. Finding the reference pipe allowed calculation of radiations to the other survey marks for the cuts on the railway boundaries, which were also located.

3 PROPERTY BOUNDARIES

3.1 Boundary Reinstatement

3.1.1 Lawrence Hargrave Drive

Surveyor Henry Fraser Hall carried out the survey to define Lawrence Hargrave Drive between Clifton and Coalcliff in 1908, and a survey to create the 30.48-metre reserve to the east of the road in 1909. The road plan is 9592-1603 and the 30.48-metre reserve is shown in plan 3045-3000. Surveyor Hall's original field notes are contained in Field Book number 7612.

A feature of the road survey was the placement of stone cubes with a drill hole and broad arrow to mark angles in the road (Figure 7). Surveyor Hall also carried out a survey in 1909 to create a right-of-way to the Clifton School and also placed stone cubes with a drill hole and broad arrow for that survey (see DP 935466). The survey team located some of the stone cubes to refix the road boundary, one of which was buried 600 millimetres.

Figure 7: One of the stone cube monuments placed by Surveyor Hall.

A stone cube was located at the southern end of the survey near Clifton School Parade as well as two stone cubes being located in Clifton School Parade (DP 935466) and two more stone

cubes at the northern end of the survey near Paterson Road. Good agreement was found between the three stone cubes at the southern end. One of the stone cubes at the northern end was shown as disturbed by DP 636375. The refix of Lawrence Hargrave Drive at the northern end showed that the most eastern stone cube has continued to move since the survey for DP 636375. The only survey mark found between the stone cubes at either end of the road survey was a reference mark drill hole and wing placed (DP 397977, 1956) in the face of the rock cliff at the most eastern corner of lot 17 of DP 1137408, which was adopted.

Surveyor Hall's use of the stone cubes found by the survey team as survey monuments is unusual if not unique. A literature search failed to provide extra background information about the stones.

Some surveyors of the time were critical of the use of 4-foot high alignment posts as it was not possible to set the instrument over them and suggested instead that placing a mark in the ground would be more user-friendly. Whether Surveyor Henry Hall's use of stone cube marks was prompted by this feeling is not known but the use of stone cubes appears not to have become widespread. However, Henry Fraser Hall still holds a significant place in the history of surveying by being appointed the Surveyor General of NSW in 1925.

Two rock marks shown as found by the road survey (plan 3045-3000) were found at the northern end of the survey (Figure 8). However, plan 3045-3000 did not show any reference to the origin of these marks. This required further investigation to establish their origin before they could be shown on the final Deposited Plan for this survey. A search located a road survey from Blue Gum Forest to Coalcliff carried out by Surveyor John Richmond in 1883 shown in plan 1778A-1603. This survey was a re-survey of that section of road that was originally surveyed in 1863. In almost 50 years of cadastral surveying, these are the oldest marks sighted by the co-author of this paper. Adoption of the two rock marks strengthened the boundary fix of Lawrence Hargrave Drive (see sheet 4 of DP 1137408 in the appendix).

Figure 8: One of the 1883 rock marks found at the northern end.

3.1.2 Mean High Water

At the southern end of the survey a 30.48-metre reserve from mean high water of the Tasman Sea abuts the land to the east of the old road reserve. Further north the 30.48-metre reserve abuts the old road reserve and, in places, cuts across it (see sheets 1 and 2 of DP 1137408). As

mean high water is a natural boundary it must be redefined to redefine the 30.48-metre reserve. Plan 3045-3000, lodged in 1909, shows high water as the eastern boundary of the 30.48-metre wide public reserve. The Survey Practice Regulation states that where a plan shows high water it can be accepted to be mean high water.

The terrain where mean high water was to be located is a rock shelf that is resistant to erosion of any significant amount in the past 100 years. Any accretion by rock falls would not be gradual or imperceptible and therefore cannot be taken to change the mean high water boundary. Therefore, the opinion was expressed, and accepted by NSW Land and Property Information (LPI), that high water as defined in 1909 would still define the mean high water boundary today. Therefore, redefining the 1909 boundary would redefine the mean high water. Survey marks along the rock shelf east of the road were more likely to be found than survey marks on the old road formation due to the instability of the cliff face.

Marks found in Clifton School Parade shown in DP 703699 and DP 397977 redefined Clifton School Parade and its intersection with Lawrence Hargrave Drive. DP 397977 also provides a connection to the southern boundary of the 30.48-metre reserve. This enabled calculations for radiations to search for survey marks shown on plan 3045-3000. Marks were also found at the northern end of the survey near Paterson Road, which provided a connection to the northern end of the 30.48-metre reserve. This would have provided a fix of the reserve but it is still incumbent on a surveyor to look for all survey marks when refixing a boundary. Many cadastral surveyors feel that one of the more rewarding experiences in surveying is where the survey team is searching for and finding survey marks that are not readily apparent, especially those marks that have not been found since they were placed.

The probability of finding the rock mark at the eastern end of the southern boundary of the 30.48-metre reserve at first appeared very small (Figure 9). The amount of slips on the side of the slope and the quantity of rocks on the rock shelf below suggested that the mark was, at least, inaccessible. However, as shown in Figure 10, the mark was located and found to be in good agreement with other traverse marks found from 3045-3000. Six traverse stations from 3045-3000 were found, as shown on sheets 1, 3 and 4 of DP 1137408, which enabled reinstatement of 3045-3000.

The refixes of Lawrence Hargrave Drive and the 30.48-metre reservation were carried out independently from marks found in both plans. However, the two plans intersect where the reservation abuts the road reserve. The abuttal common points were used to reinstate the western boundaries of the 30.48-metre reservation using dimensions shown by plan 3045-3000. The abuttal common points are shown on sheet 3 of DP 1137408 adjacent to lot 21.

The marks found placed by 3045-3000 were traverse stations with traverse lines shown as blue lines. The plan did not contain dimensions of the mean high water boundary of the reserve. However, Surveyor Hall's 1909 field book for the survey (Field Book number 7666) showed the offsets from the traverse lines to high water. Using these, it was possible to calculate joins between the ends of the offsets to produce a right line boundary approximating the mean high water boundary of the reserve as shown on sheets 1, 2 and 3 of DP 1137408 in the appendix.

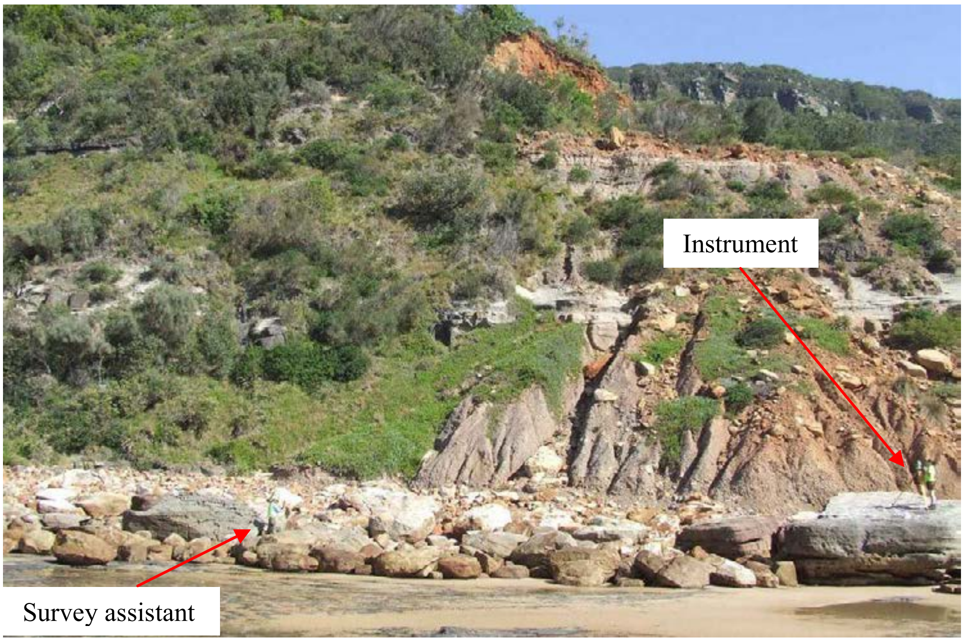


Figure 9: Searching for Surveyor Hall's rock mark.

Figure 10: Radiating rock mark placed by Surveyor Hall in 1909.

Surveyor Hall's Field Book 7666 with the offsets to high water was invaluable for refixing the eastern boundary of the reserve. The notes also include the raw field measurements. It was decided to go through and check all of the field reductions to ensure a precise refix of the boundary as originally measured by Surveyor Hall. This led to the discovery of a 1-minute error by Surveyor Hall in carrying the bearings through the traverse, which was corrected.

3.2 New Boundaries

3.2.1 Lawrence Hargrave Drive

There were some restrictions that had to be considered when creating the new boundaries for Lawrence Hargrave Drive, as outlined in Table 1. The lot numbers reference DP 1137408.

Table 1: Creation of New Boundaries for Lawrence Hargrave Drive.

Lot	Boundary	Constraint	Action
14	western	Wollongong City Council constructed a children's playground on lot 10 after a batch plant used for construction left the site.	The boundary to the first angle is set by the fence line.
14	western	The Alliance constructed gabion baskets for batter protection on lot 14 north of the playground.	Boundary placed to include gabion baskets in the road reserve.
16	western	The new road formation encroached over the western side of the old Lawrence Hargrave Drive alignment. The Roads and Maritime Services (RMS) also required a storage area in the event of restoration work in the future.	Boundary placed to remove encroachment and taken back to edge of clearing for a possible worksite.
15	eastern	Provide sufficient resumption to accommodate road and leave access to the 30.48-metre reserve and not encroach on to the public park at southern end.	Boundary placed to suit these criteria.
6	northern	Heritage items, see section 2.3.	
23	western	The construction of safety fences, gabion baskets and stormwater calming devices to control rock falls and erosion of the cliff on western side of road.	Boundary placed to include all items and maintenance access.

3.2.2 Easements

(a) Easement for stabilisation

The geological instability of the land behind the cliff to the west of the road makes it unsuitable for development and poses a threat to the long-term viability of the road. Lot 17 in DP 1137408 was under the control of the Minister for Environment and Planning. The Roads and Maritime Services (RMS) acquired this land and dedicated it as road for that reason.

The Illawarra Coke Company owns the land north of lot 17 for coke production. However, for obvious reasons, they are not using the unstable land behind the cliff adjacent to the road. Therefore, they were agreeable to the RMS creating an easement for stabilisation over that land to protect the road.

A large section of the coke works land abuts the road north of the bridge where the road formation is close to the cliff face. The Alliance removed loose material from the cliff face at the northern end and inserted rock anchors to stabilise the cliff.

The survey brief was to create easements to accommodate the rock anchors and the unstable material. However, the Alliance was unable to provide any work-as-executed plans showing the location of the rock anchors. Consultation with the Alliance engineers revealed that the geological structure of the cliff face governed the depth of the anchors but none were driven to a depth greater than 20 metres. Therefore, an easement set back at least 20 metres from the cliff face would include the rock anchors. The most northern line of the easement boundary that meets Lawrence Hargrave Drive (17°04'50" – 118.56 as shown on sheet 6 of DP 1137408 in the appendix) includes the rock anchors.

However, the easement boundary south of the rock anchors was not as easy to define. The easement should include all of the loose talus material above the cliff face. To find the top of the slope, the survey team started at the bottom and climbed up through thick bush and lantana along an eroded and overgrown track. After an hour of the climb it became obvious that the slope extended all the way to the top of the escarpment. It was then decided to create

the easement such that it would include the top of the escarpment at the south western corner of lot 13.

(b) Easements for power lines and access
With the closure of Lawrence Hargrave Drive in August 2003 the power lines along the old road were also removed. At the Coalcliff end the power was joined to the existing grid within Illawarra Coke Company land. The Alliance agreed to create an easement over the coke company's land for the overhead power lines, which is shown as easement [F] on sheet 7 of DP 1137408 in the appendix.

Easement [E] was created for access to the easement for stabilisation for maintenance purposes.

4 LAND TITLES

4.1 Reclamation of the Sea Bed

The Sea Cliff Bridge is believed to be unique in NSW because it carries traffic over the sea bed, i.e. the bridge is on the seaward side of mean high water and outside the boundary of NSW. The section of road where this occurs is shown on sheet 2 of DP 1137408 to the east of where lot 20 abuts lot 19. The eastern boundary of lot 20 (3,403 m^2) is noted as the *Approximate Extent of Reclamation* on the plan. Lot 22 (383.7 m^2) is also land reclaimed from the sea bed but its main use is for an access track.

A permanent solution for this section of road called for construction of the bridge far enough east of the existing road such that rocks falling from the cliff face would not reach the travelling public, this included rocks that may bounce off the existing pavement into the sea. This necessitated construction of some of the piers on the sea bed. Construction of piers in water is not uncommon as noted by the number of bridges across large expanses of water in NSW. Construction is usually achieved by constructing temporary coffer dams around the piers. However, construction of coffer dams on this site was not possible as the rock shelf would prevent sheet piles being driven into the sea bed.

In addition, designers were concerned about the corrosive effect of salt from the sea on the steel reinforcement within the bridge piers. This was partially addressed by designing a cathodic prevention system within the piers to minimise corrosion. There was also concern about the wave motion of the sea that could cause salt water to splash over the piers, adding to the amount of salt that could affect the steel. Raising the pile caps above sea level would minimise the possibility of sea water splashing over the pile caps and piers.

Reclamation of some of the sea bed was carried out to allow construction of the piers on compacted land raised above sea level and for access tracks for construction of the piers. Figure 11 shows one of the piers constructed on compacted fill placed on the reclaimed sea bed.

The boundary of the reclamation was defined where the toe of the batter of the imported material forming the platform for the piers met the sea bed.

Figure 11: Pier constructed on land reclaimed from the sea bed.

4.1.1 Title of the Sea Bed

The RMS had not confronted the problem of acquiring land from the sea bed prior to this project. Initial search carried out regarding title of the sea bed located an article on boundaries in the 1932 edition of the Australian Surveyor. This article reported on a lecture by A.W. Miller, MIS NSW, given to the Institution of Surveyors, NSW in September and October of 1931 (Miller, 1932). In it, Mr. J. Le Gay Brereton, Barrister-at-Law, gives precedents to the Crown owning the sea bed. He also gives precedents indicating that the title of the Crown extends seaward for three miles from mean high water.

The RMS Surveying Manager sought advice from the Chief Surveyor for the ACT, ACT Planning and Land Authority, regarding the status of land below mean high water and if there is a title for it. The advice included reference to mean high water and mean low water.

Original legal definition from England by letters patent sent to the Crown colonies decreed that the limit of State's land is mean low water. It is understood that this still applies in NSW. As the land abutting the foreshore is Crown Land under the control of the CLD of DPI, the land out to the mean low water is also under the control of CLD of DPI. During the 1970s there was a dispute between the Commonwealth and the states over ownership of the sea bed outside the area defined by the letters patent. This resulted in the High Court bring down a decision that the sea was owned by the Commonwealth. However, the Federal Government's Offshore Constitutional Settlement Act in 1982 gave the states ownership of the sea bed, known as the territorial sea.

Determination of the mean low water mark for this project was seen as of little value as land between mean low and mean high water still resides with the Crown and is controlled by the CLD of DPI. Therefore, it was decided that the reclaimed land would be placed in one lot without a partition for the land between the two mean water levels. This is shown by lots 20 and 22 of DP 1137408, which are the two areas of reclamation required for construction of

the piers. The Administration Sheet of DP1137408 shows the approval of the plan by the Nowra Crown Lands Office.

4.2 Crown Land

Plan 3045-3000 is a plan of the 100-foot (30.48-metre) reservation within portion 18, which was approved on 30 June 1909. However, this was unreserved Crown Land until the issuing of Government Gazette of 29 June 2007 folios 4182-4213, which created Reservation numbers for all unreserved Crown Land in each parish in NSW. The Government Gazette lists each parish within NSW and gives each one a different number for all unreserved Crown Land within that parish starting from R750000. All previously unreserved Crown Land in the Parish of Southend, which covers this survey, is now listed as reserved Crown Land in R752054. This includes the 30.48-metre reservation created by 3045-3000.

However, Mining Lease 3 was issued over part of the reservation shown in pencil on 3045-300 on 10 October 1910 and plan ML3. The Government Gazette issued on 5 February 1913, over that part of the 30.48-metre reservation outside of the mining lease, created Reservation R48541 for Public Recreation. The RMS Senior Property Road Corridor Officer's contact with the Department of Mineral and Resources revealed that the Mining Lease ML3 had expired and the land covered by that lease is now included in Reservation R752054. The southern boundary of lot 6 of DP 1137408 is along the southern boundary of expired mining lease ML3. Similarly, the boundary between lots 19 and 21 of DP 1137408 is along the northern boundary of the expired mining lease.

The title of DP 1052428 is a "Plan of Crown Land Showing Former Artificial ID". This is a plan of the northern portion of the 30.48-metre reservation north of the expired mining lease and is shown as lot 7037. This plan was prepared by LPI as departmental plan and created a limited title over the land. DP 1117499 is a plan for Crown Land conversion of the 30.48-metre reservation abutting the southern boundary of DP 1052428 and the northern boundary of the expired mining lease and is shown as lot 7036. The boundary between lots 21 and 24 of DP 1137408 is along the boundary between lots 7036 and 7037 as described above.

4.3 Land Owned by the Minister Administrating the Environment Planning & Assessment Act 1979

The National Parks and Wild Life Services (NPWLS) resumed land shown as lot 9 in DP 1137408 in 2005 and dedicated it as the "Illawarra State Conservation Area" (see Government Gazette 11-3-2005 folio 754). However, no instrument or advice was passed on to LPI in order to inform LPI of the resumption, so that the title to the land owned by the Minister Administrating the Environment Planning & Assessment Act 1979 (EPA) was not amended. A title search of the land showed that the EPA land comprised all of lot 32 in DP 881726, which is the original parcel of land prior to the resumption. The RMS Senior Property Road Corridor Officer alerted LPI to the resumption while preparing the search for the final plan for the Sea Cliff Bridge survey. A recent folio identifier of the land includes reference to the NPWLS resumption but still shows the land as 32/88176. Sheet 5 of DP 1137408 is a subdivision of land owned by the EPA, with NPWLS requiring lot 9 for the conservation area and the RMS requires lot 17 for road. This subdivision assisted the EPA's administration of their property.

4.4 Ownership of 30.48-metre Reservation

The 30.48-metre reservation around the shoreline is Crown Land and is normally the responsibility of the CLD of DPI. However, the RMS Senior Property Road Corridor Officer could not gain concurrence over the ownership of the land between the CLD of DPI and Wollongong City Council, with both parties advising that the land is the responsibility of the other agency. The matter was finally resolved by phone conversation between the three agencies with the CLD of DPI assuming responsibility. This allowed the RMS Property Section to enter into negotiations to acquire the land for road from the CLD of DPI.

5 PLAN PREPARATION AND PRESENTATION

The field survey for the Sea Cliff Bridge cadastral boundaries was carried out using a Leica TCRA 1103 PLUS total station that stored the data on a Compact Flash Card. The data was then transferred to LISCAD software for processing. A LISCAD *.see file was then used to create a plot of the survey. A hard copy plot of the survey was then printed and all the relevant survey information added by hand before passing onto the Cadastral Information Officer in Goulburn and the Senior Property Road Corridor Officer in Wollongong for plan preparation. The LISCAD *.see file was changed to a *.lcd file to prepare the final plan. The plan was lodged electronically by “ePlan” following normal RMS practice.

The plan title is “Plan of land to be acquired for the purposes of the Roads Act, 1993 and proposed easements” and is a plan of acquisition. A plan of acquisition is sometimes called a “non-current plan” as the lots shown on the plan are only activated after the land has been acquired by the RMS, which may be some years in the future. On each sheet of DP 1137408 the current folio identifier, plan reference and, where appropriate, reference to any government gazettes affecting the land, are provided for each lot created by the plan to assist the acquisitions process. This arrangement is an agreement between the RMS and LPI and is not available for subdivisions carried out by the private sector.

LPI granted the RMS Property Section approval to present the plan for the survey in more than four sheets as normally specified; the final number of sheets being eight, plus two administration sheets.

The plan was drawn on MGA94 grid orientation in compliance with RMS policy. Sheet 8 shows the survey control for the cadastral survey and is the only sheet to plot the Sea Cliff Bridge, but without any dimensions. This plot was considered appropriate as the bridge itself is not shown anywhere on the plan in relation to any boundaries. This will assist surveyors in the future to establish their general position in relation to the bridge structure.

6 CONCLUDING REMARKS

The creation of the property boundaries for a 21st century icon, the Sea Cliff Bridge, is an example of latest survey technology working with the traditional practices of boundary definition to refix boundaries that were created over 100 years ago. RMS surveyors carrying out the survey used the latest electronic total stations and data recorders to collect field data for the survey and current computer software to carry out survey calculations for processing the survey. The data were electronically transferred to Cadastral Information Officers for plan

preparation and verification of property information before lodging the plan electronically with the Land Titles Office. The use of the latest GNSS equipment and technology also assisted the field survey in both expedience and precision.

However, all this technology is of little value if survey knowledge and experience is not applied with it. The final DP was signed by Registered Land Surveyor Stephen Bennett, who has almost 50 years survey experience, principally as a cadastral surveyor, and that knowledge was required for this survey. The instability of the land where the survey was carried out makes it difficult to find survey marks and if found, to gain agreement between them. This survey was able to demonstrate that the application of traditional cadastral survey techniques and practices still provides the best outcome. But the logistical challenges described in this paper made it much more difficult than normal to apply those techniques and practices. The team's field search for survey monuments along the shoreline and the escarpment, and the history search to locate the origin of survey monuments placed in 1883, are evidence of the application of experience and dedication to this survey.

Refixing irregular road boundaries, natural boundaries and railway boundaries is always a challenge but not uncommon. Refixing these three boundaries when in close proximity and running nearly parallel to each other is far less common. Refixing these boundaries, as well as reclamation of the sea bed, with the logistic problems encountered during this survey, makes it unique.

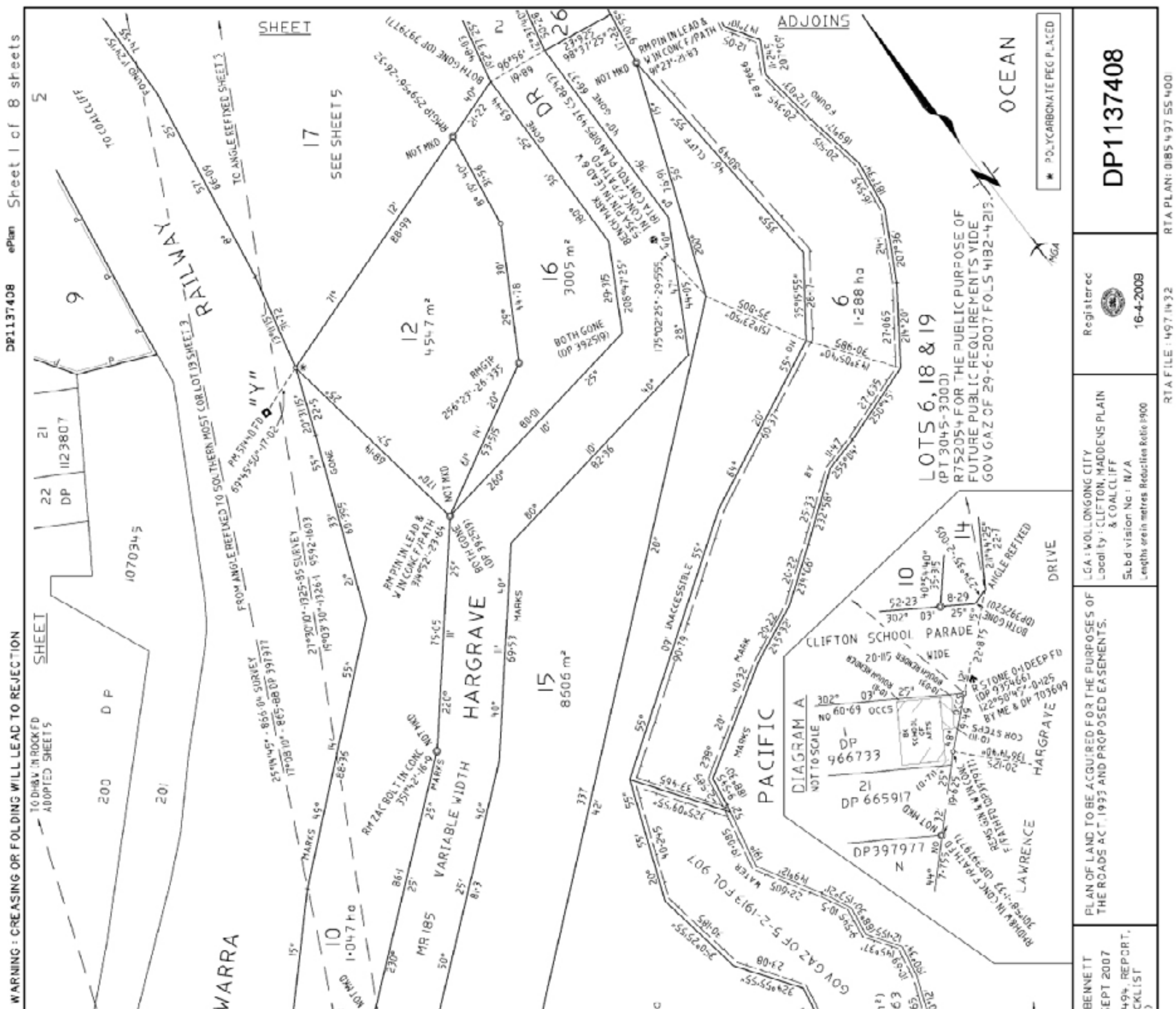
REFERENCES

Lands (2006) Surveying and Spatial Information Regulation 2006, http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+530+2006+cd+0+N (accessed Feb 2012).

Miller A.W. (1932) Boundaries, *The Australian Surveyor*, 4(1), 28-57.

APPENDIX

Deposited Plan 1137408 – Cadastral boundaries for the Sea Cliff Bridge.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WARNING : CREASING OR FOLDING WILL LEAD TO REJECTION
DP1137408
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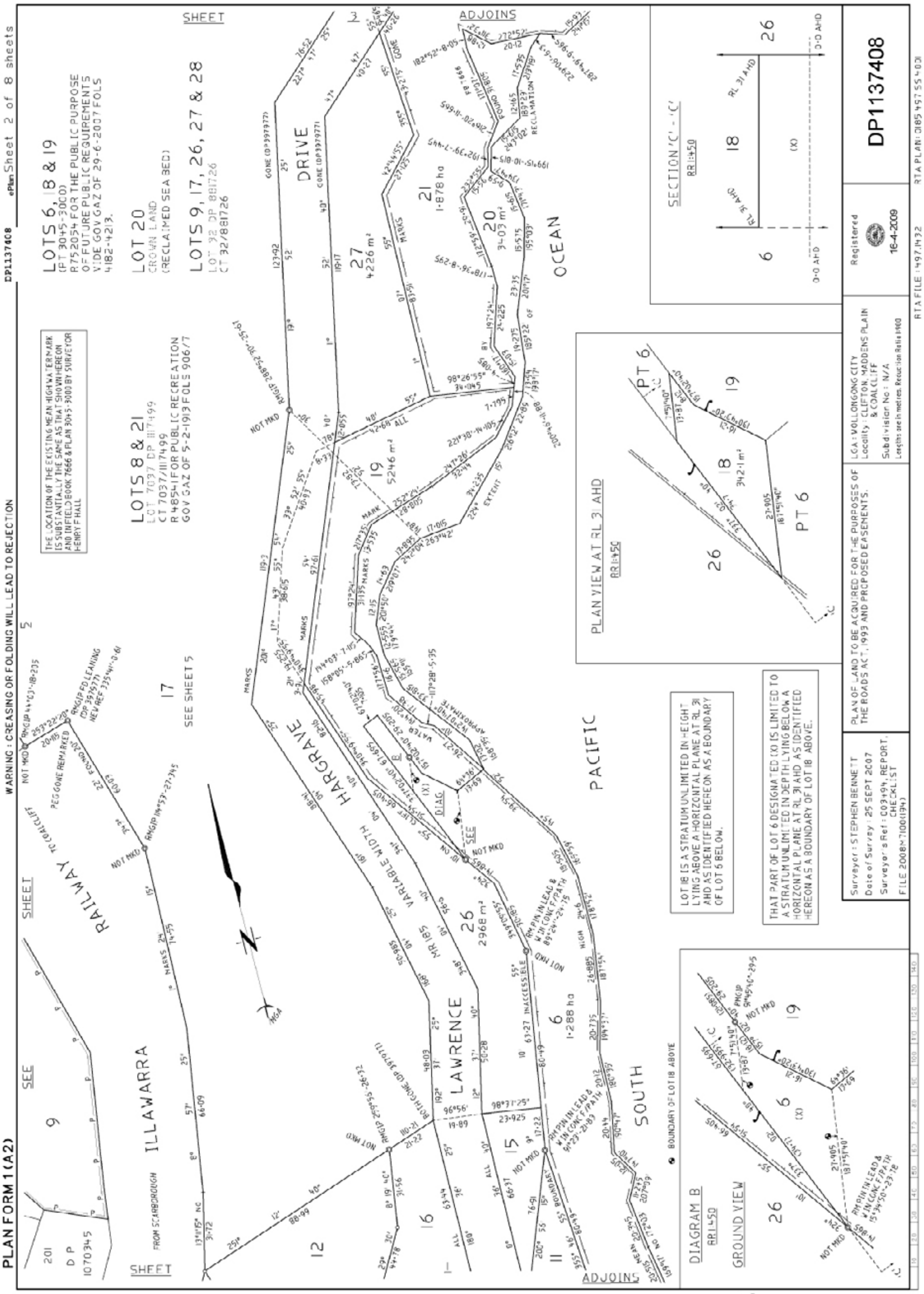
ILLAWARRA
RAILWAY
HARGRAVE
LAWRENCE
PACIFIC
DRIVE
SOUTH
CLIFTON SCHOOL PDE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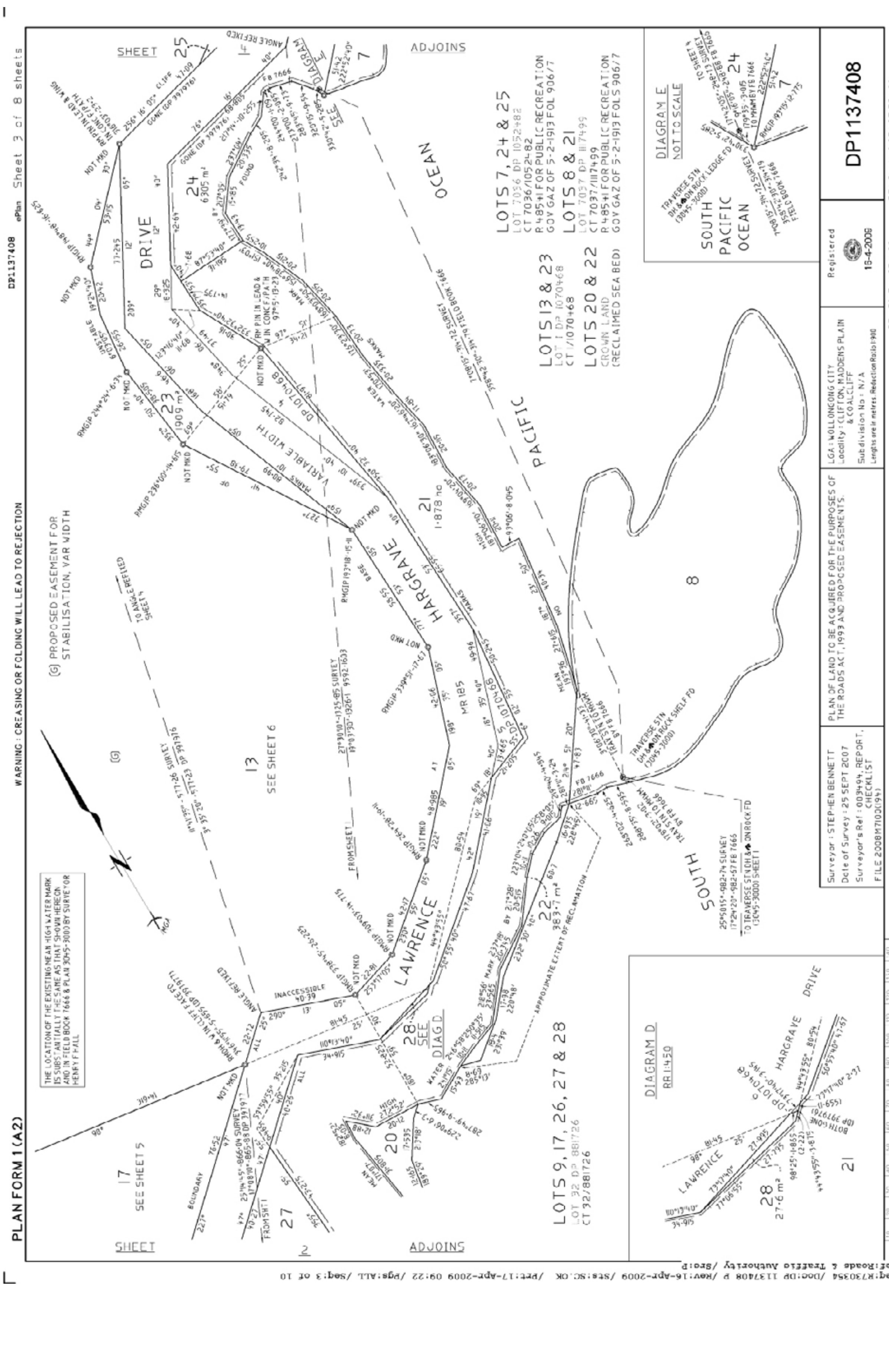
OCEAN
SOUTH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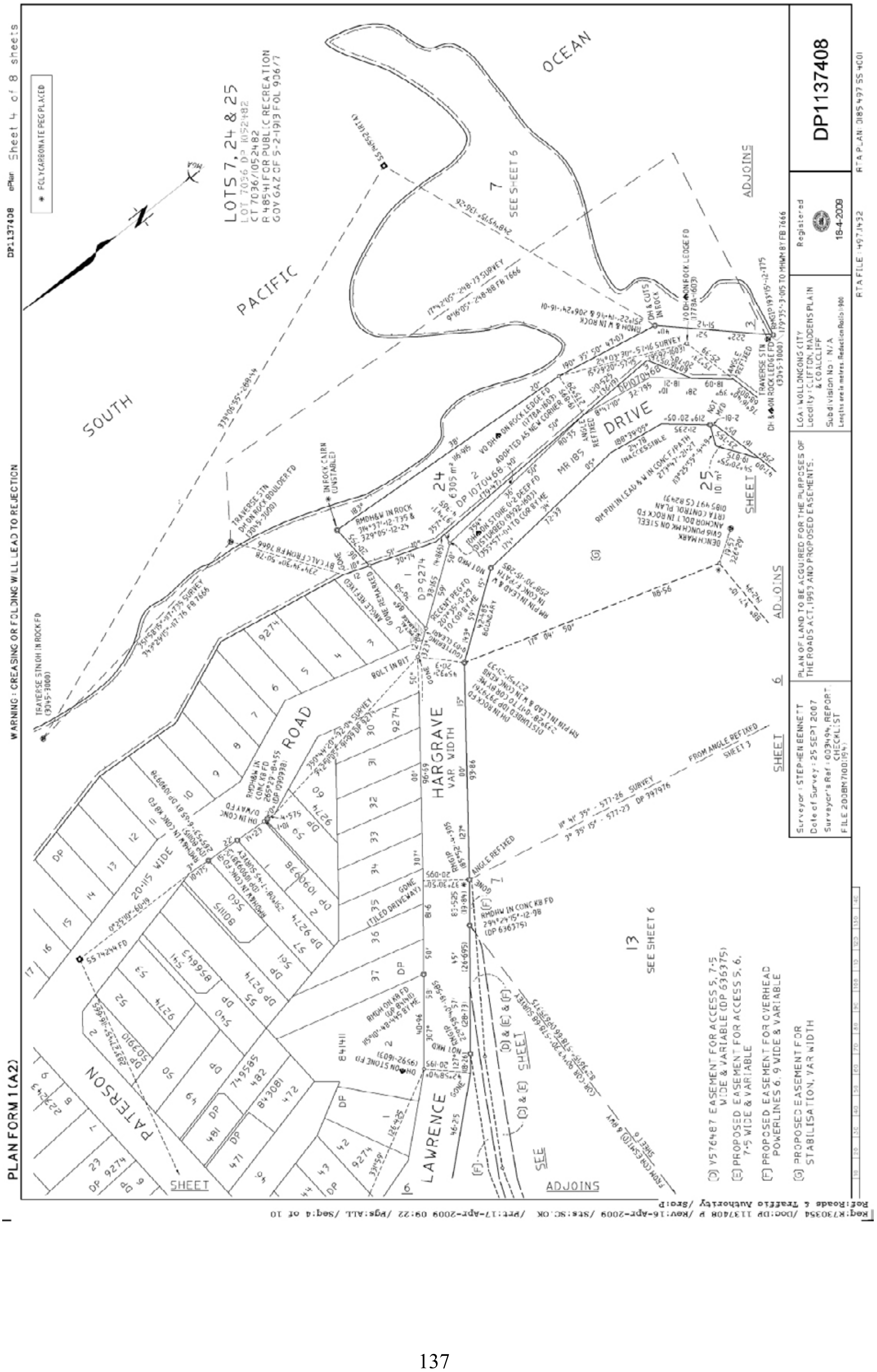
WARNING : CREASING OR FOLDING WILL LEAD TO REJECTION
DP1137408
HARGRAVE
DRIVE
LAWRENCE
OCEAN
PACIFIC
SOUTH
LOTS 7, 24 & 25
LOTS 8 & 21
LOTS 13 & 23
LOTS 20 & 22
LOTS 9, 17, 26, 27 & 28
DIAGRAM D
DIAGRAM E
NOT TO SCALE
SOUTH PACIFIC OCEAN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PACIFIC
OCEAN
LAWRENCE
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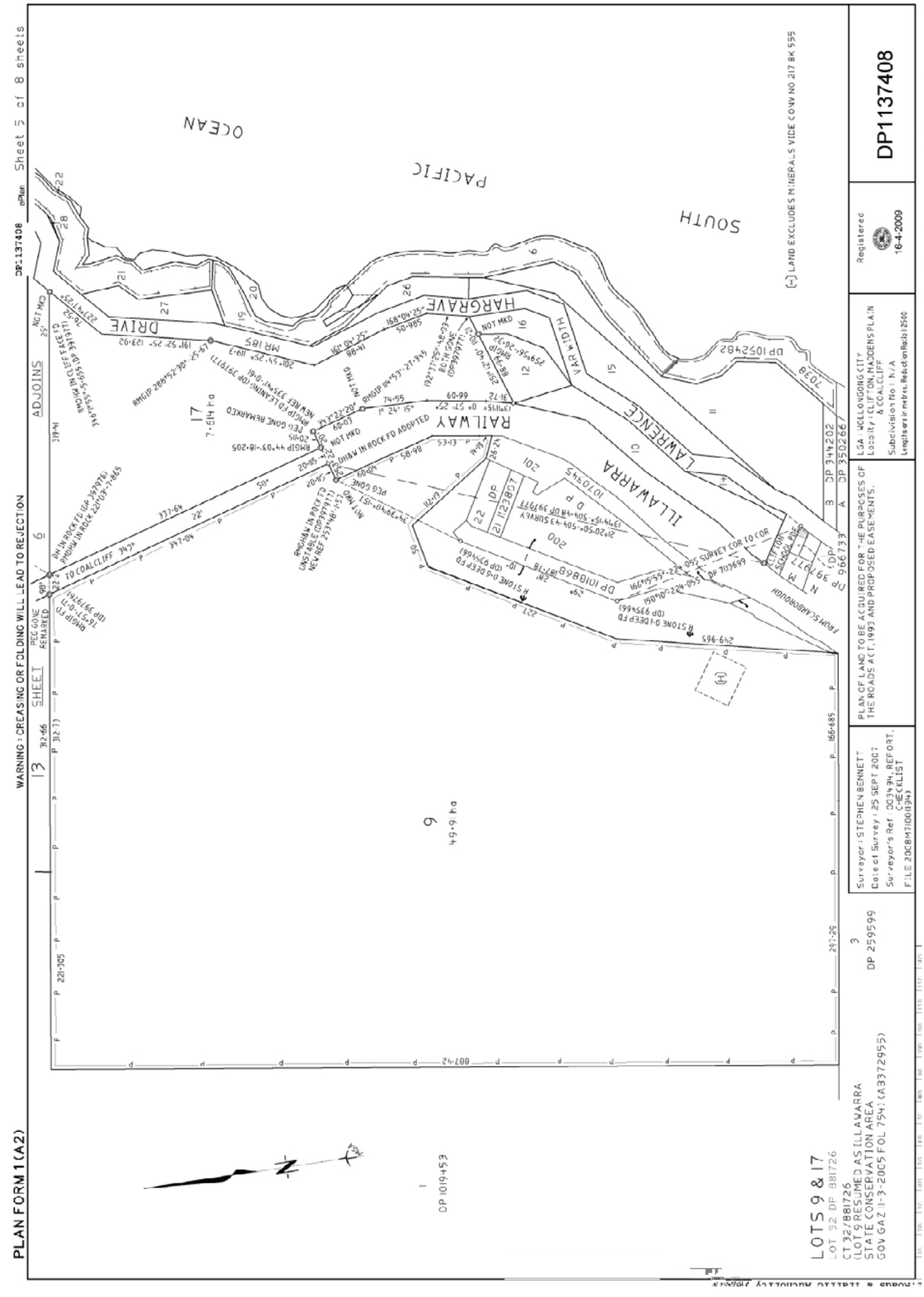
ROAD
LOTS 7, 24 & 25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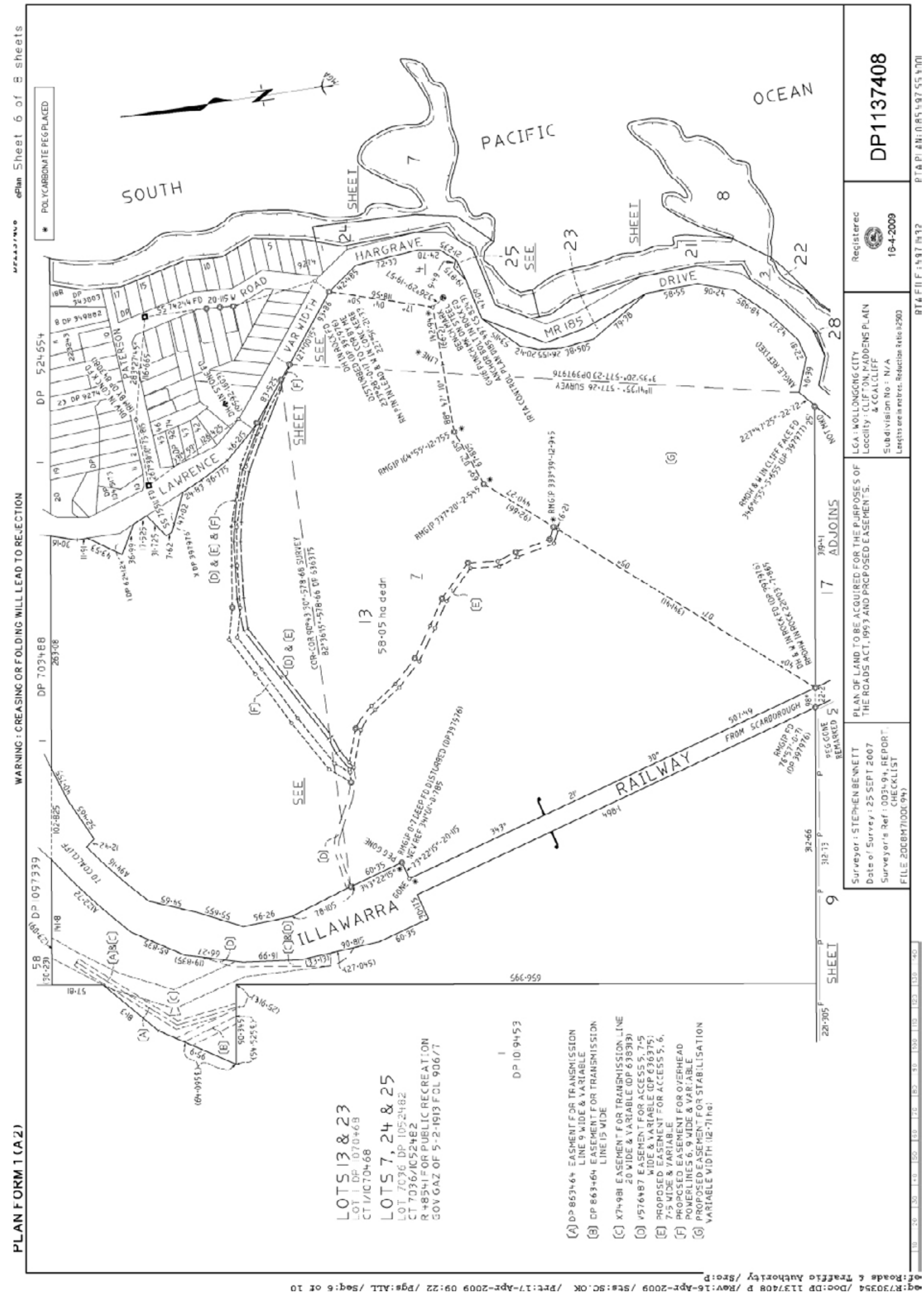
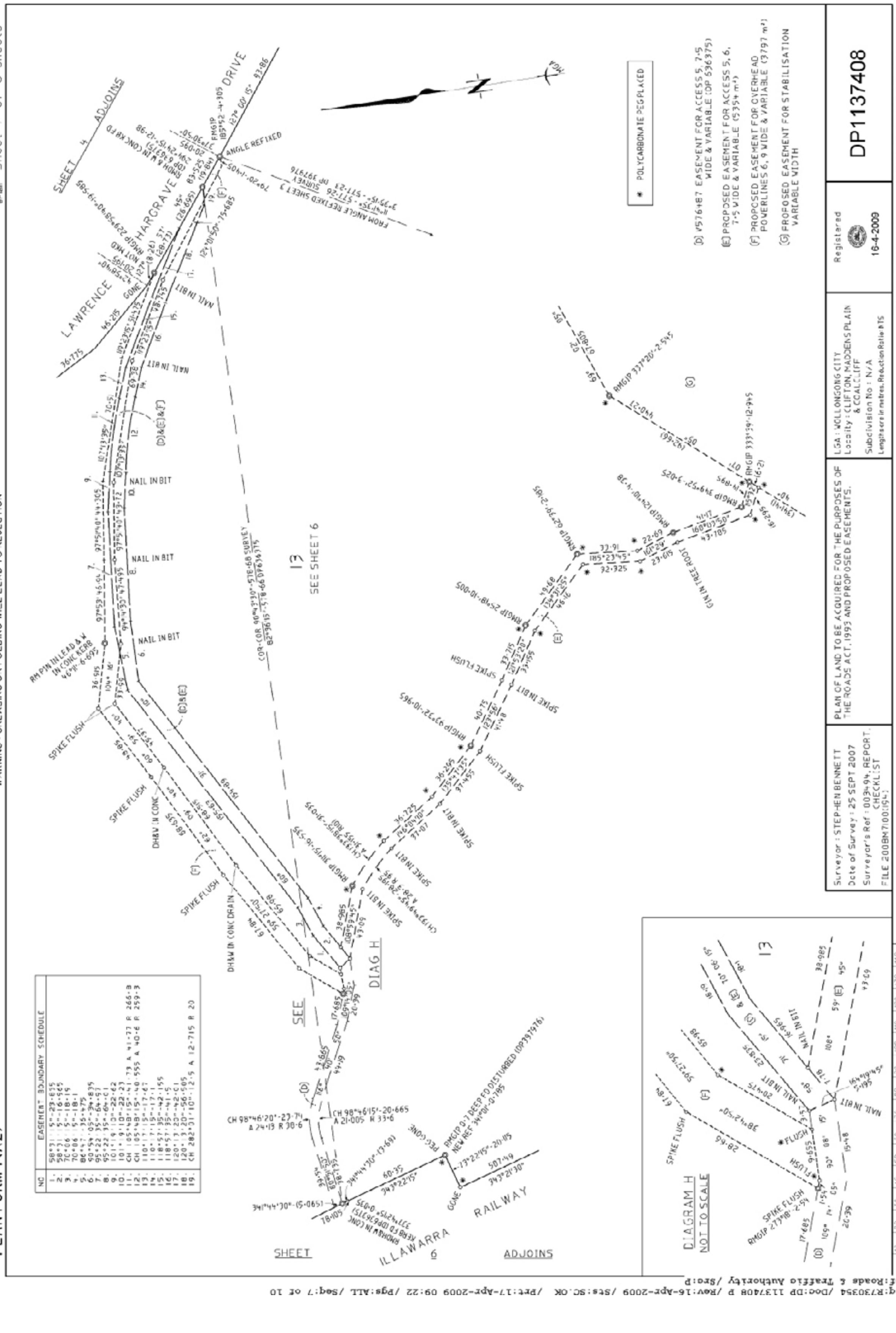
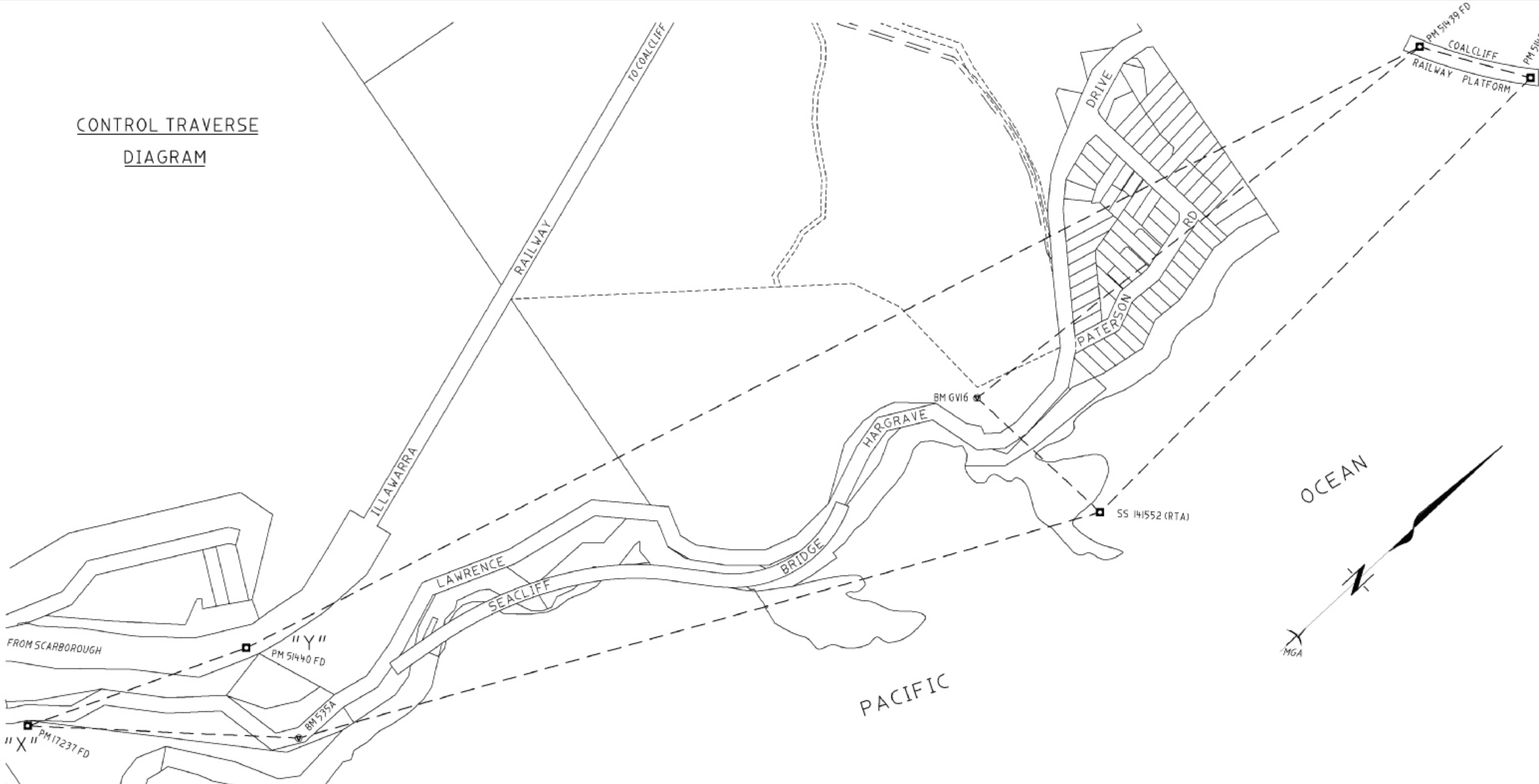
ILLAWARRA
LOTS 9 & 17


PLAN FORM 1 (A2)
WARNING : CREASING OR FOLDING WILL LEAD TO REJECTION
ePlan Sheet 6 of 8 sheets
POLYCARBONATE PEG PLACED
SOUTH PACIFIC OCEAN
DP1137408
LAWRENCE
HARGRAVE DRIVE
ILLAWARRA RAILWAY
MR 185
ADJOINS
LOTS 13 & 23
LOTS 7, 24 & 25
LGA: WOLLONGONG CITY
Locality: CLIFTON, MADDENS PLAIN & COALCLIFF
Subdivision No: N/A
Lengths are in metres. Reduction Ratio 1:2500
PLAN OF LAND TO BE ACQUIRED FOR THE PURPOSES OF THE ROADS ACT, 1993 AND PROPOSED EASEMENTS.
Surveyor: STEPHEN BENNETT
Date of Survey: 25 SEPT 2007
Registered 16-4-2009


PLAN FORM 1 (A2)
WARNING : CREASING OR FOLDING WILL LEAD TO REJECTION
Sheet 7 of 8 sheets
DP1137408
HARGRAVE
DRIVE
LAWRENCE
SEE SHEET 6
DIAGRAM H
NOT TO SCALE
ILLAWARRA
RAILWAY
PLAN OF LAND TO BE ACQUIRED FOR THE PURPOSES OF THE ROADS ACT, 1993 AND PROPOSED EASEMENTS.
Surveyor : STEPHEN BENNETT
Date of Survey : 25 SEPT 2007
Registered
16-4-2009

PLAN FORM 1 (A2) WARNING : CREASING OR FOLDING WILL LEAD TO REJECTION DP1137408 ePlan Sheet 8 of 8 sheets



CONTROL MARK TRAVERSE SCHEDULE		
FROM	TO	CONNECTION
PM 17237	PM 51440	23°06'14"- 299·837 (SURVEY COMPUTED) 23°06'14"- 299·832 (MGA GND SCIMS)
PM 51440	PM 51439	15°41'50"-1693·350 (SURVEY COMPUTED) 15°41'51"-1693·295 (MGA GND SCIMS)
PM 51439	PM 51438	58°18'31"- 148·082 (SURVEY OBSERVED) 58°18'42"- 148·079 (MGA GND SCIMS)
PM 51438	SS 141552	177°35'11"- 785·289 (SURVEY OBSERVED) 177°35'09"- 785·258 (MGA GND ⊕)
SS 141552	BM 535A	207°10'18"-1064·913 (SURVEY OBSERVED) 207°10'19"-1064·897 (MGA GND ⊕)
BM 535A	PM 17237	224°37'53"- 353·819 (SURVEY COMPUTED) 224°38'00"- 353·805 (MGA GND ⊕)
SS 141552	BM GV16	263°38'51"- 215·507 (SURVEY OBSERVED) 263°38'35"- 215·499 (MGA GND ⊕)
BM GV16	PM 51439	4°18'49"- 732·720 (SURVEY COMPUTED) 4°18'44"- 732·710 (MGA GND ⊕)

SURVEYING REGULATION 2006 : CLAUSES 35 (1) (b), 61 (2) & 62									
MARK	MGA CO-ORDINATES : ZONE 56		CL	ORD	AHD RL	CL	ORD	METHOD	ORIGIN
	EASTING	NORTHING							
PM 17237	313 082·898	6207 193·902	A	1	73·896	LB	L2	NA	SCIMS
PM 51440	313 200·554	6207 469·691	B	2	91·063	LB	L2	NA	SCIMS
PM 51439	313 658·697	6209 099·863	B	2	75·523	LB	L2	NA	SCIMS
PM 51438	313 784·702	6209 177·650	B	2	73·529	LB	L2	NA	SCIMS
SS 141552	313 817·781	6208 393·074	B	2	0·936	B	2	RTK GNSS	⊕
SS 74244	313 630·384	6208 709·277	C	NA	NA			CAD TRAV	FOUND
SS 75511	313 441·181	6208 733·133	C	NA	NA			CAD TRAV	FOUND
BM 535A	313 331·474	6207 445·681	B	2	44·582	B	2	RTK GNSS	⊕
BM GV16	313 603·603	6208 369·213	B	2	68·642	B	2	RTK GNSS	⊕
COMBINED SEA LEVEL AND SCALE FACTOR = 1·000019									
MGA CO-ORDINATES AND AHD REDUCED LEVELS ADOPTED FROM SCIMS AS AT 25 SEPTEMBER 2007									

⊕ RTA CONTROL PLAN 0185 497 CS 8243

Traffic Authority /Src:P

Preservation? of Survey Reference Marks

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ABSTRACT

In July 2009, the annual Capital Works Program planned to construct new concrete footpaths at 25 sites within the City of Ryde. Thinking that any new path may cover or destroy existing underground survey reference marks, it was decided to investigate the impact of these new footpaths on survey marks. Reading of all the Deposited Plans in the affected streets revealed that 60 reference marks had been placed (from 1921 to the 1960s). Field investigation of each mark position concluded that only 22 marks existed in situ. That is… two thirds are gone! Gone through various misadventures: driveways, services, drainage works, land regrading, fencing and retaining walls, or evaporation? It seemed clear that these 22 marks needed to be preserved during the footpath construction phase. How could this be achieved? Maybe through something visible on the ground surface to indicate the presence of a mark? A metal cover box seemed an ideal solution! Because, once placed, subsequent visits require merely the lifting of a lid and not twenty to forty minutes of probing, digging, finding the mark and restoring the ground, only for the next surveyor to repeat the same process when he/she arrives several years later, having no clue that the mark even exists. A depression in the ground only shows that someone else has looked there before! This paper investigates issues such as placing cover boxes, benefits for the surveying industry, involving the surveying industry and the Land Titles Office, and back to the future... from here to where. It also tries to answer the questions "Does anybody actually care?" and "Should we do nothing and let old reference marks go the way of alignment surveys and alignment stones?"

KEYWORDS: *Preservation, underground, reference mark, cover box.*

1 INTRODUCTION

Beginning with Ordinance 32 (23 June 1920) under the Local Government Act 1919, surveyors were required, when creating new roads, to reference mark such new roads with concrete blocks, placed on one side of the road only, at terminal points and bend points and being buried underground to a nominal depth of 4" (100 mm). The prescribed offset distance was 42" = 3'6" (1.067 m). Note that the mark, "concrete block" , is quite a substantial thing and requires a mighty effort to be placed correctly. Obviously, it was meant to last!

By 1933 (1 July), the offset distance was reduced to 18" =1'6" (0.457m), presumably to better preserve reference marks from the scourges of concrete footpaths and service utilities. By 1964 (30 October), the losses of survey reference marks due to telecommunication trenching were shouting out that a new method of preservation be tried. Surveyors were given the freedom to place reference marks wherever they felt that the mark had the best chance to last a long time: "…placed …so that the mark is not likely to be disturbed by existing or proposed services…" (Ord. 32).

High visibility was considered an advantage and large masses of concrete, close by, in the form of kerb and gutter, suggested stability and permanency, so pairs of drill hole and wing (DH&W) in kerb became the standard. By 2010, wholesale losses of DH&W in kerb have been caused by roundabout construction, replacement of kerb and guttering and drainage upgrades. Thus the search for reference marks is focussed back to the older, underground survey reference marks!

This paper is presented in two parts:

1. Preservation of underground marks by metal cover box.
2. Preservation of marks by re-establishment.

2 PRESERVATION OF UNDERGROUND MARKS BY METAL COVER BOX

In July, 2009, I became aware that, in the annual Capital Works Program, it was planned to construct new concrete footpaths at 25 sites within the City of Ryde. Thinking that any new path may cover or destroy existing underground survey reference marks, it was decided to investigate the impact of these new footpaths on survey marks. Reading of all the Deposited Plans in the affected streets revealed that 60 reference marks had been placed (from 1921 to the 1960s). Field investigation of each mark position concluded that only 22 marks existed in situ. That is…two thirds gone! Gone through various misadventures: driveways, underground services, drainage works, land regrading, fencing and retaining walls, evaporation?

It seemed clear to me that these 22 marks needed to be preserved during the footpath construction phase. How to achieve this? Something visible on the ground surface to indicate the presence of a mark, like a metal cover box, seemed an ideal solution (Figure 1).

Figure 1: Metal cover box indicating presence of survey mark.

Once placed, subsequent visits require merely the lifting of a lid and not twenty to forty minutes of probing, digging, finding the mark and restoring the ground, only for the next surveyor to repeat the same process when he arrives several years later, having no clue that the mark even exists. A depression in the ground only shows that someone else has looked there before!

The metal cover boxes used by Ryde City are stock standard with 'SURVEY' embossed on a circular lid. From the foundry the boxes are painted black and this is how they were initially used. It was soon decided to paint the lids white to maintain the survey mark colour convention and to distinguish them from the yellow painted SCIMS marks, stop valves and hydrants. A minor bonus is that little white squares are clearly visible on the Ryde aerial photos, indicating where some of the marks are!

Back to the footpath construction... 18 cover boxes were placed. Proximity to concrete driveways prevented the placement of the other 4. The sites of the marks were noted on the construction plans, with text saying "SURVEY REFERENCE MARK - PRESERVE AT ALL COSTS". After construction, all 22 had survived (Figure 2).

Figure 2: Metal cover boxes clearly identify the presence of survey marks during construction.

For deeply-buried reference marks, 150 mm diameter PVC tubing allows access from the surface to the top of the mark (Figure 3).

Figure 3: Using PVC tubing to allow access to deeply-buried marks.

The negative... Cover box has a cost. Field inspection required after construction to correct any misadventures that occurred during construction (e.g. concrete spillage onto mark or cover box shift).

The positive... One person operation. Footpath construction adjusts cover box to finished level.

Here I must acknowledge and thank NSW Land and Property Information (LPI) for the generous donation of our first 20 cover boxes. Subsequently, Ryde City has been purchasing cover boxes directly from the foundry and placing them during the course of normal survey work, as the finding of buried reference marks occurs.

2.1 How to Increase the Rate of Preservation?

I thought that the easiest way to locate marks would be via the private sector, with surveyors who worked in the Ryde City area, contacting us with a find and location. It seems so simple:

1. Surveyor locates buried mark during fieldwork.
2. At calculation or plan drawing phase, surveyor sends e-mail to Survey section at Ryde City telling of find.
3. Said mark is promptly cover boxed and preserved by Council.

None of the frustration and time wasting of a fruitless search! Also, with Ryde City carrying out all the cover boxing, there is a certain uniformity and standard maintained. An article was placed in Azimuth in March 2011, to inform surveyors.

2.2 How Wrong was I?

So far, 480 marks have been cover-boxed. But, only 10 have been notified to Ryde City by the surveying industry (and these from just three firms). Why such complacency?

Nevertheless, Ryde City is pressing on regardless! For example, in a 1-kilometre square (covering about forty streets) around my office, there are merely 8 buried reference marks remaining (Figure 4).

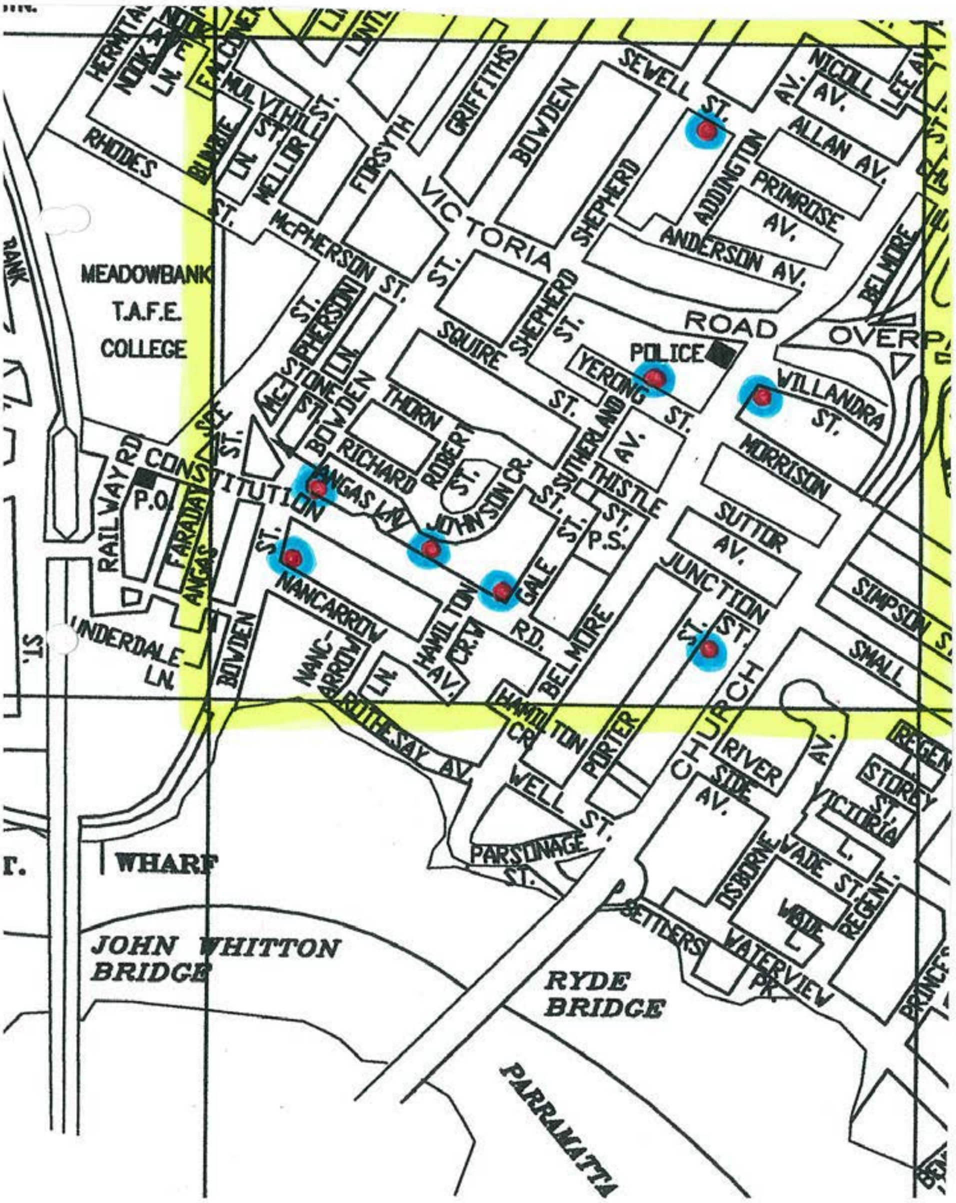

Figure 4: Only 8 buried reference marks remaining in this 1-kilometre square area.

We have no idea how many buried reference marks still exist in Ryde City that are yet to be uncovered and then covered.

I should bring to your attention the subdivision of Dobson Crescent in Ryde where the surveyor in 1956 was fifty years ahead of his time. In his Deposited Plan 24598 (Figure 5) he placed 27 concrete block reference marks to define the street, i.e. a mark at every 12.19 m! He obviously foresaw how many marks would be lost, as only 10 survive today!

A suggestion for what to show on plans:
(DP24598)
RM CONC BLK FD (COVER BOX)
41` 15’ 0.465
(0.4 DEEP)

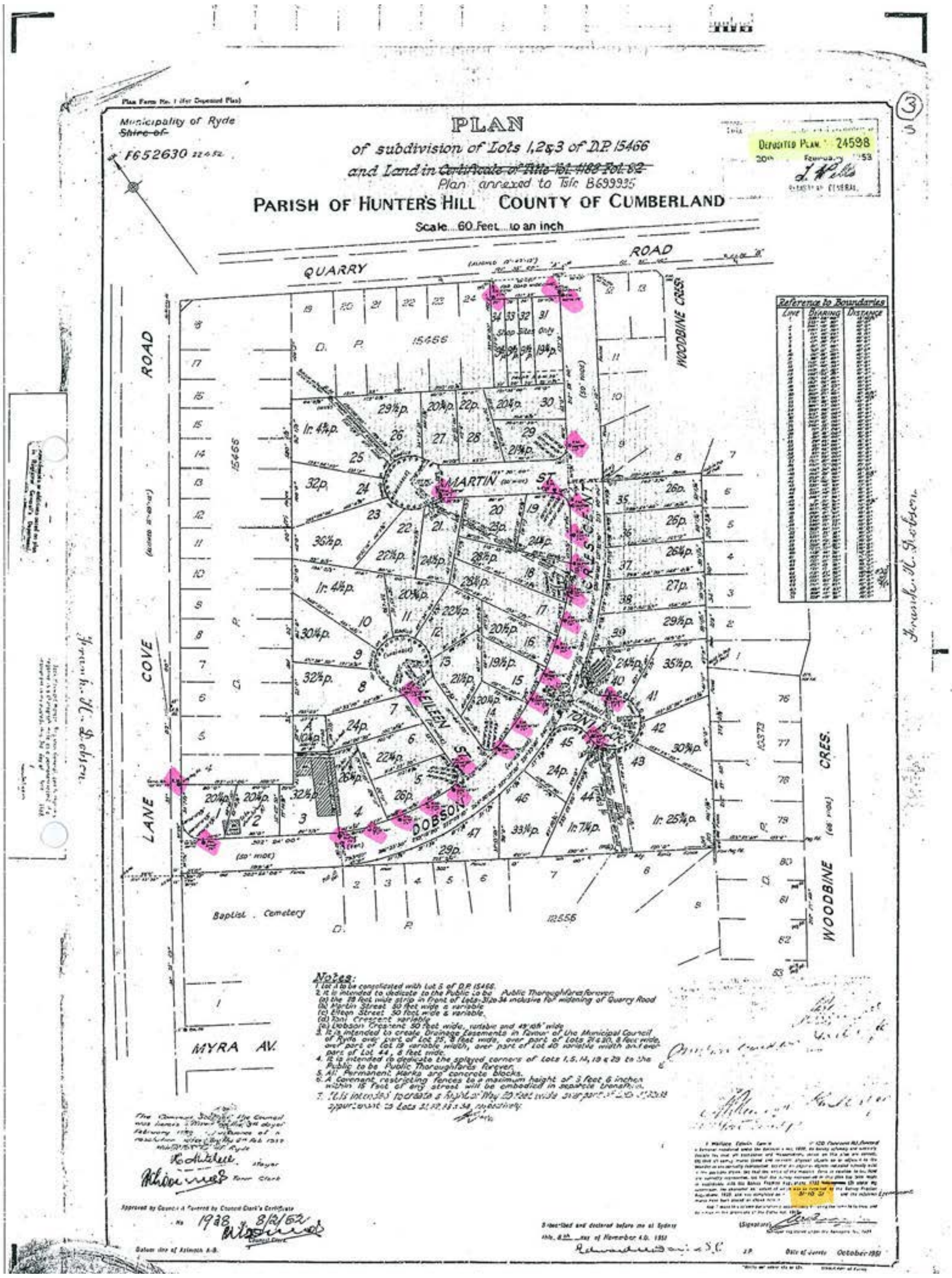

Figure 5: DP 24598, showing 27 concrete block reference marks placed in 1956.

2.3 What is in the Future?

With a couple of years' experience we are now in a position to foresee something of the future. In Ryde we will establish a database which contains information on each found reference mark, such as location, origin (placed by which DP), MGA coordinates, photograph and when recorded. This information can be illustrated electronically in a GIS layer (in our case, on RydeMaps).

Ryde already obtains annual Capital Works programs from the main underground services providers such as electricity. Knowing construction programs in advance, we can access the database and find which reference marks are in danger of disturbance. We know of 4 marks which have gone since being cover-boxed. Undergroundings of the electrical network and telecommunication network were the culprits! The rollout of the National Broadband Network could well be the next big threat!

By having the reference marks cover-boxed and well documented there is a chance that any losses could be subject to Section 24(1) of the Surveying Act 2002 which states that "a person shall not remove, damage, destroy, displace, obliterate or deface any survey mark unless authorised to do so by the Surveyor-General. In addition to a maximum penalty of 25 penalty units (which is currently $2,750) a person found guilty by a court may be required to pay compensation up to $10,000 towards the cost of reinstatement plus up to $10,000 towards loss or damage suffered."

May I end Part I with two unsolicited testimonials:

"In recent years I …have experienced the pleasure of finding a number of the metal cover boxes over marks – this is a great initiative." (John Higgins)

"…I have been digging up a few blocks and GI pipes in the Parramatta area lately and wondering if they might start putting covers on like in the Ryde Council area. Any chance of convincing your Council neighbours of the benefits of preserving these marks?" (Chris Hill)

3 PRESERVATION OF REFERENCE MARKS BY RE-ESTABLISHMENT

Re-establishment requires locating the reference marks by survey and either
(a) re-marking, after construction, in concrete footpaths and kerbs, or
(b) connecting existing marks to the survey control network and preparing a plan for lodgement at LPI.

3.1 Re-marking

This requires the input of a registered surveyor. Essentially, re-marking means the placement of a mark in the same location as the reference mark which is to be destroyed. Registered surveyors are charged with maintaining the integrity of the State's cadastral system, and as such are best placed to oversee this re-marking. Apart from anything else, we are the ones who will be using these marks.

With advanced warning that a footpath or kerb is to be renewed, any threatened reference mark can be well surveyed before reconstruction occurs, and thus be replaced afterwards on

the new footpath or kerb. A drill hole and wing as the replacement mark should suffice, as a new laid kerb or path hardly looks as if it has been there for fifty years, making it fairly obvious that the reference mark is not the original one. Perhaps a drill hole with two wings cut would be more obvious as a re-mark!

Then there is the question of what to do when a service utility lays an underground supply and restores the ground surface with turf! Should a like mark be re-instated, i.e. block for block, pipe for pipe (even re-using the original mark, if retrieved)? Validation comes with subsequent public plans of survey (being lodged for registration at LPI) showing, adopting and referencing the new marks.

A 500 m section of concrete kerbing along Cox's Road was recently removed and replaced. Four survey reference marks (drill hole and wing in kerb) were destroyed. These were the only remaining marks prior to construction. Before construction, and during construction, a survey party was in attendance which enabled those marks to be surveyed several times. After construction I felt almost duty bound to re-mark those drill holes in their previous positions.

The negative... Big investment in time and effort: a double visit by field party, requiring co-ordination with construction. Risk of error in replacement.

The positive... New mark visible in same position as old.

3.2 Connecting

This means surveying the threatened reference marks and preparing a plan which shows the reference marks connected to the survey control network and MGA coordinates. The plans lodged are designated "for survey information purposes only". Shouldn't LPI be accepting such plans free of charge, thereby encouraging the survey fraternity to utilise this system for preservation of mark position?

The negative... Big investment in time and effort: a visit by field party and connection to control marks. No marks visible. Risk of error in connection. The need to prepare a plan for lodgement at LPI.

The positive... Public plan available showing connection to control network and MGA coordinates. A new mark can be re-instated in the future if required.

4 WHO CARES?

All new surveys are connected to MGA. If the reference marks go then the boundaries can be reconstructed from the MGA network. Even losing SCIMS marks… does it really matter… when we've got satellites? Maybe with reference marks it's the comfort of knowing that in some places you are spot-on and in exactly the same place as the original surveyor.

Times change, techniques change, expectations change.
How many trees have you marked recently?
When was the last time you saw an alignment post?
When was the last time you saw an alignment stone (Figure 6)?

Figure 6: Alignment stones.

5 CONCLUDING REMARKS

We, as registered surveyors, should be doing our darnedest to preserve the reference marks which still exist and we should be mindful of placing future reference marks in positions which will last a long time.

Does the surveying industry have a problem with re-instating a drill hole and wing? When we place an underground reference mark, such as a GI pipe, should we be required to place a cover box at the same time? A cover box is visible at the surface and shows the general public and adjacent property owner the existence of a valuable survey reference mark (Figure 7).

Figure 7: Metal cover boxes clearly identify the presence of survey marks.

The Development of an Australian Standard in Subsurface Utility Engineering (SUE)

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ABSTRACT

While the location of subsurface utilities often appears on design plans, due to the lack of historical evidence utility locations may not be exactly as shown or the records may not fully account for all the buried utility systems. This lack of reliable information during design and construction activities can result in costly conflicts, delays, utility service disruptions, redesigns, personal injuries to workers, and even lost lives. Standards Australia (SA) has begun the formal process of developing an Australian Standard for the practice of Subsurface Utility Engineering (SUE). SUE is an engineering process that combines civil engineering, geophysics, survey and CADD/GIS. It provides much more accurate information on the location and condition of subsurface utilities than has been traditionally available. The 24-36 month process, which began in May 2010, commenced with a needs assessment and input from various constituents. The first official meeting of the Technical Development Committee, comprising representatives of government, private industry, research, academia, users, suppliers and professional organisations, was held in August 2011, and the Committee has begun to draft the proposed Standard. There may be an opportunity for the work to develop into a joint Australia-New Zealand Standard. A major challenge for the Development Committee is that this is a "consensus" Standard. Although each party recognises the value of a Standard, each member represents different and often disparate interests. Unless consensus can be reached, the development of the Standard will lie on the shelf, similar to the recommendations from the 1977 ISNSW Seminar which originally advocated it 35 years ago. This paper outlines the process of developing the Australian Standard, the net benefit to the community, progress of the project to date and a review of the key elements proposed for the Standard. SA anticipates that the new standard will be published in March 2013.

KEYWORDS: *Subsurface Utility Engineering, SUE, Australian Standard, Standards Australia.*

1 INTRODUCTION

The concept of Subsurface Utility Engineering (SUE) was introduced to APAS at the 2011 conference in Bathurst, NSW (Gordon, 2011). SUE is an engineering process that combines civil engineering, geophysics, survey and CADD/GIS. It provides much more accurate information on the location and condition of subsurface utilities than has been available to date. Knowing precisely "where and what" a subsurface utility is, its condition and its status in its asset lifecycle can significantly reduce the occurrence of interference and conflict with valuable infrastructure.

In an effort to improve public safety and reduce costly property damage, Standards Australia (SA) has begun the process of developing an Australian Standard for the practice of Subsurface Utility Engineering. Broad definitions of SUE are already in place and promoted by governmental agencies in the United States (American Society of Civil Engineers, 2003) and Canada (Canadian Standards Association, 2011) and are being developed in the United Kingdom. Such a Standard will provide all levels of government, utility instrumentalities and developers with an understanding of the inefficiencies, risks and associated costs of the current practices of acquiring utility asset information.

The proposed Standard will recommend the absolute positioning of subsurface utilities in three dimensions as an improvement upon the current widely adopted methods of relative positioning. In countries prone to natural disasters, such as Australia and New Zealand, or terrorist attacks, such as the USA, absolute positioning appears to be a logical and necessary improvement when called upon to locate critical subsurface utility assets after the event.

2 NET BENEFITS TO SOCIETY

Historically, inaccurate or incomplete subsurface utility records have resulted in unintentional strikes on subsurface utilities by construction organisations and members of the public. However, with a SUE standard, many of these conflicts can be avoided. A United States Department of Transport (USDOT) guidebook (United States Department of Transport Federal Highway Administration, 2003) states that the proper use of SUE will eliminate many of the utility problems typically encountered on highway projects.

Studies in the United States (Department of Building Construction, Purdue University, 2000; Pennsylvania State University, 2007) and Canada (University of Toronto, 2005) have demonstrated that adopting a SUE process results in significant net tangible benefits to society. Consequently, SUE standards have become a routine standard of care requirement on highway and bridge design projects in the United States (American Society of Civil Engineers, 2003) and Canada (Canadian Standards Association, 2011).

3 COST BENEFIT

According to a survey conducted by Toronto University in 2004, two broad categories of savings emerged from using SUE – quantifiable and qualitative savings (University of Toronto, 2005). The Purdue University study (Department of Building Construction, Purdue University, 2000) quantified a total of US$3.41 in avoided costs for every US$1.00 spent on SUE. Subsequent university studies elsewhere have concluded higher benefits (Pennsylvania State University, 2007).

To relate these benefit/cost studies to Australia, we can use information supplied by the former Roads and Traffic Authority of New South Wales (RTA), now Roads & Maritime Services (RMS). RMS has a mature SUE process operating from within its Surveying Branch. RMS's 2009 Annual Report indicated that the RMS managed a road network that includes 17,981 km of RMS-managed State roads. Expenditure on capital works on these roads was $2,262,000,000 in 2008-09. To show the potential financial benefits of using SUE, let us assume that it was only used on projects encompassing one fifth, or 20%, of these funds

($452,400,000). Typically in the United States, 10% of total project expenditures are allocated to preconstruction and 5% of these preconstruction expenditures are spent on the SUE process. Thus, $452,400,000 x 0.10 x 0.05 = $2,262,000. As a reality check, this amount is well below the 2010-11 expenditure of RMS ($2.8 million) for the location and mapping of subsurface utilities in Sydney alone using in-house and contract resources. Adopting the conservative Canadian savings outlined above, $2,262,000 x 3.41 = $7,713,420 in benefit.

These substantial savings are primarily the result of two processes:
1. Project designers seriously considering accurate SUE information when designing projects, thereby avoiding spending money for unnecessary utility relocations and later during construction for delay claims.
2. Actual subsurface utility location immediately prior and during the construction stage of a road project, avoiding costs for utility hits and ensuring that all on site are aware of the location of the subsurface utility services.

These benefits are also recognised elsewhere across Australia. New South Wales RailCorp and Main Roads Western Australia (Main Roads Western Australia, 2009) have also adopted SUE-based standards for the mapping of subsurface utility services.

The cost of conflicts with subsurface utility infrastructure is not often appreciated, particularly in comparison with the cost of natural disasters. These costs represent a saving to the community had the subsurface utility asset not been hit. For example, the $800 million cost of one incident in September 2009 where a contractor cut through Telstra cables in York Street, Sydney exceeded the current loss (in 2006 dollars) from the 1976 and 1986 Sydney hailstorms ($730 million and $710 million respectively), equated to 70% of the current loss from Cyclone Madge in 1973 and was almost equivalent to the original loss figures of the 1989 Newcastle earthquake. The important consideration is, whereas natural disasters cannot be avoided, the impact of strikes on subsurface utility infrastructure can be significantly reduced by using the SUE process.

The adoption of absolute positioning of subsurface utility infrastructure in three dimensions is also of significant value to society in the aftermath of a natural disaster or a major terrorist incident. Instead of relying on relative positioning to structures which may not survive the event, absolute positioning is referenced to a global reference system. Even if major movement has occurred, this movement is measurable and the application of movement data to the original position of the subsurface utility can be made to determine its new position.

The proposed Standard should also increase consumer confidence in a utility organisation's records management system by reducing inaccurate mapping and increasing the quality of stored information.

4 THE SUE INITIATIVE

Standards Australia has two pathways for Standards development: *Externally Funded* and *Resourced*. The *Resourced* pathway is available at no cost provided that the project meets certain criteria and resources are available. By October 2010, sufficient funds had been pledged to commence the SUE Standard project under the *Externally Funded* development pathway.

Principal financial contributors are:

- Australian Local Government Association (ALGA)
- Austroads
- Essential Energy
- National Utility Locating Contractors Association (NULCA)
- NSW Board of Surveying & Spatial Information (BOSSI)
- Roads & Maritime Services (RMS)
- Roads Australia
- South Australia Department of Transport Energy & Infrastructure
- Vac Group Pty Ltd
- Water Services Association of Australia (WSAA)

Funding has also been committed by the Emergency Information Coordination Unit of LPI NSW (EICU), the Surveying & Spatial Sciences Institute (SSSI), Dial Before You Dig and the Surveying and Mapping Industry Council of NSW (SMIC). These additional funds may be required (i) during the project for out-of-pocket expenses by committee members and (ii) once the Standard is published for education, training and the 5-year review of the Standard. This management of the funding is an independent initiative of SMIC, and SMIC takes full responsibility for the collection and disbursement of funds apart from amounts contracted directly with stakeholders by Standards Australia. SA does not oversee the collection or distribution of these funds by SMIC, and SA does not authorise any organisation to collect any funds on behalf of SA or any of its committees. For transparency stakeholders should be aware that Mark Gordon is the Chair of Standards Australia Committee IT-036 Subsurface Utility Engineering and also the Chairman of SMIC.

5 SA STANDARDS DEVELOPMENT PROCESS

Standards Australia (SA) is an independent, non-governmental organisation that leads and promotes a respected and unbiased standards development process. SA represents Australia on the International Organisation for Standardisation (ISO). A number of principles continue to be the basis for all SA Standards. These include open committee discussions for all parties of interest, a balanced representation on working committees, an 80% agreement with a lack of sustained opposition ("consensus"), and neutral facilitation by SA staff.

Once funding had been pledged, the next step in the process was to form a Technical Development Committee, which is responsible for developing and drafting the Standard. Typically, the Committee is comprised of representatives from national "umbrella" organisations representing many interests. It reports back to, and obtains advice from, those interests. Sectors of interest are determined by Standards Australia, and may include consumer/community groups, employer bodies, government (federal, state and local), independent professional and technical bodies, manufacturers/suppliers, regulatory and controlling bodies, researchers/academics and testing organisations, unions/employees, and user and purchasing bodies.

The Committee collectively represents the views of all stakeholders. In order to maintain the credibility and transparency of the standards development process, there are no special rights or privileges conferred on funding organisations. Funding organisations essentially contribute to a process but they do not buy the outcome of that process, i.e. they do not influence the outcome beyond that provided by the representative of their national organisation on the

Committee.

Whilst funding was being confirmed, a preliminary meeting of the SUE Standard Technical Development Committee was held on 21 March 2011. Standards Australia appointed Mark Gordon (Austroads) as Chair, supported in the capacity of Deputy Chair by independent international expert, Nick Zembillas. Nick has been a member of both the USA and Canadian Standards development committees.

Membership of the Technical Development Committee currently includes the following organisations:

- **Users:** Australian Local Government Association (ALGA), Australasian Railway Association (ARA).
- **Suppliers:** Dial Before You Dig, Energy Networks Australia (ENA), Water Services Association of Australia (WSAA), NBN Co.
- **Technical Associations:** Institute of Public Works Engineering Australia (IPWEA), Streets Opening Conference, National Utility Locating Contractors Association (NULCA).
- **Industrial Associations:** Australian Services Union.
- **Professional Associations:** Geospatial Information & Technology Association (GITA) ANZ, Surveying & Spatial Sciences Institute (SSSI), Engineers Australia (EA).
- **Government:** ANZLIC – The Spatial Information Council, Austroads.
- **Academia:** University of New South Wales (UNSW).
- **Regulatory:** Heads of Workplace Safety Authorities (HSWA).

6 MOVING FORWARD

The SA Standards development process contains seven distinct stages:

1. **Concept**: Defining and evaluating a new project initiative.
2. **Initiation**: Formally initiating the project and undertaking detailed project planning.
3. **Design**: Completing the design of the Standard or solution.
4. **Build**: Building the Standard, including public consultation.
5. **Implementation**: Approval for publication and delivering the Standard.
6. **Finalisation**: Formal closure of the project.
7. **Benefits Realisation**: Ensuring the benefits envisaged at the start of the project have been realised.

At this point in time, Stage 2 – initiation – is complete and Stage 3 has been commenced. Stage 3 involves the development of the content for the Standard, including discussion and consensus on the draft and editing it for public comment. It is most important to engage as many stakeholders as possible to ensure that consensus can be realised, and this is a primary reason for continuing education through presentations at seminars and conferences. Utility authorities, public works and transportation officials in addition to other stakeholders must be made aware of the development of the Standard so that they have the opportunity to take an interest or contribute to its development. It is far better to be an active participant rather than have a final Standard imposed without the advantage of time to analyse, plan, and prepare for any changes in current procedures. Further education will take place in conjunction with Stage 6, when an industry education and training program will be launched. Stage 7 will take place 12 months after the publication of the Standard, for a review of actual benefits realised. The review process is then repeated every 5 years, so that the Standard maintains its currency.

Subject to consensus, it is anticipated that the Standard will be approved and in place by March 2013.

7 KEY ELEMENTS PROPOSED

Although it is still too early in Stage 3 of the process to identify what the proposed Standard will contain, the current key requirements of the Australian SUE Standard, as identified by the stakeholders, are:

- To build on accepted best practices and processes through detailed research and analysis.
- Application of Quality Levels A, B, C, D currently adopted in overseas Standards and Guidelines such as the American Society of Civil Engineers' ASCE-3802 Standard *Guideline for the Collection and Depiction of Existing Subsurface Utility Data* (American Society of Civil Engineers, 2003) and the Canadian draft CSA S250 Standard *Mapping of Underground Utility Infrastructure* (Canadian Standards Association, 2011).
- The adoption of the locational absolute accuracy in three dimensions for the highest Quality Level (A).
- The inclusion of comprehensive metadata to identify the nature of a subsurface utility, its condition and status.
- To ensure the Standard is in plain English, with a content that is realistic, achievable and practical without placing an undue burden on practitioners and utility organisations.

An Australian Standard is not compulsory. However, it is hoped that the SUE Standard will be adopted by utility organisations and regulators as reflecting best practice. It is expected that there will be widespread support for the Standard and that this support will be exhibited through a modification by stakeholders of their internal processes, practices and systems. Most importantly, it would be ideal if government organisations in charge of the transport corridors in which most utilities are located insist on the adoption of the Standard for the placement, repair or relocation of utility services within those corridors to the extent that such activity reflects the highest quality level and locational absolute accuracy.

8 CONCLUDING REMARKS

In Australia, inaccuracies and inconsistencies in subsurface utility information have been recognised as major contributors to unnecessary and avoidable cost overruns, service disruptions, redesigns and personal injuries since at least an Institution of Surveyors NSW seminar on the topic in March 1977 (ISNSW, 1977). The development and adoption of an Australian Standard in the location and mapping of subsurface utilities, known as Subsurface Utility Engineering, will provide immediate tangible benefits to our society and provide the foundation for more efficient design and construction activities in the future.

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Dial Before You Dig: It's the Law in New South Wales

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ABSTRACT

After a series of embarrassing power cuts to the Sydney CBD in 2009, the New South Wales Government criminalised reckless and deliberate damage to gas and electricity networks. As a result, New South Wales is the only Australian jurisdiction to specifically require notification of excavations to Dial Before You Dig. Despite this requirement, major damage to underground utilities still occurs. Repair costs and lost business total thousands of millions of dollars every year. Many workers are also put at risk from contact with gas mains and electricity cables. Understanding the nature of utility networks allows surveyors to avoid liability and reduce the risk of damage to networks under your work sites.

KEYWORDS: *Utilities, underground networks, damage, liability*.

What is Dial Before You Dig?

- Dial Before You Dig is a non-profit referral service. It represents most of Australia's underground asset owners
- Dial Before You Dig has a single contact number - **1100**
- Dial Before You Dig is online - **www.1100.com.au**

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The Straw that Broke the Camel's Back

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It's the Law in New South Wales

- Changes to the NSW Electricity and Gas Supply Acts:
  - Cost recovery for cable damage
  - Making Dial Before You Dig and notification of works time and place compulsory
    - Maximum penalty – 20 penalty units
  - Injunctions where networks are in danger

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- Mandatory notification of cable damage
  - Maximum penalty – 20 penalty units
- Cable damage made a criminal offence
  - Maximum penalty – 4,000 penalty units for a corporation, or 200 penalty units or imprisonment for 5 years (or both) for an individual

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- When do you use Dial Before You Dig?
  - Work requiring consent or approval
  - Work by a public authority
  - Work on underground utility services
- What exemptions are there?
  - Emergency work
  - Potholing or soft digging

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Consequences of Damage

- **Disruption**
- **Repair costs**
  - Typically $50 a pair for Telstra
  - Jemena charges for lost natural gas
  - Average electricity repair cost is $25,000
    - In 2009 the record was $1 million
- **Third party losses**
  - Australian record is $800 million

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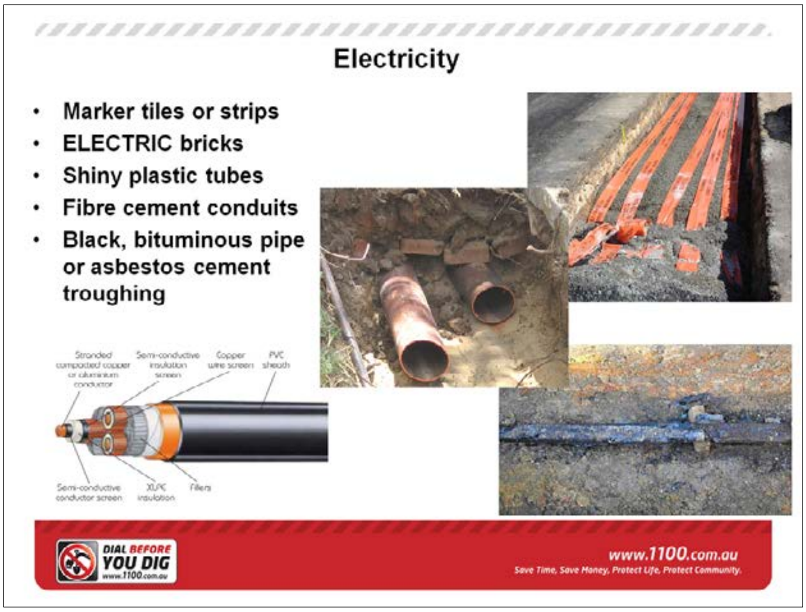
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• Marker tiles or strips
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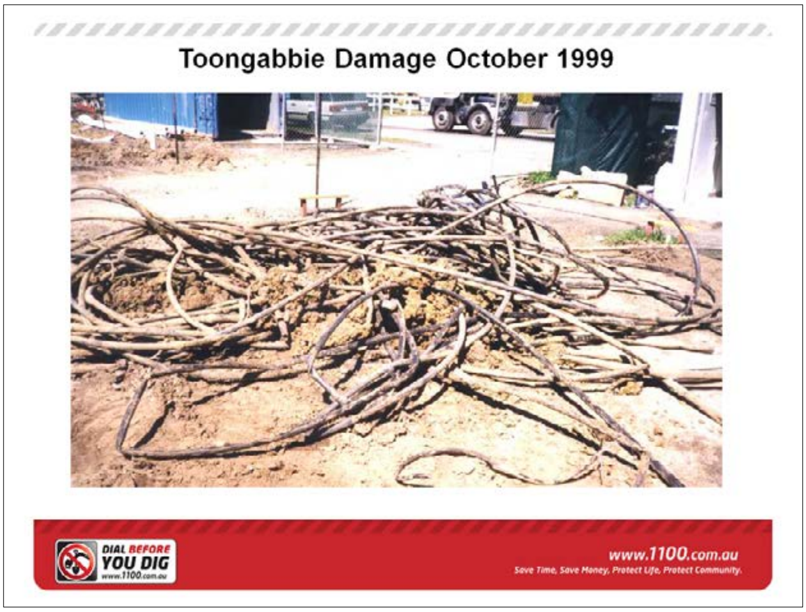
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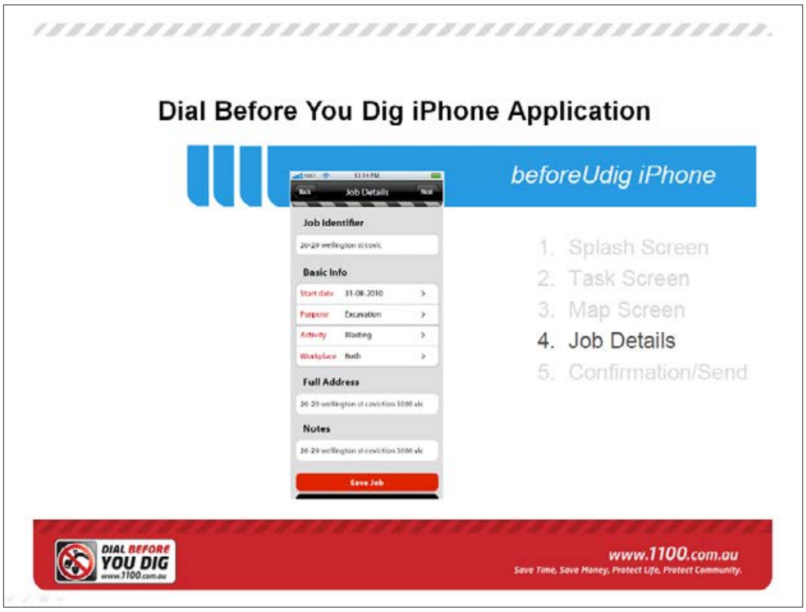
Dial Before You Dig iPhone Application
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Job Details
Job Identifier
Basic Info
Full Address
Notes
Save Job
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Working Near Traffic: A Surveyor's Perspective

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ABSTRACT

Working on or near main roads can be a risky activity. This paper concentrates on the use of the Traffic Control at Worksites Manual for surveying activities as a method of identifying and managing risk. The manual assists in ensuring that the workforce is able to work safely in the vicinity of road users and their vehicles and work site plant. All Roads & Maritime Services (RMS, ex-RTA) projects, including contractors and local government, are required to comply with the manual. However, it is also applicable for anyone responsible for the safety of their workforce who need to work near traffic. This paper provides an introduction to the available training options, risk assessment techniques, relevant sections for surveying activities, typical Traffic Control Plans (TCPs), documentation and signage requirements.

KEYWORDS: *OHS, WHS, surveying, traffic, safety.*

1 INTRODUCTION

The new Work Health & Safety (WHS) legislation has re-enforced the duties of care as stated in the previous Occupational Health & Safety (OHS) legislation. The main drivers are: the employer must ensure the health, safety and welfare of its employees, contractors, visitors and the public at its work sites – consultation with the workforce on safety matters, risk assessment by all organisational members and documentation of all assessments and safety measures implemented.

One of the biggest potential hazards facing surveyors is working in or near traffic. One of the best sources of material to provide guidance and manage this risk is the Roads & Maritime Services' Traffic Control at Worksites Manual (RMS TC@WM 2010). The current version is number 4, issue 2 with the first issue appearing in the 1980s. The manual is heavily weighted towards controlling risk in the construction and road maintenance areas.

This paper aims to provide surveyors with some of the experiences gained by Roads & Maritime Services (RMS) surveyors over several decades. Their daily activities of trying to conduct surveys on motorways, freeways, tollways, highways (HW), main roads (MR), secondary roads (SR), tourist roads (TO), bridges, viaducts, transitways (TW), and even cycleways (2012)! Figure 1 gives several examples of common worksites.

MR 258 Wombeyan Caves Road

HW 2 Hume Highway near Campbelltown

HW 4 – Snowy Mountains Highway

M4 Motorway – viaduct near James Ruse Drive

Figure 1: Some of the worksites for RMS surveyors.

2 DEFINITIONS

The TC@WM is under the control of Traffic Management experts and one of the most confusing areas is understanding what is meant by some of the terminology. Table 1 lists some of the most common terms that are used throughout the manual and this paper (Reference Section 2.3 TW@WM 2010).

Table 1: Definitions of work sites.

Intermittent work	Work which is undertaken on travel lanes, in gaps in traffic, without obstructing traffic and without compromising the safety of the workers. Intermittent work may be planned or unplanned.
Short-term work	Work requiring traffic control during work taking less than or equal to one work shift and where traffic control is not required when the work is complete and where road conditions are returned to normal when the shift ends.
Long-term work	Work requiring traffic control and taking longer than one work shift and where some form of traffic control must remain when the site is left unattended and may lead to operate both day and night.
Mobile work	Work which entails work vehicles moving continuously along the roadway at speeds significantly lower than other traffic.

Spotter	A person whose sole responsibility is to watch out for and warn workers of approaching traffic. The spotter shall remain within sight and hearing distance of the worker(s) (generally within 2 m). An advanced spotter may also be required and is to be within sight or radio contact at all times.
Traffic Control Plan (TCP)	A diagram showing signs and devices arranged to warn traffic and guide it around, past or, if necessary, through a work site.
Average Daily traffic volume (ADT)	The total traffic volume during a stated period, divided by the number of days in that period. Treatment of hazards may differ between ADTs of less than or greater than 3,000 vehicles.
Road Occupancy Licence (ROL)	Allows for a specified road space to be used for purposes other than transport. Licences for major roads are issued by the RMS Planned Incident Unit of the Transport Management Centre. The approval process may take up to 14 days and there is no guarantee of approval. For council roads, application is to be made to the local council authority.

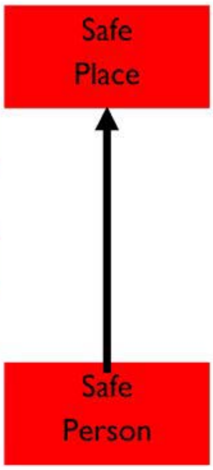
3 RISK ASSESSMENT

3.1 Risk Control

A hierarchy approach to managing risk exists with the optimum being to eliminate the hazard. Table 2 (RMS Part 7 2012) lists these controls, with personal protective equipment as the least affective.

Table 2: Hierarchy of control measures.

CONTROLLING RISKS	
Elimination	Get rid of the hazard out of the workplace. This is the best option, if it can be done.
Substitution	Use something less hazardous. For example water based chemicals rather than solvent based ones.
Isolation	Use barriers to shield or isolate the hazard. For example guards on machines, enclosures for noisy machinery.
Engineering controls	Design and install equipment to counteract the hazard.
Administrative controls	Arrange work to reduce the time people are around the hazard.
Personal protective equipment	Have people wear protective equipment and clothing while near the hazard. For example ear plugs or face masks.



WHS best practice controls are those that are above purely administrative controls – where a ‘tick and flick’ mentality may degrade the effectiveness of the systems in place. RMS surveyors have been eliminating the risk of surveying on the roadway by using technologies such as reflectorless EDM, close range photogrammetry, terrestrial and mobile laser scanning. Night surveys are being increasingly used as a substitution for daytime surveys. Road occupancy and lane closures are an engineering solution to lessen the risks.

3.2 Training and Certification

Qualifications in traffic control are a necessary option to assist in controlling risk when working near traffic. Knowledge gained can be applied to working near major roads, busy minor roads, construction sites, mining sites and large infrastructure developments. Table 3 is

a summary of the five qualifications in traffic control. Each qualification is 'stand alone'. A person may be required to have multiple qualifications to satisfy workplace needs. All qualifications expire after 3 years and retraining is required to maintain currency.

Table 3: Summary of traffic control qualifications.

Qualification (and colour)	Description	Course duration
Traffic Controller (blue card)	Personnel required to control traffic with a stop/slow bat. Able to control traffic at a roadwork/construction site.	1 day
Traffic Controller (grey card)	Personnel required to control traffic with a stop/slow bat. Unauthorised to control traffic at a roadwork/construction site. For example, security personnel.	1 day
Apply Traffic Control Plans (yellow card)	Personnel required to set up and close down signs and devices at work sites with Traffic Control Plans.	1 day
Select/Modify Traffic Control Plans (red card)	Personnel required to select and make minor modification to existing (standard) Traffic Control Plans to suit the work location.	2 days
Design & Inspect Traffic Control Plans (orange card)	Personnel required to design new Traffic Control Plans, produce major upgrades of standard plans or perform inspections of work sites.	1 day

Most of the training focuses on short or long term site treatment, usually for construction purposes. Intermittent works are only covered briefly, which is unfortunate as most of surveying activities are adequately covered by these measures.

3.3 Site Specific Risk Assessment

RMS requires that a risk assessment is to be undertaken at all worksites and when circumstances change. All hazards at a project site are identified and analysed using a matrix system – based on WorkCover documentation and shown in Table 4 (RMS policy 2.0 2012). All of the hazards during the planning, setting up, operating, changing and dismantling of a Traffic Control Plan are listed. Appropriate control measures are developed to mitigate those risks. A monitoring system is required to assess the suitability of the adopted control measures.

Risk rating system analyses the potential hazard, without controls in place, by assessing the consequences and the likelihood of the hazard occurring. RMS uses a 1 to 6 scale with:

1 – High risk: immediate action is required
2 – Significant risk: important to do something about this hazard as soon as possible
3-4 – Medium risk: risk control measures are required
5-6 – Low risk: manage by routine procedures

In line with best practices, RMS Surveyors conduct a residual risk rating value after developing the controls measures. This is a reality check that the proposed controls do, in fact,

reduce the risk to the workers. Depending on the analysis of the risks at the site, intermittent, short term, long term or mobile systems may be appropriate. There are no hard and fast rules.

Table 4: RMS risk assessment reckoner.

RISK ASSESSMENT RECKONER	**LIKELIHOOD -** **how likely is it to happen and how often?**			
CONSEQUENCES – **How bad is it likely to be?**	Very **L**ikely could happen at any time **VL**	**L**ikely could happen some time **L**	**U**nlikely *could* happen, but rare **U**	Very **U**nlikely *could* happen, but probably never will **VU**
Extreme - Kill or cause permanent disability or ill health **K**	**1**	**1**	**2**	**3**
Major – Long term illness or serious Injury **S**	**1**	**2**	**3**	**4**
Moderate – Medical attention and several days off work **M**	**2**	**3**	**4**	**5**
Minor – First aid needed **F**	**3**	**4**	**5**	**6**

4 THE MANUAL IN DETAIL

4.1 Estimating Average Daily Traffic (ADT) Flow (9.15 TC@WM)

ADT is used throughout the manual to determine the amount of minimum controls that are required to be in place. ADT figures and maps for many roads are available from the RMS internet site (2012). Alternatively, an estimate may be calculated using Table 9.3 of the TC@WM (2010), which is reproduced in Table 5.

Table 5: Calculating estimated ADT.

NUMBER OF VEHICLES PASSING IN 5 MINUTES	CALCULATION	ESTIMATED ADT
8 or more vehicles	16hrs x 96 vehicles = 1536	> 1500
7 vehicles	16hrs x 84 vehicles = 1344	> 1000 but ≤ 1500
6 vehicles	16hrs x 72 vehicles = 1152	> 1000 but ≤ 1500
5 vehicles	16hrs x 60 vehicles = 960	> 300 but ≤ 1000
4 vehicles	16hrs x 48 vehicles = 768	> 300 but ≤ 1000
3 vehicles	16hrs x 36 vehicles = 576	> 300 but ≤ 1000
2 vehicles	16hrs x 24 vehicles = 384	> 300 but ≤ 1000
≤ 1 vehicle	16hrs x 12 vehicles = 192	< 300

Table 9.3 Calculating estimated ADT

NOTE: Traffic must be counted in both directions to determine the total traffic volume per 5 minutes

4.2 Common Intermittent TCPs Suitable for Surveying

Reference: Traffic Control at Worksites Manual (TC@WM 2010). Refer to section 9.14 for general requirements.

4.2.1 TCP 459 Intermittent Work 2 Way Carriageway

RMS surveyors use this TCP for conducting detail surveys adjacent to the roadway, see Figure 2, reproduced from the Traffic Control at Worksites Manual (TC@WM 2010). The instrument is usually greater than 3 metres clear of the traffic lane.

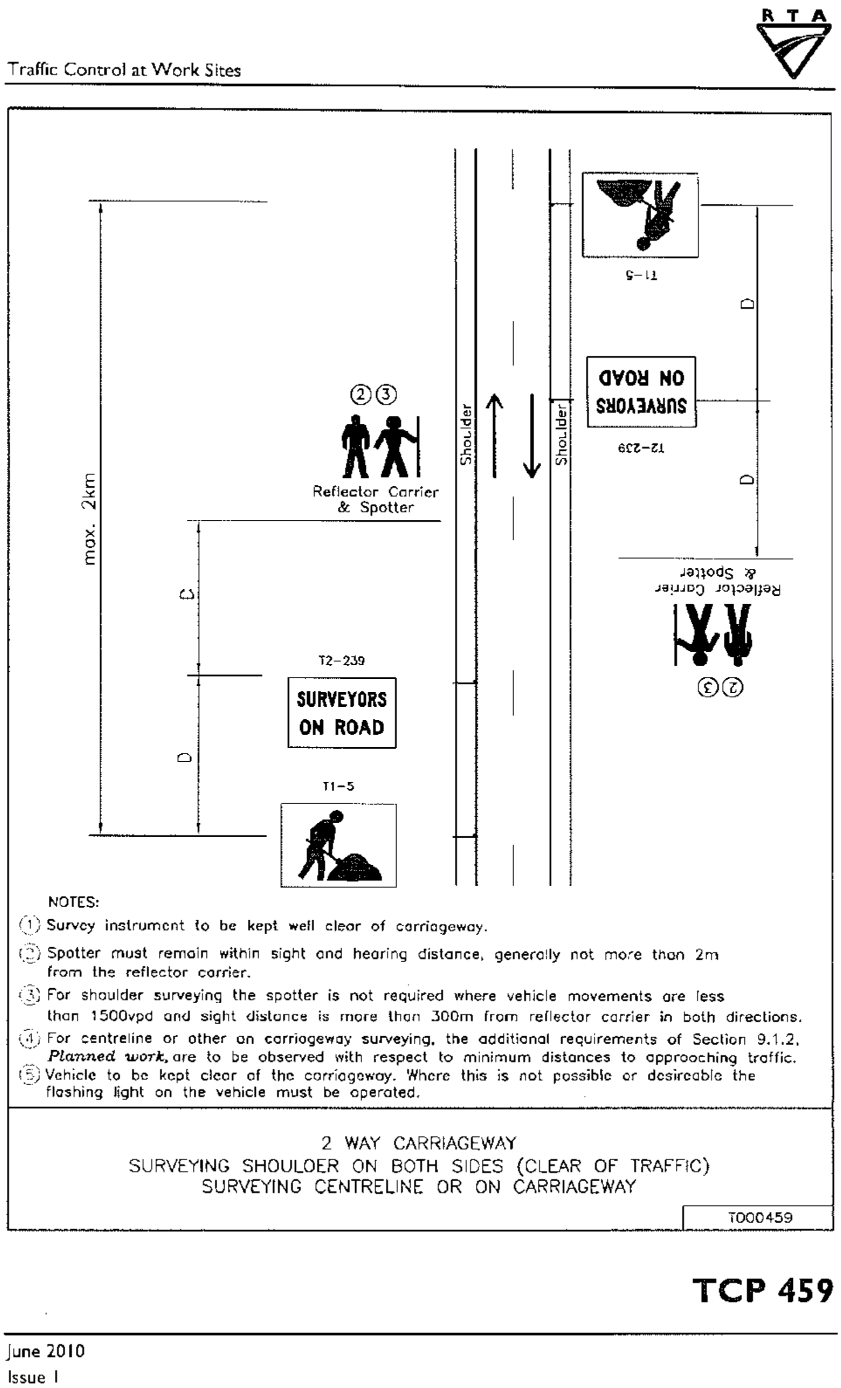


Figure 2: TCP 459.

4.2.2 TCP 463 Intermittent Work 1 Way Carriageway – Surveying on Median

RMS surveyors use this TCP (TC@WM 2010) for detail surveys or investigation surveys in wide medians – see Figure 3. The instrument is usually greater than 3 metres clear of the traffic lane. The sign T-239 'Surveyors on Road' is included as it is promoting the profession and indicates to drivers that there are workers on foot in the area, when they may be expecting big earth moving equipment.

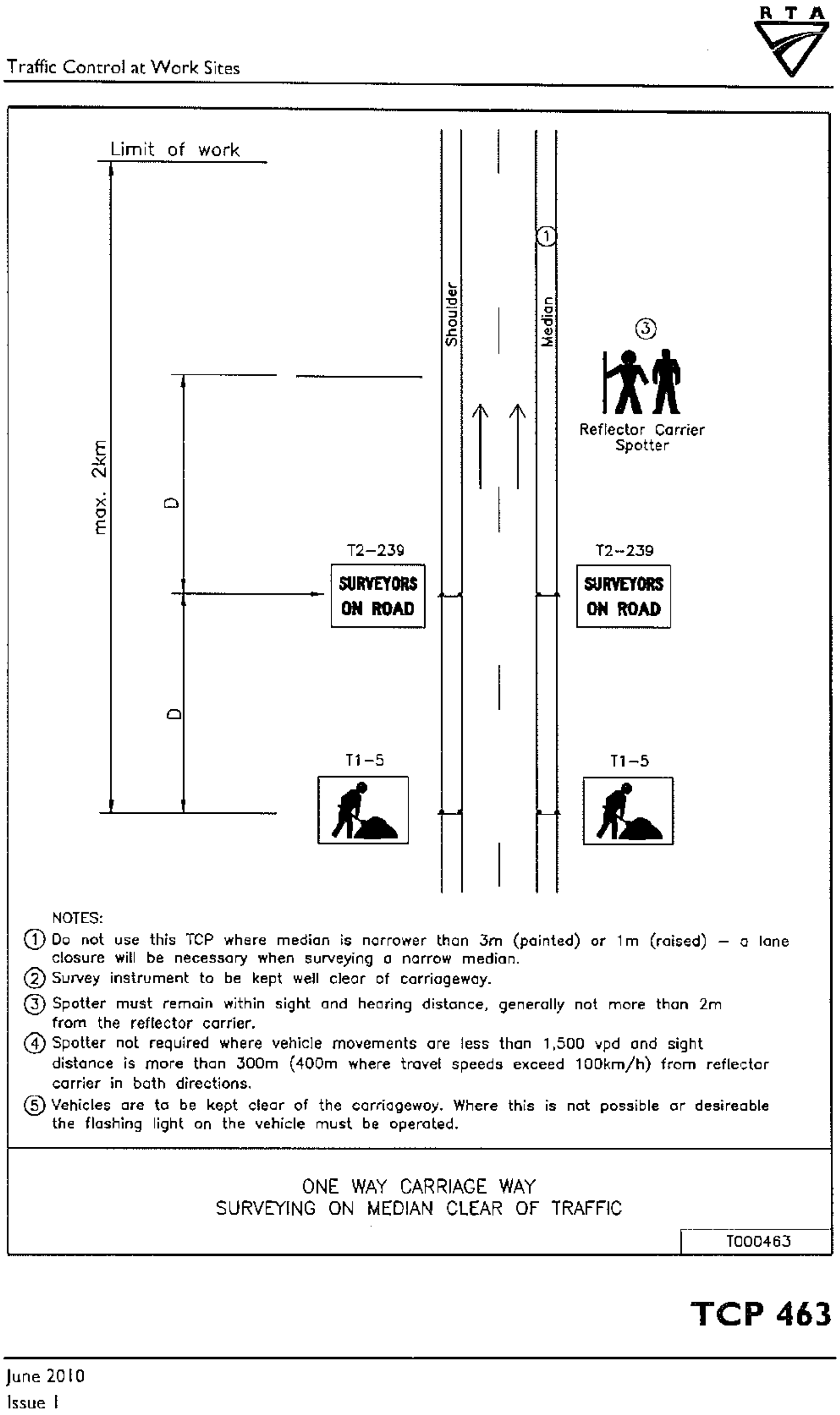


Figure 3: TCP 463.

4.2.3 TCP 831 Intermittent Work 2 Lane 2 Way Carriageway

RMS surveyors use this TCP (TC@WM 2010) for investigation surveys on quieter rural roads (low ADT) – see Figure 4. The instrument is usually greater than 3 metres clear of the traffic lane and a spotter is used.

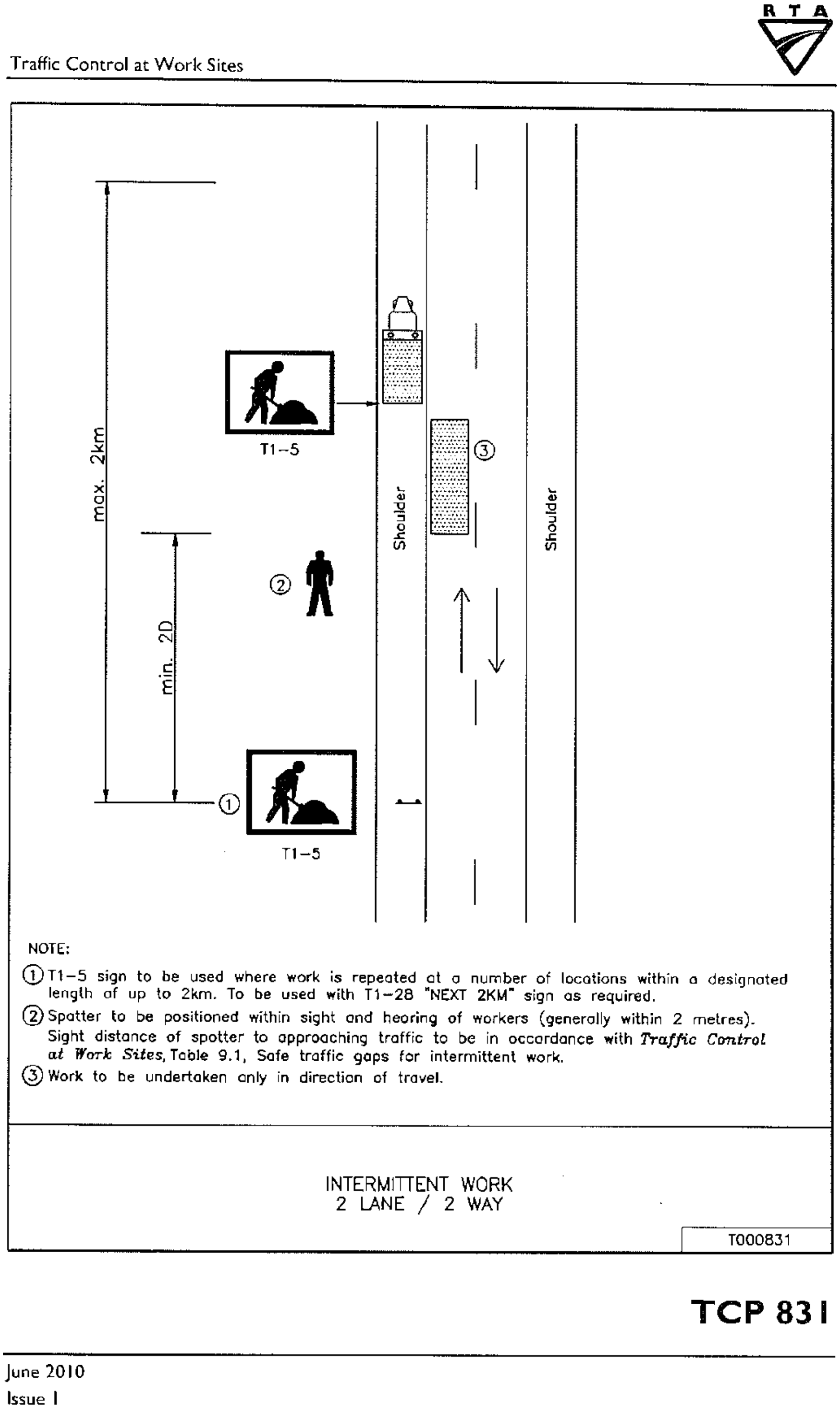


Figure 4: TCP 831.

4.3 Safe Traffic Gaps for Intermittent Work (9.1.2 TC@WM)

When playing in the traffic, RMS surveyors rely on understanding safe gaps in traffic with the activity usually taking less than 10 seconds. These are detailed in Table 6. An escape route needs to be developed and agreed upon before commencing work.

Table 6: Safe gaps related to speed zones.

ROAD SPEED ZONE (D) km/h	**MINIMUM SIGHT DISTANCE (m)**	
	WITH A LOOKOUT PERSON **(spotter* to be generally within 2 m)** (10 secs travel time or 3Dm)	**WITHOUT A LOOKOUT PERSON** (20 secs travel time or 6Dm)
40	120	240
50	150	300
60	180	360
80	240	480
90	270	540
100	300	600
110	330	660

* - In addition, consider using an advanced spotter with radio contact.

4.4 Using Traffic Control Cones as Delineation Devices (3.3.3 TC@WM)

The recommended heights of safety cones are shown in Table 7. A reflective band is required for night usage.

Table 7: Traffic cone sizes.

Size	**Usage**
300 mm	Pedestrian control only
450 mm	Urban & rural roads (< 70 kph)
700 mm	All other roads (> 70 kph)

4.5 Size of Signage (3.2.2 TC@WM)

Generally, standard signs are available in two different sizes designated as (A) and (B). Table 8 is a summary of the main features. As well, sizes (C) and (D) may be used to emphasise the message. The dimensions of the sign relate to the type of sign. These can be found on the RMS traffic signs and sign design specifications website (2012).

Table 8: sign sizes defined by proximity to traffic and zone speed.

Sign	**Offset up to 90 km/h**	**Offset up to 110 km/h**
A	8 metres or less	4.5 metres or less
B	Greater than 8 metres	Greater than 4.5 metres

Size B may be appropriate for expressway type roads or for added emphasis.

4.6 Static Work Requirements (3.6 TC@WM)

Safe clearances between workers and through traffic at static work sites (RMS, 2010) is summarised in Table 9. Intermittent and low impact works as well as mobile works are exempt from these requirements.

Table 9: Safe clearance at static sites.

Greater than 6m (Sec 3.6.1)	**3 – 6m** (Sec 3.6.2)	**Closer than 3m** (Sec 3.6.3)	**1.2 - 3m** (Sec 3.6.3)	**Closer than 1.2m**	**Actions**
✓					If visible to motorists, place Workers sign (T1-5) in advance of work area.
	✓	✓	✓		Place Workers sign (T1-5) in advance of work area.
	✓	✓	✓	✓	Vehicle mounted warning device (Sec 3.3.9).
	✓				If traffic volume (vpd) > 10,000 seek approval to temporarily restrict speed to 80 km/h.
		✓	✓		Refer to Section 3.6.3 – safety barriers, delineation and containment fencing and possible speed restriction &TCP.
				✓	Refer to Section 3.6.4 – safety barriers, delineation and containment fencing and possible speed restriction &TCP.

5 DOCUMENTATION

RMS surveyors have third party Quality Assurance (QA) accreditation. QA systems are notorious for generating paperwork. This can consist of documentation for procedures, work instructions, guides, forms, checklists, templates, etc. A yearly induction into the Surveying WHS system includes a work instruction for the section, site induction checklist (signed daily), checklist for working near traffic (intermittent or short term), generic Safe Work Method Statement (SWMS), RMS risk reckoner, a guide (being extracts of RMS policies, procedures and TC@WM) and RMS WHS tip sheets.

Appendix E of the TC@WM (2010) has a number of checklists that may assist in defining the hazards and implementing safety controls. The checklists are: Safety Inspection, Roadwork Speed Zones, Traffic Controllers, Portable Traffic Signals, Flashing Arrow Signs, Variable Message Signs, Signs and Devices, End-of-Queue, Working on Foot Near Plant, project Vehicle Movement Plan (VMP), Miscellaneous (intermittent, mobile and other works), Daily checklist for Short term work sites and Weekly checklist at Long Term work sites. These may assist other organisations to develop their specific documentation.

6 CONCLUDING REMARKS

Worker safety is a primary concern of the RMS surveying discipline. Our prime objective is to ensure that personnel have safe systems of work to ensure that they arrive home safely every night. Our system for working adjacent to traffic is just one of many systems developed to meet our objective.

Traffic control training is essential to help understand and manage the risks and requirements of having a safe workplace. Even with the limited exposure to mobile and intermittent work within the courses, they are still highly recommended. Refresher training every three years is mandatory.

For efficiency and risk management, RMS surveyors have a rule of thumb, if traffic controllers are required for a project, RMS surveying will usually sub-contract this activity to registered providers. This ensures that the most skilled worker for a task is used. However, before starting fieldwork, all proposed systems are discussed, agreed upon and documented. Qualifications of the sub-contractors are examined and documented.

The governing committee of the TC@WM can be approached to make amendments to the manual. It is hoped that government surveying entities will group together to review, develop and promote more surveying specific TCPs to be included in the manual. The economic and safety benefits are obvious.

The information contained in this paper is provided as general information and is not to be relied on for specific projects. It is a distillation of the RMS surveying discipline extensive systems and is solely the opinion of the author, and is not to be construed as representing the opinions or views of RMS.

7 ACKNOWLEDGEMENTS

This paper would not have been possible without the hard work and dedication of the RMS Work Health and Safety Branch personnel, Mark Gordon, RMS Principal Surveyor, for his leadership and dedication to safety in the workplace and RMS Surveyors in general who yearly review the WHS and actively participate in systems improvement.

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Can Emergency Management Go Virtual?

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ABSTRACT

Current trends internationally and nationally show increasing collaboration between national to local jurisdictions to share tools and technologies, such as geospatial services and data for emergency response purposes. This presentation discusses the management frameworks in supporting spatial data collaboration as well as touching on the tools and technology they utilise. It looks at what is happening in other organisations as well as the NSW Rural Fire Service (RFS). This includes the NSW RFS mapping of fire fronts and how it is made available to all NSW emergency service organisations, and a discussion on how emergency information is shared with the public through applications such as the 'Fires near me' iphone application and web maps. The provision of GeoRSS map services which can be used by other websites such as 'Bushfire Connect' and the virtualisation of incident information are also described.

KEYWORDS: *GIS, mapping, virtual, emergency management.*

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The Bank: A Mathematical Determination

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ABSTRACT

Historically, the bank of non-tidal stream, be it called a river, creek or other description, has been determined from localised features such as vegetation, soil structure and/or steps in the land profile. This paper considers the possibility that there may be a more precise and repeatable mathematical way in which the bank can be located. Also considered is whether the definition of the bank is too complex and if it can be simplified without causing significant change to boundaries.

KEYWORDS: *Non-tidal, bank, mathematical, determination.*

1 INTRODUCTION

Since boundary surveying began surveyors have contemplated the location of the bank along the non-tidal section of a river. What physical feature could be used as to delineate between land and river? Is it the edge of the water or the extent of arable land, or something in between? Both these features have more than likely been used quite extensively but the level of water in rivers rise and fall depending upon rainfall, rising to sometimes cover the broad acreages on either side then falling to a narrow channel in times of diminished rain. Similarly, the extent of land alongside the river used by Man changes with the activities conducted, so that in places usage stops some distance from the water but in other cases runs right to the water's edge. Using any of these criteria for the location of the bank would not be suitable for delineation of title. A more focused location is needed.

There have been many papers written and theories expressed as to what feature should be adopted as the limit of the river and land (e.g. Kernebone, 1986; Sloane, 1989; Ticehurst, 1994; Willis, 1974). Some have suggested a change in vegetation types, others the change in soil structure. Still others included features such as the low bank, either top or bottom, and the base of the high bank. Each has its merits, has more than likely been used in the past and will continue to be used in the future, but none may be present in any situation or the feature itself may be spread over a wider area than expected and leave considerable room for conjecture.

Adoption of any of these features may be a plausible and practical location for the bank but at the same time be invalid when it comes to satisfying the definition that surveyors need to comply with.

2 THE BANK DEFINITION

Like all definitions that are given within legislation, the explanation of what is the bank is not straight forward or simple. From Section 172 Crown Lands Act 1989

"***bank*** means the limit of the bed of a lake or river".

This sounds simple but the definition depends on defining the bed and therein the complications start.

"***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 droughts".

(Note: ***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.)

Although convoluted, most of the definition is quite straight forward. However, the surveyor is left wondering as to what are extraordinary freshets? After contemplating that the surveyor then must consider the problem of what is the difference between an ordinary drought and an extreme drought? The act is silent on these issues and it leaves the surveyor to search elsewhere.

One thing that is quite clear from the definition and something that many surveyors seem to get wrong is that quantity given for the river (or lake) stage is the average or mean and not the normal or usual. Mathematically, the normal and average entities are different and only coincide in one specific circumstance. In this instance, however, the two are distinctly different and use or contemplation of the normal stage of the river as a definition of the bank is definitely wrong and will underestimate the extent of the bed required to accommodate the average or mean stage.

3 DEFINING THE UNDEFINED

Before the average or mean stage (according to the bank definition) can be determined, an understanding of what is an extraordinary freshet must be reached. It is only then, when the river stages that should not be made reference to are identified, can they be ruled out of the contemplation.

With just about everything now obtainable on the internet, a quick search should give a reasonable definition.

From *thefreedictionary.com*

Freshet

n.

1. A sudden overflow of a stream resulting from a heavy rain or a thaw.
2. A stream of fresh water that empties into a body of salt water.

The American Heritage® Dictionary of the English Language

Extraordinary

adj.

1. Beyond what is ordinary or usual: *extraordinary authority.*
2. Highly exceptional; remarkable: *an extraordinary achievement.*

3. Employed or used for a special service, function, or occasion: *a minister extraordinary; an extraordinary professor.*

The American Heritage® Dictionary of the English Language, Fourth Edition

This is only one source; there are many others which provide a similar definition. So putting the two definitions together, an extraordinary freshet would be an exceptional rise in the river that is larger than what would be ordinarily, normally or usually expected from a rainfall event or snow melt (the fresh water stream flowing into the sea can be ruled out in this instance). Similarly, at the other end of the scale, an extreme drought event would see the river fall lower than when it simply gets low due to a usual period of low or no rain. The river may even stop flowing.

But how does this help? What is an ordinary flood or freshet? How can the extraordinary ones be identified and ruled out of the determination of the mean? Similarly, how can an ordinary drought or low water event be determined?

4 REFINING THE DEFINITIONS

What if every single high water event was recorded, then the highest in each year over a fairly lengthy span of years was selected, and then the mean taken of the selected highest records? The result would be a determination of the statistical mean annual flood event. Or in everyday terms the rise in the river that could be expected each year, or the ordinary freshet or flood. It may not necessarily be a large event, nor would it be expected to occur every year. It may not happen for three or four years or more but could happen two or three times in a single year. River flows in this part of the world are not regular events like monsoon induced flows but rather happen randomly (e.g. Edgar, 2001; Finlayson and McMahon, 1988; Prosser et al., 1999; Telfor, 1999), intermittent and often flashy (Janicke, 2000).

At the other end of the scale, the lowest water level for each year could be averaged to find the mean annual low water. Again, this would not necessarily happen regularly but statistically it is likely to occur at least once a year.

Putting the two together would result in a determination of the mean flood flow and the mean low flow, between which all usual or ordinary flows should occur. Only the outliers or the extraordinary freshets and extreme drought events would occur either side of these two water levels. Since these outliers have now been identified, they can then be excluded from the determination of the average or mean of all the other events which, according to the definition, gives the cadastral bank. Figure 1 illustrates this theory.

Here it can be seen how the cadastral bank falls neatly in the middle between the mean high and mean low flows with flows that could occur outside these limits not included. The cadastral bank should not be confused with the geological bank or the high bank. This is the point against which the river rises in what hydrologists sometimes call bank full discharge (e.g. Church, 1996; Leopold et al., 1964; Page, 1988; Pickup and Warner, 1976; Rutherfurd et al., 1999b; Telfor, 1999). The geological bank is that point just before the river flows up out of the banks into the floodplains (where they exist). Incidentally, this is most likely the location which early surveyors sometimes took as the bank or cached in other terms, the limit of arable land.

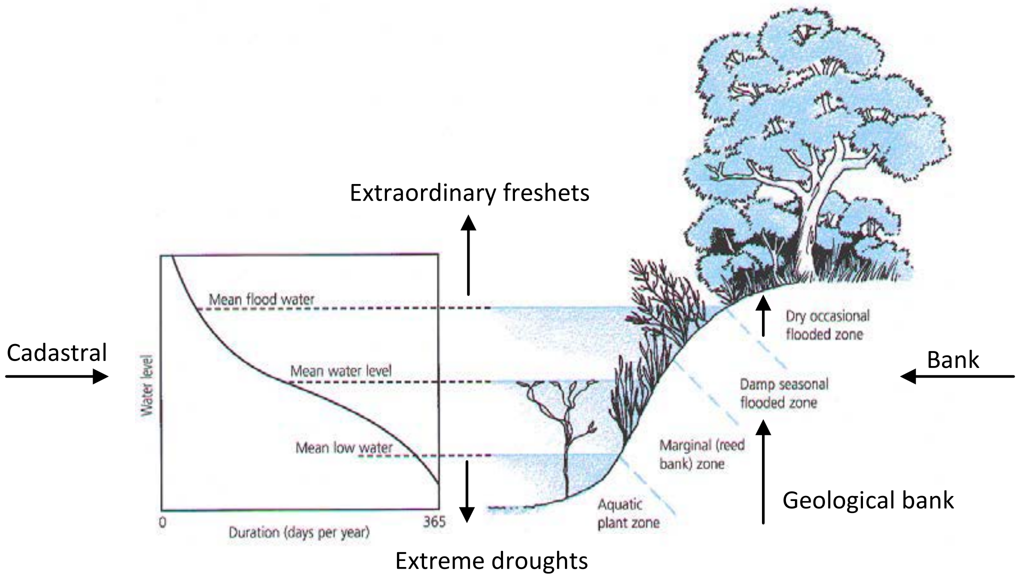


Figure 1: Stream levels, cadastral and geological banks (Rutherfurd et al., 1999a).

5 RIVER FLOW DATA

Where can a surveyor get river data that could help determine the various constituents in the above theory? Unfortunately data is not available everywhere, however there are a large number of river gauges throughout New South Wales, so there could be one near your survey or you could be between a couple so you might be able to interpolate. At the time of writing, various State Government agencies contribute information to the NSW Water Information web site http://waterinfo.nsw.gov.au. By going to the Rivers and Stream real-time data section, the general public can obtain directly, quite a bit of river flow data. More data may possibly be obtainable by contacting the relevant agency contributing the data.

6 THE MATH

Some stream gauges have in excess of 50 years of data, so with a set of readings for every day there will be quite an amount of information. Fortunately, spreadsheets can handle such large volumes of data and with a little bit of manipulation the required analysis can be extracted.

The characteristic flow of a river might surprise some people. In order to get an appreciation of the range of data, the daily flow and gauge height, if available, should be plotted. The typical result for stream flow in Australia is shown in Figures 2 and 3.

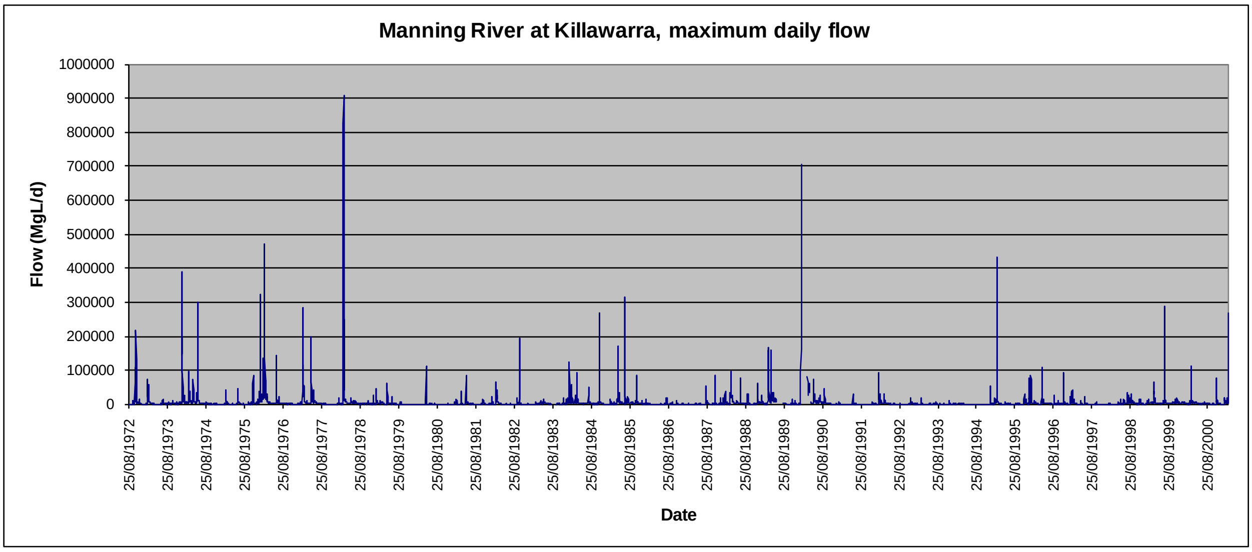


Figure 2: Daily stream flow of Manning River at Killawarra.

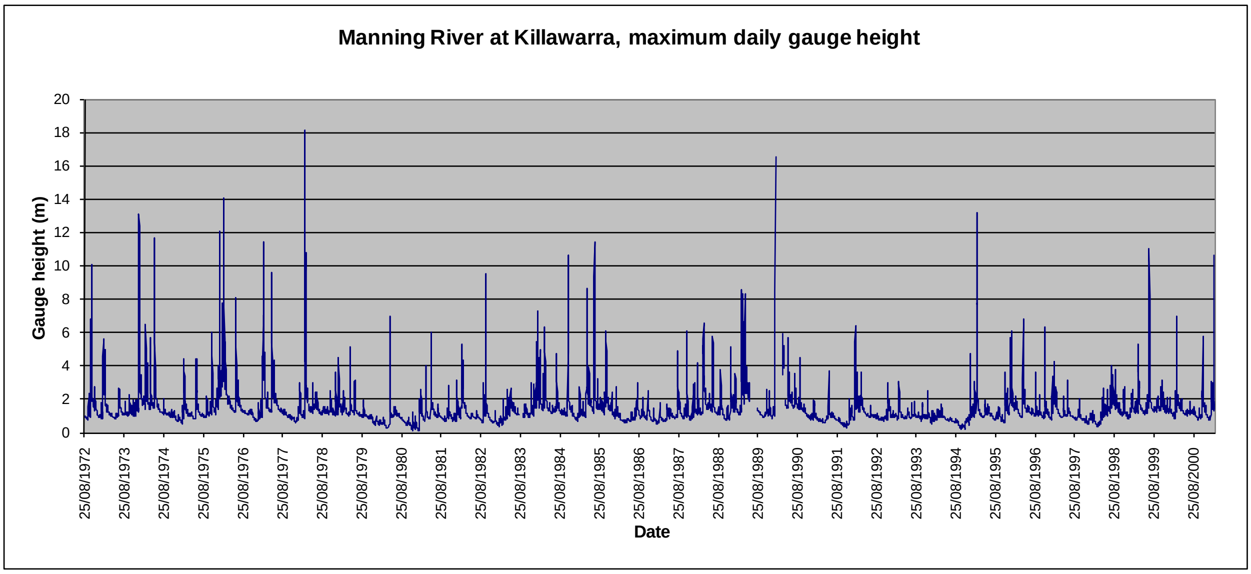


Figure 3: Daily stream height of Manning River at Killawarra.

What should be fairly evident from this example is that for most of the time the river flows at fairly low levels with the river height at less than 2 metres for the majority of the time. Even without undertaking any calculations, it is also quite evident that the average and normal flows of the river are likely to be distinctly different.

The first part of the exercise is to identify the flow and gauge height (there is a correlation between the two, so either or both can be used) that corresponds to the average annual flood. For each calendar year, the maximum flow, or height, is found and then the average of the resulting dataset is taken. Spreadsheet formulas can do the data searching and averaging, you only have to write the formula. For this dataset the mean annual flood value is 197,463 mgL/d or 9.42 m gauge height. This is roughly half the height the river reached at its maximum and could potentially have a significant effect on where the bank is located. Going through the same process, the mean annual low flow values of 306 mgL/d or 0.68 m gauge height are found. The low flow figure is barely discernable on the above charts but the average annual

high flow can easily be seen. Above this value there are nearly 30 extraordinary high river flows that can be excluded from the cadastral bank average flow computation.

Using these two pieces of information, the spreadsheet can again be interrogated and the average taken of all readings that fall between the average annual high and low flow values, the result being 4912 mgL/d or 1.75 m on the gauge. This is significantly closer to the low flow value than it is to the high flow value as could be expected from viewing the charts in Figures 2 and 3. How this looks on a revised hydrograph displaying only those exclusive flows between the annual high and low flows is shown in Figures 4 and 5.

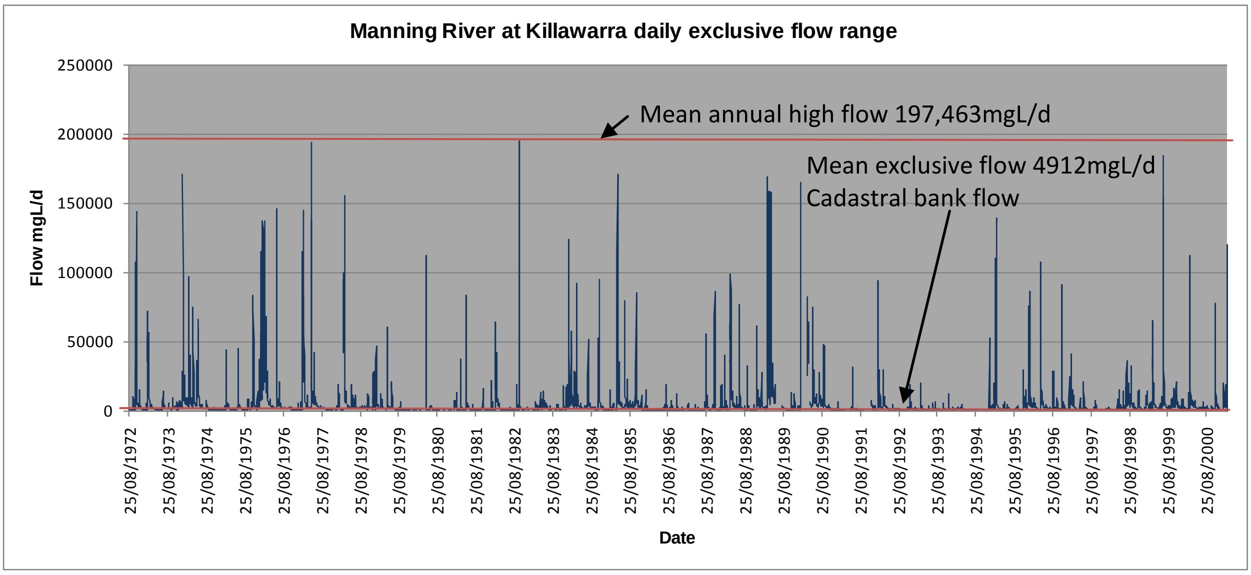


Figure 4: Daily stream flow of Manning River at Killawarra of flows between mean annual high flow and mean annual low flow.

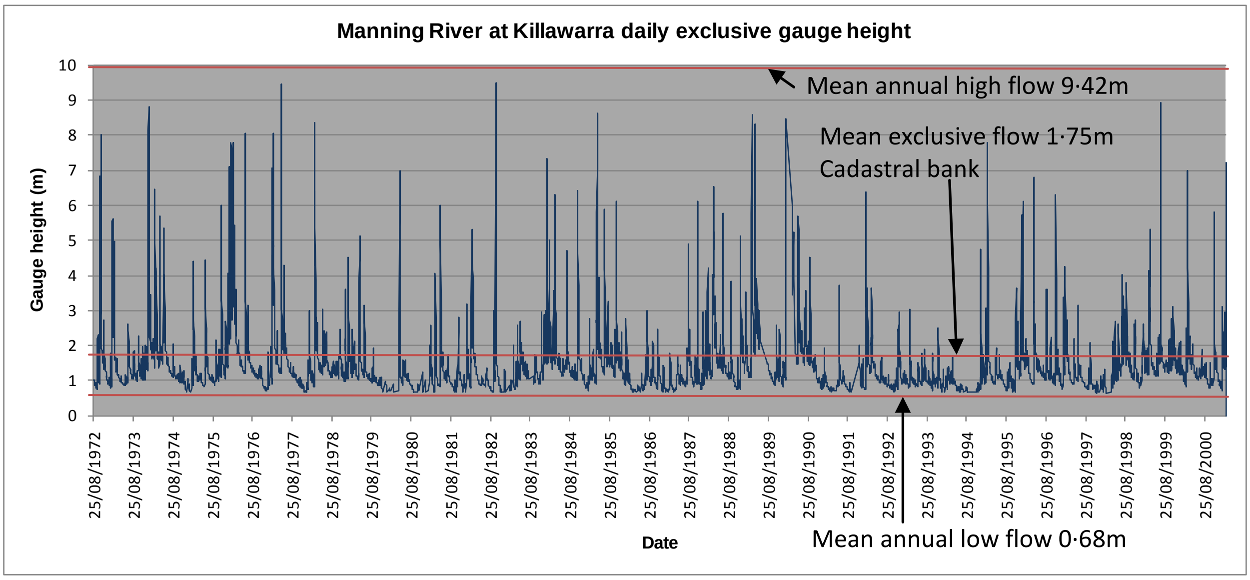
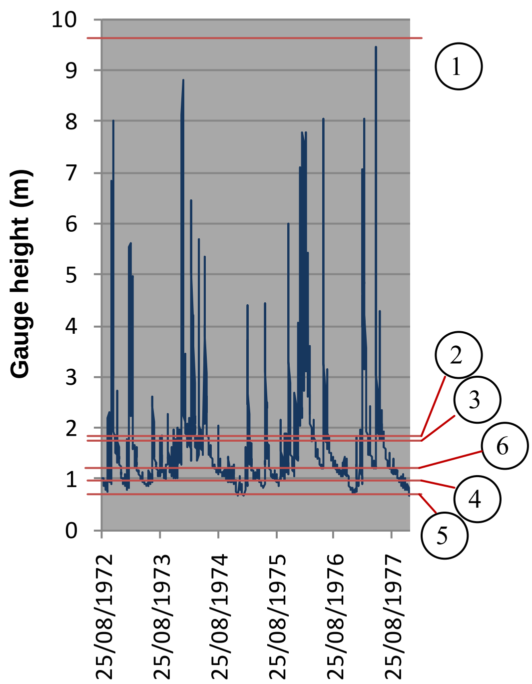


Figure 5: Daily stream gauge height of Manning River at Killawarra of flows between mean annual high flow and mean annual low flow.

To put this in a little more context, the charts need to be considered with a few other variants (Figure 6). Although all are not necessary in respect to the bank definition, they provide further clarity and why some interpretations of the bank definition are not correct. One of the variants that may lead to confusion is the normal flow, which is often substituted into the definition instead of the average flow. Another variant is something that may simplify the definition, the average of all flows.



Variant	Flow mgL/d	% time flow at or below var't	% chance flow occurs at or above var't	Gauge height m	% gauge height range
1	197,463	99·7	0.3	9·42	52
2	5,492	84·8	15.2	1·81	9
3	4,912	83·1	16.9	1·75	9
4	900	30·2	69.8	0·96	5
5	306	7·2	92.8	0·68	3
6	1540	50	50	1·14	6

1 Mean annual high flow
2 Mean all flow
3 Mean exclusive flow or cadastral bank
4 Most frequent or normal flow
5 Mean annual low flow
6 Equal flow time above and below level

Figure 6: Stream flow variants used to consider the cadastral bank definition.

7 THE EFFECT

The first thing that should be obvious is that most of the river flow action occurs in the low flow end of the range. In fact, 90% of all flows occur in the bottom 1% of the flow range. The next is that a casual observer of the river is more likely to see it flowing at a low flow level rather than an average level. The most frequently observed flows occur in 5% or less of the gauge range. If you are looking for that point where the river is equally likely to be flowing lower or higher than that observed, then at only 6% of gauge range, it is not much higher than the most frequent flow and still in the region of low flows. Also, the mean of all flows is not much different to the mean of exclusive flows required in the definition of the bank.

The second thing is that the theoretical flow regime indicated in Figure 1 does not hold and what actually occurs is completely different. Figure 1 suggests that the mean water level is at a point where there is an equality of both time and flow either side of the mean in the natural occurrence of the river. (Note that this unique situation is the only instance where normal and average values are the same quantity.) What is perceived as a normal distribution for time, level and/or flow, in reality, given the data so far, does not occur and the graphed distribution of these variables is heavily skewed to the low flow side (Figures 7 and 8).

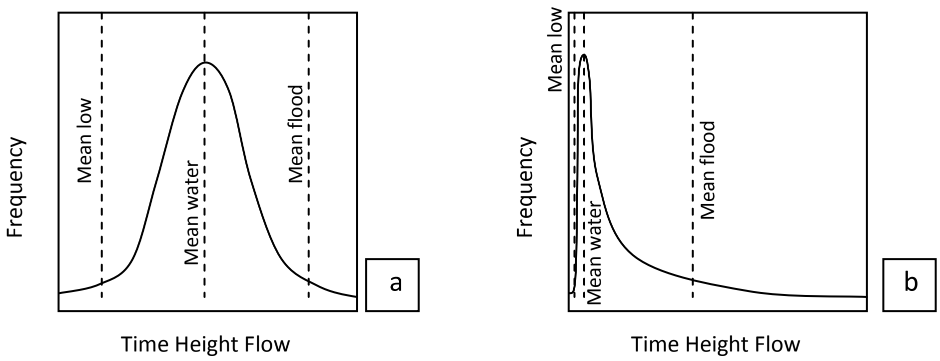


Figure 7: Expected distribution curve from Figure 1 (a) compared to distribution curve from the data (b).

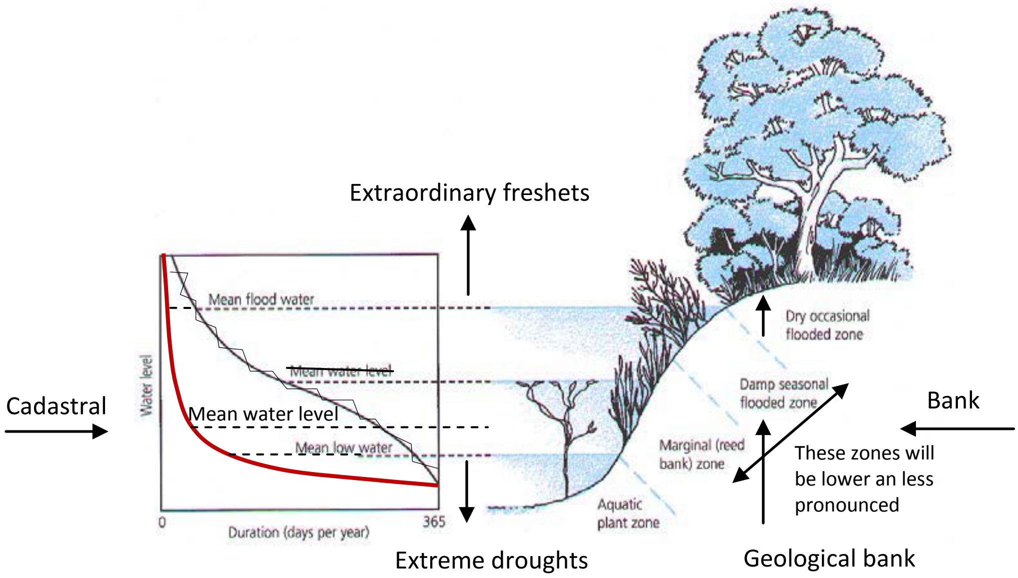


Figure 8: Stream levels, cadastral and geological banks adjusted from Figure 1 to match the data.

8 PUTTING THE MATH INTO PRACTICE

Theory is nice and mostly necessary; however putting it into practice can be another matter. By chance, a few kilometres upstream from the gauge site a not too old river bank survey can be examined to see if the bank, according to the math, matches what the surveyor determined in the field. The survey can also be compared with the original determinations of the bank to see if they agree and, if not, determine if the older plans were correct.

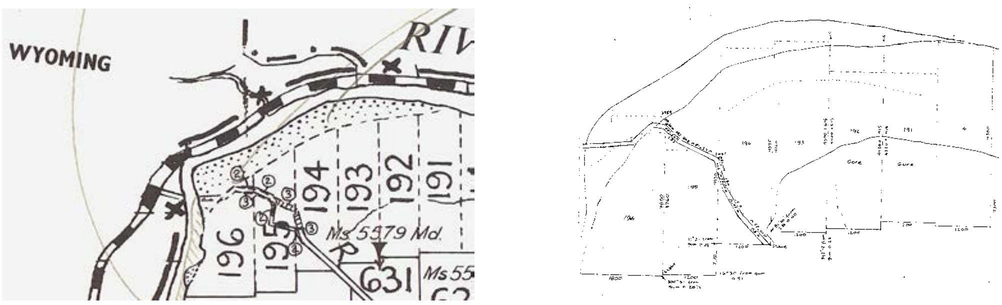


Figure 9: The parish map (left) and lot plan (right) show a shingle bed between the parcels of land and the river channel.

Both plans in Figure 9, and incidentally also the parish map from the opposite side of the river, paint a picture of a high bank dropping to a shingle bed with a water channel on the outside of the bend. This, at first glance, would seem to fit the definition where the water channel, which can move around and holds the normal flow of water, is the stream within the bed, some of which is usually dry shingle. The shingle bed would be that area that is occasionally covered when the river increases slightly but not in an extraordinary flow event. However, the later survey paints a completely different picture (Figure 10).

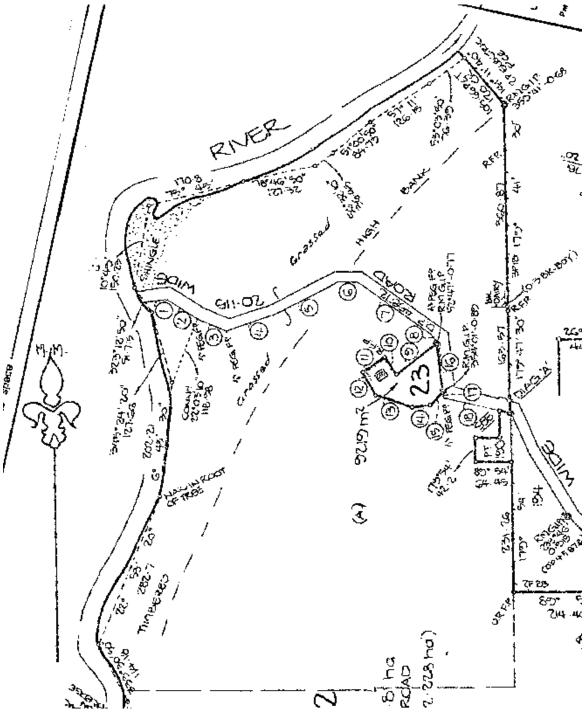


Figure 10: The later survey is to the water channel and includes all shingle.

There are significant differences in the later plan when compared to the earlier information. There is a line, back from the river, identified as the high bank that seems to correspond to the bank at the back of the shingle bed depicted on the early plan and parish map. This newer survey still depicts a shingle bed adjacent to the water channel but definitely includes it as part of the land. The first impression of this plan is to question whether or not the surveyor's location of the bank would comply with the definition. It could be readily postulated that the area shown as shingle could be that area of land needed to allow for the occasional increase of water.

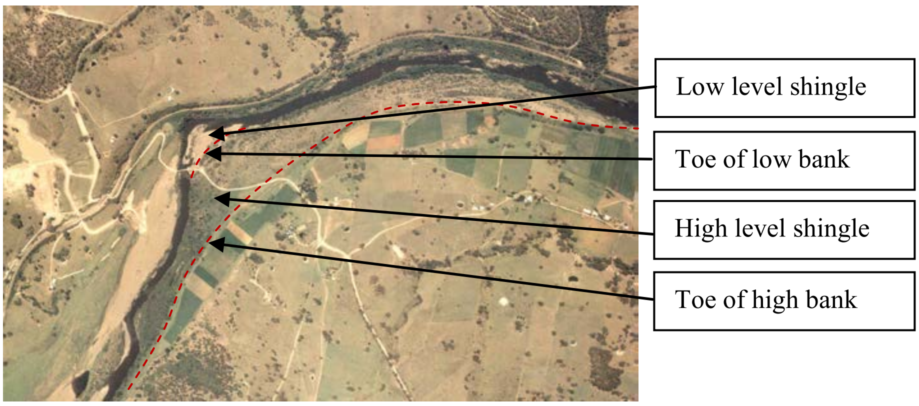


Figure 11: 1991 aerial image of the area.

Overlaying the cadastral plan of Figure 10 on an aerial photo of the area (Figure 11) shows what the surveyor's interpretation of the bank is; the water's edge.

Figure 12: Overlay of recent survey plan to aerial photo

If the flow in the river, at the level indicated by the aerial photo, corresponds to the level mathematically determined as the cadastral bank flow, then the surveyor's determination of the bank would be correct. But does it match with other bank indicators such as vegetation and/or soil types?

The area of high level shingle is about 3-5 metres above the water level of the aerial photo. Presuming the water in the river is at the normal flow level and the mathematics show us that the cadastral bank is not quite 1 metre above this level, then it is most likely that the high shingle bed is not part of the river, according to our definition, but part of the land. The high level shingle bed consists of river gravel grassed with varying cover amongst river oak, bottlebrush and the occasional young gum. The river oak is a shingle bed colonisation species (Doyle et al., 1999) so this would indicate the area to be at least part of the geological river structure. From observations, bottlebrush tends to grow beside the river which would also suggest that the area is part of the river. The grass and gum however suggest a land environment. Evidence of the river rising and covering the area is quite prevalent so it is definitely part of the river but what part? Vegetation in this instance does not provide a definitive answer in locating the bank.

The mathematics shows that the cadastral bank level is towards the lower end of the gauge compared to the full capacity of the river. Much of what the river would cover in times of high flow is excluded from being part of the cadastral bed by virtue of the definition (see Figures 1 and 7). The higher shingle bed would be classed as a high-level river flat (Cohen et al., 1998; Fryirs and Brierley, 1998) and yet be still within the geological structure of the river between the geological banks. It would, however, be part of the adjacent land tenure in the cadastral view of the world.

Soil, being suggested as another indicator, is also mixed in this area. The soil is patchy and mostly consisting of river sands, thus the lack of cultivation in the area seen on the aerial photo. The soil indicators are that the area is part of the river ,and without anything else other

than soil and vegetation the surveyor would have to conclude that the old plans were correct. The mathematics, however, does not support this position of the bank.

The lower shingle bed, however, is a different world. It consists of open undulating gravel regularly scoured by water with finer grained gravel on higher areas where the water does not always reach. When the river does not scour the vegetation out, river oak and bottle brush thrive. Despite there being no soil, grass can start to grow amongst the lighter gravel if there is sufficient time between river rises to prevent it being scoured out. The indicators certainly point to this area being part of the river and within the cadastral bed according to the definition. Does the mathematics support this?

To mathematically establish where the bank is located, firstly the quantum for the average flow at the site needs to be determined. The methodology of how this could be achieved is beyond the scope of this paper, however it may be possible using stormwater runoff computations or, if between gauges, interpolated flow based on proportional catchment areas of the gauge sites and observation site. Presuming that the quantum of flow is obtainable, the next step is to determine the extent over the bed such a flow would occupy. In order to do this a cross section is required, together with the slope of the river. Getting the survey gear out will provide the cross section, and the slope of the river can be determined from the topographic maps, or you can try and measure it yourself. The theory of how wide the flow will be is based on the fact that a given cross sectional area is required for a given quantity of flow to pass a particular point in any given period of time depending upon velocity of the flow. The formula, which can be found in just about any hydrology text, is as follows:

For Velocity (m/s)

$$V = \frac{R^{2/3} . S^{1/2}}{n} \tag{1}$$

where R = Hydraulic radius = A/W (2)

A = Cross sectional area of water flow (m^2)

W = Wetted perimeter, the length of water touching the bed and bank of the cross section (m)

S = Energy slope of the water surface (m/m)

n = Manning's roughness coefficient for the channel

For discharge (l/s)

$$Q = A.V \tag{3}$$

Determining the values for S and n is the most difficult part of applying the formula. Small variations in these can make significant changes to the velocity V and thus alter the required cross sectional area A of the section. This then has an impact on the location of the bank. If the edges of the river are steep, this would not make a huge difference. However, if the edges were fairly flat, then the differences could be quite significant.

For this exercise the process has been shortened. Even though the site is not at the stream gauge, it is only a few kilometres upstream and there are no major tributaries in between. The flow of water passing this site would therefore be very close to the quantities calculated at the gauge. Determining how much of the bed this quantity of water covers at the review site need not take a lot of work, only a little bit of observation. The water information website is updated daily, so it can be regularly reviewed and a watch kept to see when the river would likely to be flowing at the desired capacity (Figure 13). The mass of lines in the charts of Figures 2 to 5 is now spread out in hourly increments spanning a few days as well as the

supporting digital data. Once it is determined that the river is flowing at the right level, it is simply a matter of going to the site with camera in hand to record where the water level is. The water level for flows corresponding to the normal flow and the mean cadastral flow were recorded from the same spot to show the differences (Figures 14 and 15).

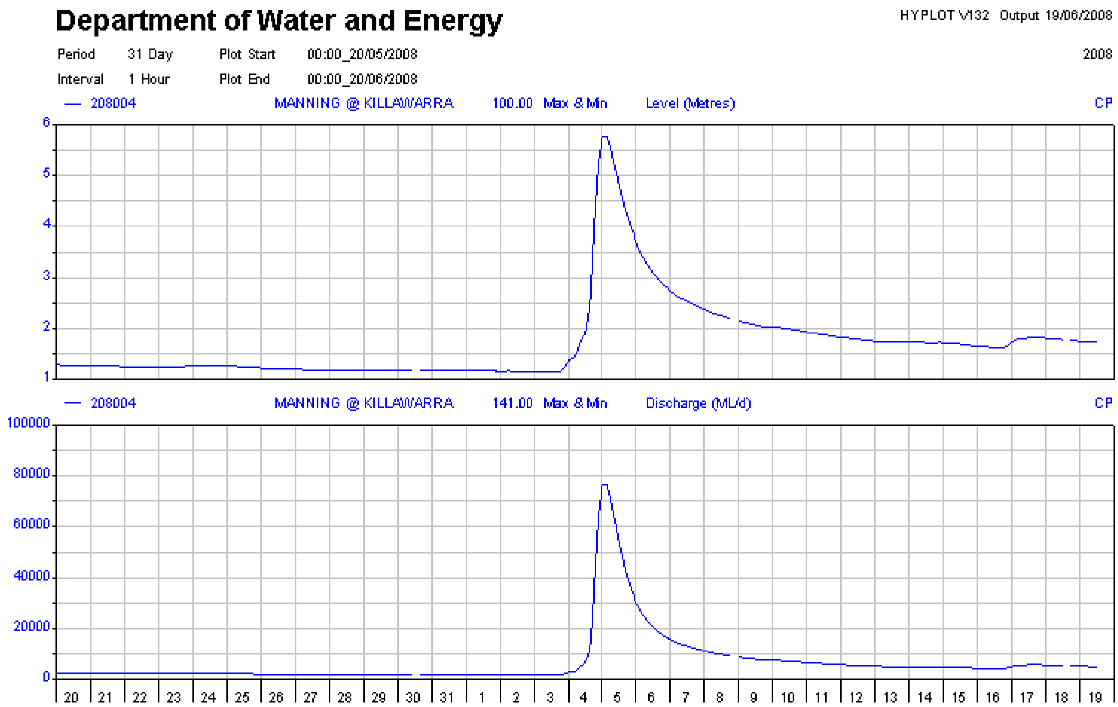


Figure 13: One month hydrograph of Killawarra gauge from NSW Waterinfo website.

Using such a technique may be plausible anywhere along the river system. From examining a representative set of records from gauge sites on different rivers around the State, it is quite apparent that the determination of flow from the gauge readings can vary significantly. The relation between height and flow does not appear to be completely rigid. There can be a reasonable aberration in the particular flow required for locating the cadastral bank, so a degree of tolerance will be required at the site observation.

Figure 14: The river and low shingle flat at flow corresponding to the usual or normal flow.

Figure 14 shows the water level in the river at a flow corresponding to the normal flow. It is the flow most likely to have been occurring when the surveyor undertook the survey in the latest plan. Inspection of the aerial photo (Figures 11 and 12) shows that the water level is at about the same as in the scene shown in Figure 14. The water amongst the gravel in the middle is also seen on the aerial image. The surveyor determined that the body of water within the shingle bed was not part of the river but part of the land and consequently above the level of the bank. If this were the case, there should be no water as water flows freely through the gravel. Figure 15 shows the level the river would flow at if it were flowing at a capacity that meets the mathematical definition of the bank. The low shingle bed has now disappeared.

Figure 15: The same scene as in Figure 14 but with water flowing at about the cadastral bank capacity.

9 CONCLUSION

The change in the scene from normal flow (Figure 14) to the mean flow "without reference to extraordinary freshets in time of flood or to extreme droughts" (Figure 15) makes it quite evident that the surveyor who did the later plan did not adequately assess the flow characteristics of the river and underestimated what area of bed was required to cater for the average or mean flow. The surveyor also could have been one who habitually rewords the definition to the normal flow. From the images it is clear that the surveyor's assessment of the bank was to the edge of the normal flow. Also from the images it is quite clear that the higher shingle terrace, seen in the right background is not part of the cadastral bed of the river but part of the land tenure. It would take quite a lot more water to cover the higher flat.

What is not quite clear from the images is where the cadastral bank is located amongst the lower vegetation. Up until the time the image in Figure 14 was taken, there had been an extensive dry period where the occasional scouring of the lower shingle had not taken place, so the vegetation had grown quite thickly. In the gravel in this area, near the high terrace bank, there exists a low point through which the water flows at the level of Figure 15 leaving a higher island in the middle. Gravel is generally moved about in this channel when the river rises over the low bed and vegetation usually struggles to take hold. Sometimes the gravel builds up and the channel becomes clogged but the next flow can equally move the gravel away and reinstate the flow.

Given the changing dynamics of the lower shingle bed, the information obtained through mathematical evaluation of the river flow, and the visual identification of the various derived components, the conclusion is that the cadastral bank is located along the toe of the low bank (Figure 10). The bridge abutment, as an artificial construction, must be ignored.

In this instance, the difference between what the surveyor determined and the "true" cadastral bank might seem to be insignificant in the overall extent of the land surveyed, however the exercise has provided a wealth of information. Within this site the low shingle bed is relatively small but in other river systems the similar shingle bed might be quite extensive. So such an exercise may be of greater significance elsewhere. Whether the mathematics held elsewhere also needed to be explored so the Manning River was not the only river examined for characteristics of stream flow. The same mathematical analysis was conducted on a representation of other rivers throughout the State (Table 1). Results were surprisingly similar everywhere which suggests that the situation explored here on the Manning could be equally applied elsewhere.

Table 1: Comparison of test site data to other rivers throughout NSW.

River Station	Brogo Angledale	Wilson Avenel	Clarence Baryulgil	Macquarie Bruinbun	Gwydir Bundarra	Macleay Georges Junction	Namoi Goangra	Mann Jackadgerry	Manning Killawarra	Hastings Kindee	Murrumbidgee Wagga Wagga	Barwon Walgett	Darling Wilcannia
% of maximum flow daily record													
Mean total flow	0.6	0.8	0.7	0.6	0.7	0.3	1.9	0.6	0.6	0.8	2.3	1.6	11
Mean exclusive flow	0.4	0.8	0.6	0.6	0.6	0.2	1.3	0.5	0.5	0.8	2.3	1.2	11
% daily flow less than													
Mean total flow	90	89	86	80	86	92	83	86	85	86	69	80	70
Mean exclusive flow	86	88	84	80	85	91	80	84	83	85	69	77	69
% of total gauge depth daily flow													
Mean total flow	9	11	9	10	12	13	34	10	9	12	22	42	32
Mean exclusive flow	7	11	9	11	11	12	28	10	5	13	22	35	32
Gauge reading													
Mean total flow	0.9	0.86	2.1	0.85	1.82	1.01	3.39	1.51	1.81	0.98	2.35	6.35	3.7
Mean exclusive flow	0.75	0.85	2.04	0.88	1.75	0.96	2.9	1.41	0.88	1.0	2.4	5.47	3.7

This exercise also shows that mathematics would be a viable methodology to locating the bank, in a cadastral sense, of any non-tidal stream. What such a methodology can also provide is repeatability. The data should provide the same answer no matter who did the computations. The subjectivity and uncertainty in using indicators such as soil and vegetations types has also been eliminated. Even if there is no physical bank, such as in a situation where the land slopes gently down to the water over a large distance, the limit of the bed can still be defined.

10 BANK DEFINITION CONSEQUENCES

What does the mathematics mean for our convoluted definition of the bank? Quite simply, the definition is too complicated and can be simplified without causing any significant change in

the result. A simpler definition would be, "*the bank is the limit of the bed adequate to contain the average or mean flow of the river*".

The analysis shows that the average of all flows is only marginally different from the average of flows excluding extraordinary freshets and extreme droughts. The lateral difference between the two would be insignificant on any bank other than one of very gradual slope. For the most part river banks tend to be relatively steep, so a small percentage change in the height of the river will probably not be noticeable. In practical circumstances, a river bank definition is unlikely to be conducted using such rigorous mathematics but instead conducted visually, estimated from experience and such knowledge that this paper supports. The mathematics tells us that the area of river bed required to cater for the average flow is likely to cover any low lever shingle bed adjacent to the usual flow channel. It would be relatively simple to locate the back of such a shingle bed or the toe of the low bank. Changes in vegetation and soil may not be a reliable indicator as the same types could spread either side of this low bank. The only difficulty comes where there is not a definable low bank and or shingle bed feature near the low flow channel.

11 CONTEMPLATION

For most of the time, the flow of a river or stream is confined to a smaller channel within the bed, with the cadastral bank statistically only having about 15% chance of being reached. The quantum of flow that reaches the cadastral bank also relates to a recurrence interval of about 1 in 1 year or a little higher. The case *Boyle Concessions Ltd v Yukon Gold Co 1917* ruled out yearly occurring flows (in the case a monsoon flow) as being gradual. According to the mathematics, it is the statistical 1 in 1 year, or greater, flows that get to the bank to define the shape of the river. What does this mean for the concept of gradual change occurring? Something to contemplate.

FOOTNOTE

It may be appropriate for a surveyor to determine the bank today in accordance with the ideas presented in this paper. That, however, does not mean that this was the position of the bank in the past. Proving the location of the bank today, even using mathematics, is not proof of the location of the bank when the land was originally defined by survey or that the original survey was in error. Australian rivers are renowned for randomly flowing at much greater volumes than what is normal. During these times, significant amounts of materials, which are within the water's reach, can be moved around. Gravel banks may not have previously occurred in a particular location. What is gravel today may be a migrating bar that is on its journey downstream and may be gone tomorrow. Also what seemingly appears today as gravel beds a little above what the mathematics suggest is the bank, does not exclude that area as being part of the bed as at one time in the past the level of gravel may have been lower. If these or similar situations are the case, it will be up to the surveyor to determine if the change has been by gradual, or other means.

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A Surveyors' Guide to Navigating the Roads & Maritime Services, Maritime Services Division Plan Endorsement Process

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ABSTRACT

This paper is intended to provide a guide for surveyors which explains the main aspects of the cadastral plan endorsement process as currently conducted by Roads & Maritime Services, Maritime Services Division (hereafter to be simply referred to as Maritime). Maritime was previously known as the Maritime Authority of NSW trading as NSW Maritime. On 1st November 2011 both the former NSW Maritime (NSWM) and the former Roads & Traffic Authority (RTA) were replaced by a single new agency known as Roads & Maritime Services (RMS). Maritime is the owner of extensive areas of wetland such as Sydney, Newcastle and Port Kembla harbours and Botany Bay. Much of this land is bounded by Mean High Water Mark (MHWM) boundaries, and where a cadastral survey of adjoining land is carried out, the endorsement of the common foreshore boundary by Maritime is essential prior to plan registration by NSW Land and Property Information (LPI). This paper has been written to assist both public and private sector surveyors to obtain Maritime endorsement for their plans as efficiently as possible. This can hopefully be achieved by providing an explanation of the review process including where and when it is required and by stressing the importance of obtaining Maritime search information and advice, prior to commencing such surveys. Example plans, issues commonly encountered and general suggestions as how to best navigate the system to the benefit of both surveyors and their clients are included.

KEYWORDS: *Boundary, cadastral, endorsement, maritime, MHWM.*

1 EXTENT OF MARITIME WETLAND OWNERSHIP

Maritime holds the freehold title to Sydney Harbour (almost all), Botany Bay (upstream to the Captain Cook Bridge), Port Kembla Harbour and the Port of Newcastle including upstream to the Tourle Street Bridge over the Hunter River (south arm) and to the Stockton Bridge over the Hunter River (north arm) and the Hannell Street Bridge over Throsby Creek.

Foreshore boundary enquires regarding Port Hacking, Georges River, Pittwater, Hawkesbury River and other tidal waterways should be directed to the Crown Lands Division of the Department of Primary Industries.

2 PLANS REQUIRING FORESHORE BOUNDARY ENDORSEMENT BY MARITIME PRIOR TO LODGMENT AT LPI

All definitions of Mean High Water Mark (MHWM) and Former Mean High Water Mark

(FMHWM) that form a common boundary with Maritime owned land need to be endorsed, except where the identical boundary has been previously endorsed by Maritime on a registered plan.

In the case of a proposed change to a MHWM boundary, Clause 48 of the Surveying and Spatial Information Regulation 2006 under the Surveying Act 2002 (hereafter to be simply referred to as the S. & S. I. Reg. 2006) applies: *"**48 Changes in boundaries formed by tidal waters** (2) Approval to the adoption of a changed position referred to in subclause (1) (a) must be obtained from: (b) the owner of the adjoining land, if the adjoining land below the MHWM is not Crown land."* In such cases surveyors must be aware of the modified doctrine of accretion and erosion under Section 55N of the Coastal Protection Act 1979 which applies to all Maritime owned wetland.

Previously endorsed MHWM and FMHWM boundary definitions usually do not satisfy Clause 65 of the S. & S. I. Reg. 2006 – *"**65 Method of showing natural feature boundaries** (c) must approximate the boundary by bearings and distances."* In all such cases recent plans adopting these definitions need to be endorsed by Maritime to verify that the short lines shown satisfy the requirements of Maritime and Clause 65.

Maritime endorsement is **not required for right line boundaries**. There are significant lengths of right line boundaries around the Sydney Harbour foreshore sometimes resulting from reclamations where the approved extent of the reclamation was a "limit line" surveyed as a right line. Also some complicated MHWM boundaries with many "S" shaped curves have been rationalised by adopting a straight "equalising line" through the curves and have been surveyed as right line boundaries.

Samples of typical plans endorsed by Maritime are shown later in this paper (see Figures 5, 8 and 9).

3 THE IMPORTANCE OF MARITIME SEARCH INFORMATION

Maritime holds extensive field book and plan information archived in a traditional Plan Room environment (Figure 1). Most of this information is available in digital format and includes field books dating from 1900 and "P" plans dating from the late 1800s. Currently search information is available without cost on request to the Survey Manager; it is delivered by email with a zip file attachment. An example search zip file report is shown in Figure 2. Foreshore boundary location information is also available in the form of a geo-referenced DXF file generated from the Maritime Geographic Information System (GIS). It would be very unusual for a relevant foreshore boundary definition of Maritime land not to be available in our extensive archive of field book information.

The **importance of requesting Maritime search information prior to attempting any field work** for foreshore subdivision, consolidation, redefinition or construction set-out surveys cannot be overstated as these all require adoption of the Maritime foreshore boundary definition. Maritime considers that foreshore definitions as shown in Maritime field book records take precedence over registered plans where such plans have not been endorsed by Maritime or former Authorities such as NSW Maritime, Waterways Authority, Maritime Services Board or the Sydney Harbour Trust (established in 1901). There are numerous cases of differences in foreshore boundary definition between that shown on Title Diagrams from non-endorsed LPI registered plans (Figure 4) and Maritime definitions (Figure 3).

Figure 1: Maritime has a traditional style plan room archiving records from the late 1800s, most being available in digital format.

```
#  Archive search.zip
1997-07-29 10:56          92750         RP_5218_2.TIF
2010-08-30 14:09         274218         plan_ma2027.pdf
2010-09-17 11:02         261215         subdivision_plan_annexure_a.pdf
1999-05-06 12:34         412166         041_045.JPG
1999-05-10 07:06         215038         057_038.JPG
1999-05-28 07:01         139451         193_001.JPG
1999-05-28 10:05         267102         202_065.JPG
1999-08-17 16:01         173682         237_011.JPG
1999-08-25 14:07         221681         434_049.JPG
1999-08-27 07:49         174619         548_045.JPG
2006-12-12 10:27         185925         548_056.JPG
1999-08-31 10:20         324034         568_024.JPG
1999-08-31 10:20         319829         568_025.JPG
2010-06-17 10:27         186166         568_026.JPG
1999-08-31 10:20         343190         568_027.JPG
1999-08-31 10:20         326357         568_028.JPG
1999-08-31 10:20         316548         568_029.JPG
1999-08-31 10:21         335427         568_032.JPG
1999-08-31 10:21         335055         568_033.JPG
1999-08-31 10:21         323785         568_034.JPG
1999-08-31 10:21         324124         568_035.JPG
1999-08-31 10:22         347345         568_054.JPG
2009-10-01 14:35         252893         568_067.JPG
2006-12-12 10:26         213413         577_013A.JPG
1999-08-31 12:15         336699         577_025.JPG
2006-12-12 10:21         182331         604_015.jpg
1997-07-29 10:56         134471         RP_5218_1.TIF
# Total Packed Files 1  File size 6669139K
```

Figure 2: Zip file report of Maritime supplied search information for the plan in Figure 5.

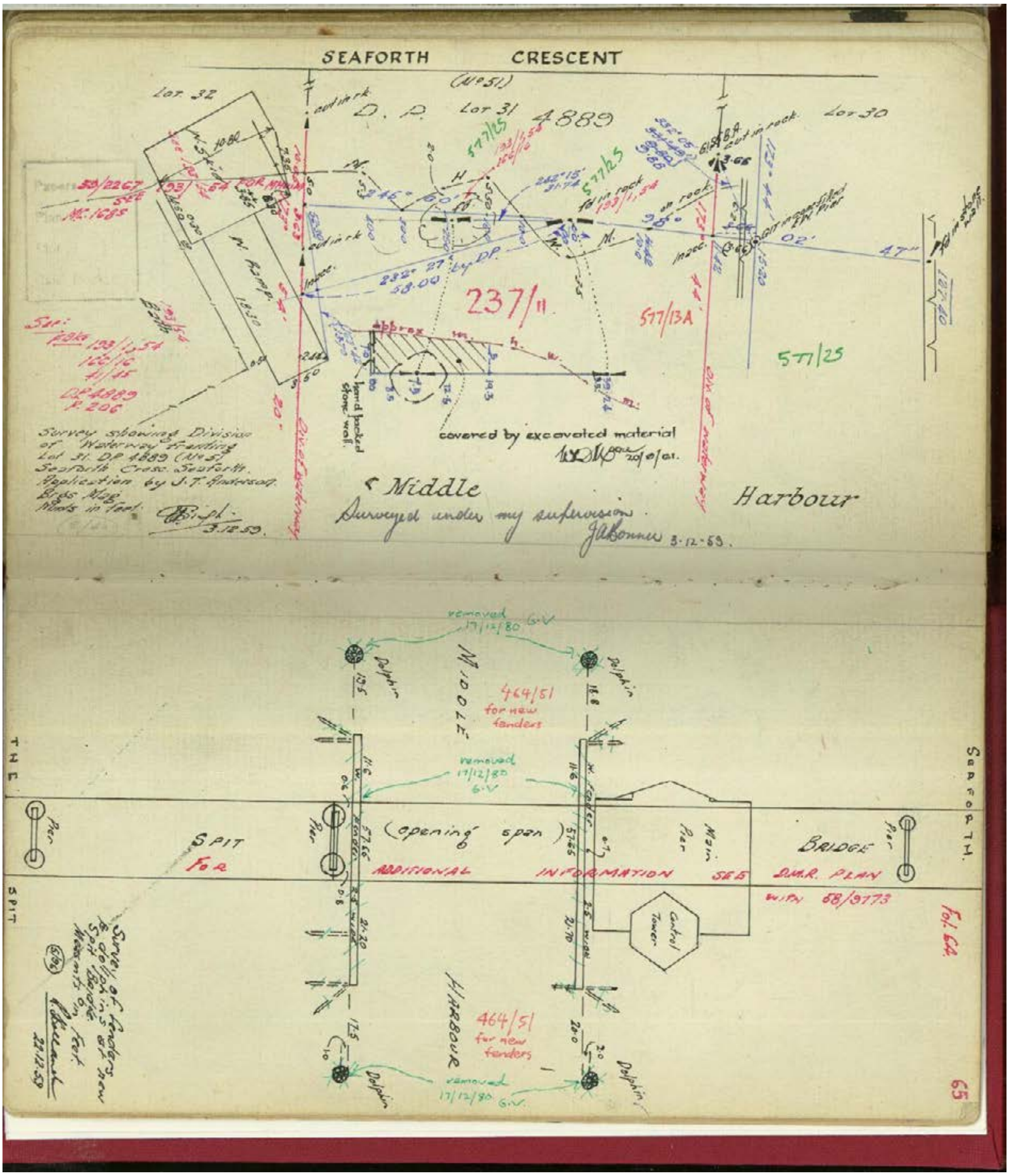


Figure 3: Maritime Field Book 202/65 of 1959, the upper part shows the MHWM adopted in the Figure 5 plan.

The existence and consequences of these differences is not understood by foreshore land owners, their legal representatives and some surveyors! Subdivision of Maritime wetland, typically for the long-term leasing of marine facilities, is one situation that can result in the need for a full redefinition of the adjoining privately owned land. Both the subdivision and redefinition can be included in the same plan, see Figure 5 for an example. Figure 4 shows a part of DP 4889 where the foreshore boundary is only depicted by a wavy line and the area of Lot 31 is shown as 1,201 m^2. Figure 5 shows a recent plan being in part a plan of redefinition of Lot 31 in DP 4889 with an area of 1,230 m^2. This area represents an increase of 29 m^2 over the Title Diagram area. Note also a connection on the recent plan (Figure 5) to an old rock mark from plan P206574 surveyed in November 1893.

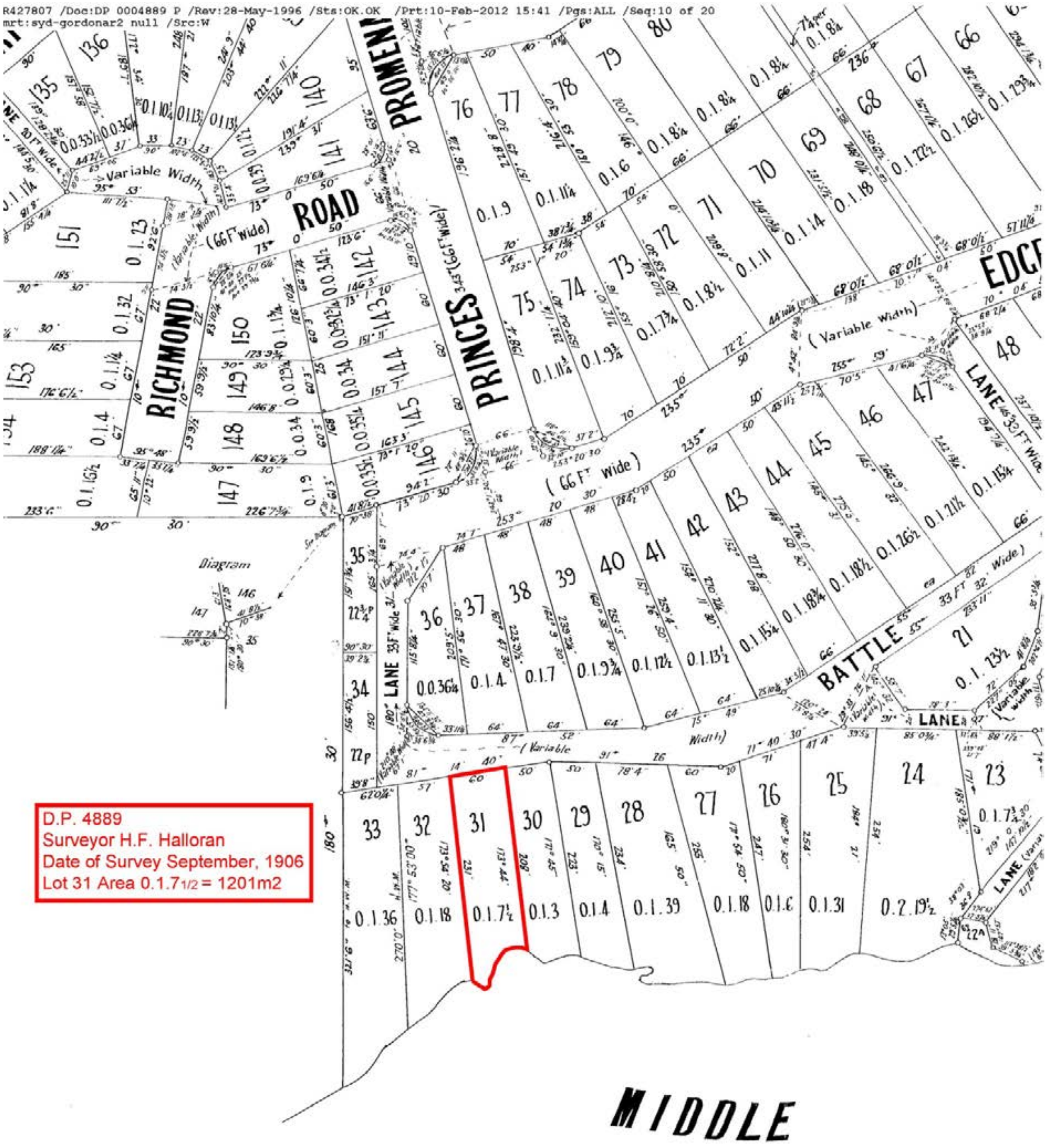


Figure 4: 1906 survey of Lot 31 with foreshore boundary defined by side boundary lengths and only a wavy line between corners.

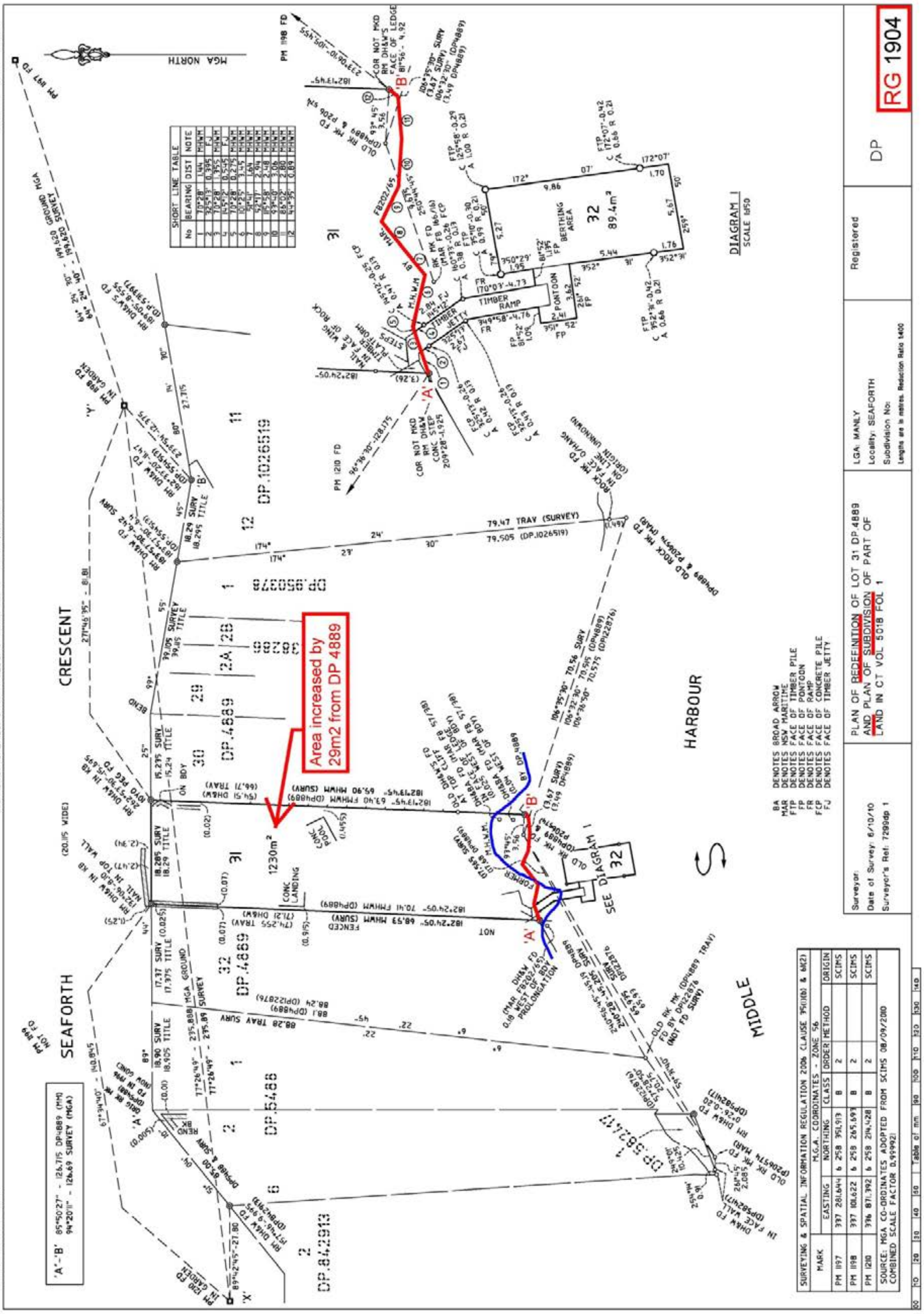


Figure 5: The endorsed foreshore boundary defined from Maritime field book 202/65 is shown by “red edging”. Note the blue line indicating this boundary from DP 4889.

4 NEW MHWM SURVEYS

In the very unusual situation that a new MHWM survey is required, generally because a suitable field book definition is not available, the following methods are acceptable:

- Observe a MHWM tide, or very close to it, under calm conditions and mark or stake the contour of that tide on site (Figure 6, lower photo). In Sydney Harbour, MHWM is currently adopted as being 1.48 m on the Fort Denison tide gauge with gauge zero being 0.925 m below the Australian Height Datum (AHD). Tidal heights at the Fort Denison gauge can be obtained in real time by contacting Harbour Control at Sydney Ports Corporation.

- Although observing a MHWM tide under suitable conditions is the preferred method of determining a new MHWM boundary, levelling from an acceptable survey control or bench mark is more commonly used. In Sydney Harbour, MHWM is currently adopted as being 0.555 m AHD.

5 COMMON SURVEY AND PLAN ISSUES REVEALED BY THE MARITIME PLAN REVIEW PROCESS

5.1 Survey Issues

- Insufficient effort in locating survey marks in the vicinity of the subject property, particular effort is needed in locating marks and occupations shown in Maritime field books. This effort is necessary because marks and occupations are essential for re-establishing the boundary definition shown in such field books. Field work often has to be planned around low tides to avoid the problem of some survey marks being submerged at other times and some marks also require a small boat for practical foreshore access.

- Lack of compliance with Clause 66 of the S. & S. I. Reg. 2006 which is particularly relevant to surveys requiring endorsement by Maritime – ***"66 Surveys of land fronting tidal waters*** *In the case of a survey of land adjoining tidal waters, a surveyor must show on a survey plan the description and relationship of any sea wall and reclaimed land adjacent to the MHWM"*.

- There is also some reluctance to comply with Clause 64 of the S. & S. I. Reg. 2006 – "***64 Method of showing boundaries generally*** *(1) A survey plan must show: (c) the description (including age, nature, construction material and relationship to the boundary) on any substantial structure (including any fence) (i) that is within one metre of the land surveyed"*.

- Survey errors in the location of marks and structures through erroneous radiations not detected by other checks as a part of good survey practice.

- Connections to survey control marks are incorrect or they refer to the incorrect control mark or plan corner.

5.2 Plan Presentation Issues

- Inadequate or ambiguous labelling of MHWM and FMHWM boundaries and their associated short lines.

- Differentiation of sections of MHWM and FMHWM where both exist along a single foreshore boundary often causes the surveyor confusion that is apparent in the plan.

- Foreshore boundary dimensioning can be confusing or ambiguous and is usually best presented in a table showing the short line dimensions and status, i.e. MHWM, FMHWM or right line.

- There is insufficient use of diagrams or diagrams are too small to be effective.

- Many lots simply do not close and or have incorrect areas shown. This is inexcusable!

6 THE MARITIME PLAN REVIEW PROCESS: SUMMARY AND SUGGESTIONS

After verifying that you are dealing with a MHWM/FMHWM boundary and the adjoining property is Maritime owned wetland, you should request search information from Maritime via an email to the Survey Manager. If you are not reasonably experienced in the type of survey required, also ask Maritime for a sample plan.

Complete the field work ensuring that particular effort is made to locate and connect to all marks shown in Maritime field books that are in the general vicinity of your survey. All structures within the immediate vicinity of the foreshore boundary need to be surveyed and included in the geo-referenced DXF/DWG file that Maritime requires on completion.

On completion of your plan, email a PDF file of the plan and administration sheet to the Survey Manager, this direction supercedes that given in the Surveyor General's Directions No. 6 Water as a Boundary – Procedures – December 2004 Sections 8.1 and 8.2 (a).

Although survey reports are not mandatory in all cases, surveyors should provide reports to explain any aspect of their definition or interpretation that may not be obvious to others. Photographs, with date and time stamps to determine the height of the tide at the time of photography, and concise explanations can be invaluable in explaining various site specific situations (Figure 6). It is in the surveyor's and therefore his or her client's interest to provide good reports and photographs where necessary, as this will help reduce the Maritime review turn-around time. Good reports can also reduce the need for a Maritime field inspection. Field inspections are conducted for specific cases where the survey and plan review raises concerns and occasionally on a randomly selected basis for audit purposes.

Fundamental to the Maritime plan review role is the reconstruction of the plan boundaries using "CivilCad" software to facilitate the direct comparison of foreshore boundaries as derived from the plan being reviewed, Maritime field books and the Maritime GIS (Figure 7).

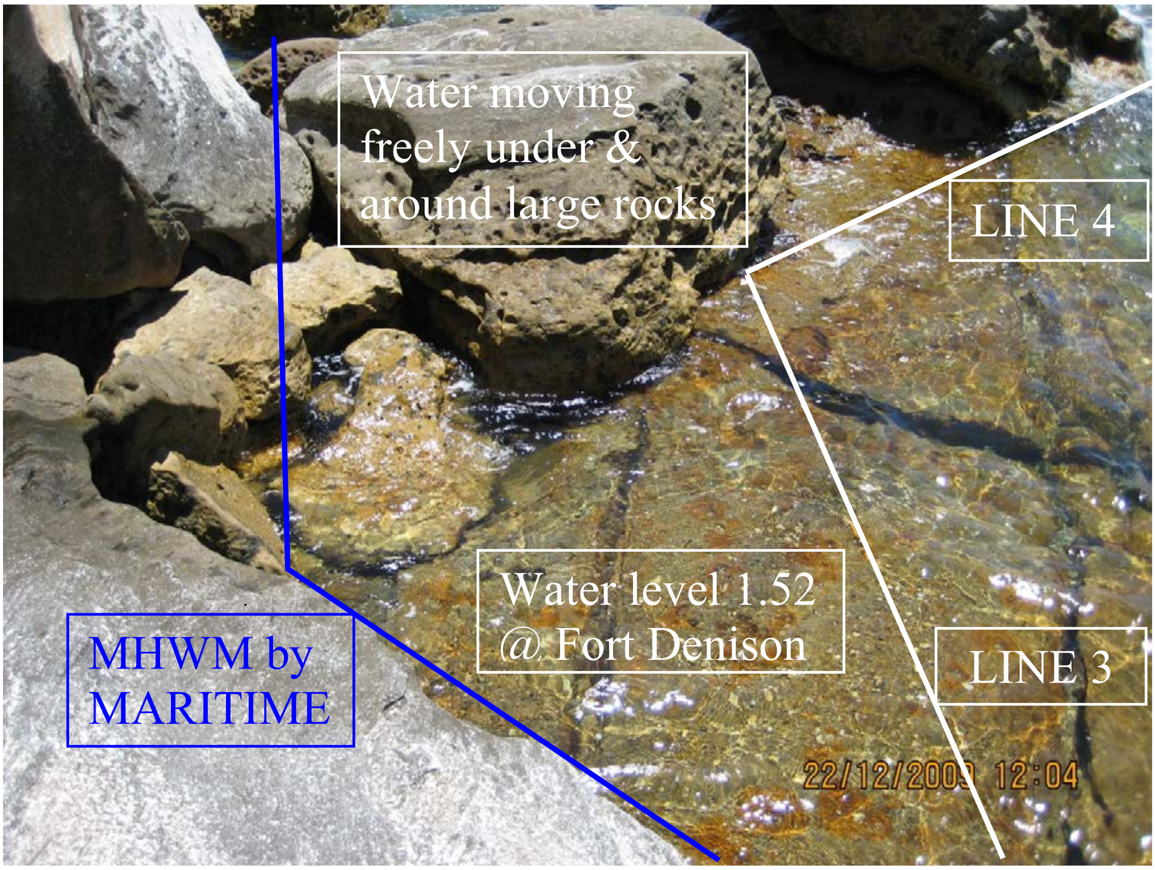


Figure 6: Photo above supplied by surveyor doing a new MHWM survey. Photo below from Maritime field investigation at a time of being within a few centimetres of a MHWM tide (1.48 m at Fort Denison).

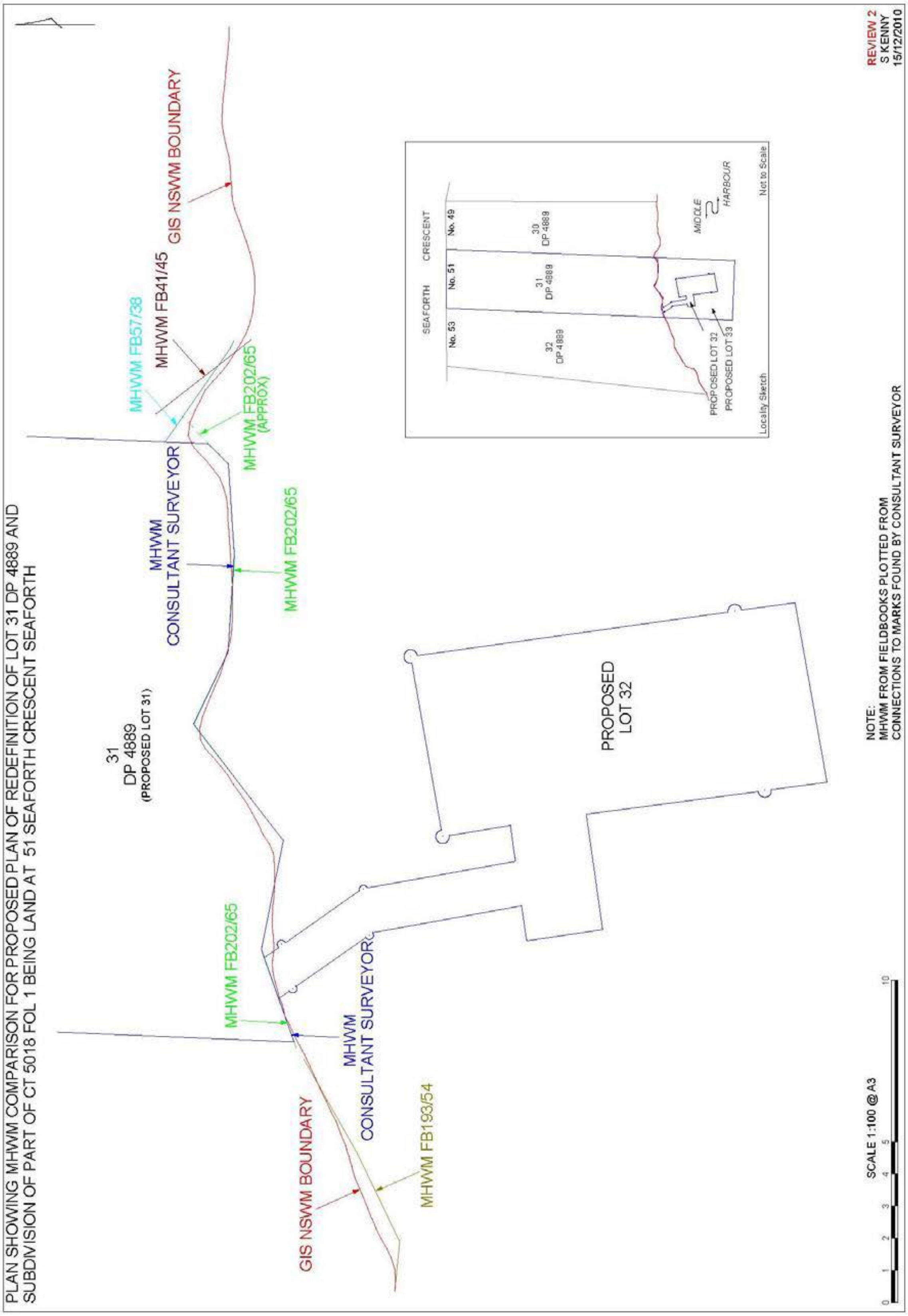


Figure 7: Comparison of the foreshore boundary constructed from the survey under review, Maritime field book/s and the Maritime GIS. This comparison is for the plan in Figure 5.

In the interest of expediency, the changes Maritime requires to a plan under review are issued in the form of hand written comments added to the hard copy plan. The plan is then scanned and returned by email to the surveyor for plan amendment or occasionally further field work. Two or three plan review cycles are typical; however this varies depending on both the survey and plan complexity and quality.

When the plan under review is considered satisfactory, Maritime will request the surveyor supply the original plan administration sheet signed by the surveyor, by mail or courier. Some surveyors choose to provide the original administration sheet earlier in the review process. However, as amendments are often required to the plan description or the list of plans used, Maritime recommends that this document is not provided until requested.

A further requirement of surveyors at the completion of the plan review process is to provide a geo-referenced (MGA Zone 56 coordinates) DWG/DXF file of the plan boundaries, connections to survey control marks and all structures in the immediate vicinity of the foreshore boundary.

The final plan endorsement process involves "red lining" of the endorsed boundary and cataloguing the plan in the Maritime "RG" plan registration system (Figures 5, 8 and 9). Also required is the stamping and endorsing of the plan administration sheet (Figure 10), updating the GIS with the endorsed boundary and preparing a letter specifying the endorsed boundary for plan lodgement purposes.

The above documents and the investigation invoice, currently a nominal $219 incl. GST, will be mailed to the surveyor or can be collected from the Maritime Rozelle Office by arrangement.

7 CONCLUDING REMARKS

Maritime's intention is to review and endorse plans as quickly as our limited resources and other work commitments permit. Plans are generally reviewed in the order that they are received. However, some surveyors are pressured by their clients to seek priority or special treatment for the review of their particular plan. In such cases surveyors are best advised to tell their client at the outset of the need for Maritime plan endorsement and the likely time required. The advice of the Survey Manager should be sought at this stage.

Surveyors can also definitely reduce the time necessary for the review and endorsement of their survey by producing a high-quality survey and plan supported by a concise report and/or photographs as necessary.

Maritime must review all submitted plans with the "Public Interest" in mind and also ensure that both the boundary definition and plan presentation standards relevant to foreshore boundaries are satisfactory in terms of both Maritime's requirements and the S. & S. I. Reg. 2006.

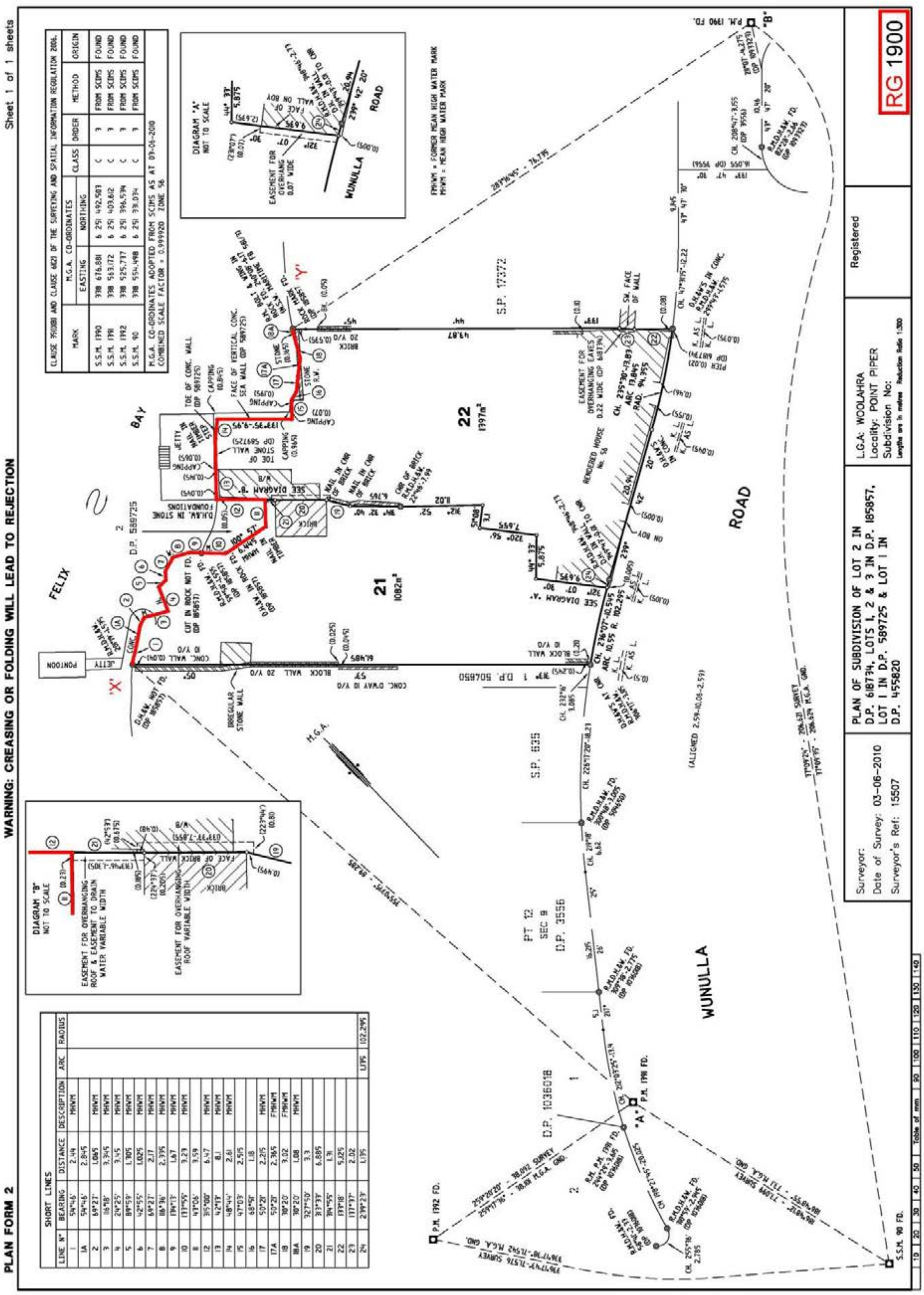


Figure 8: Endorsed plan of subdivision catalogued as "RG 1900".

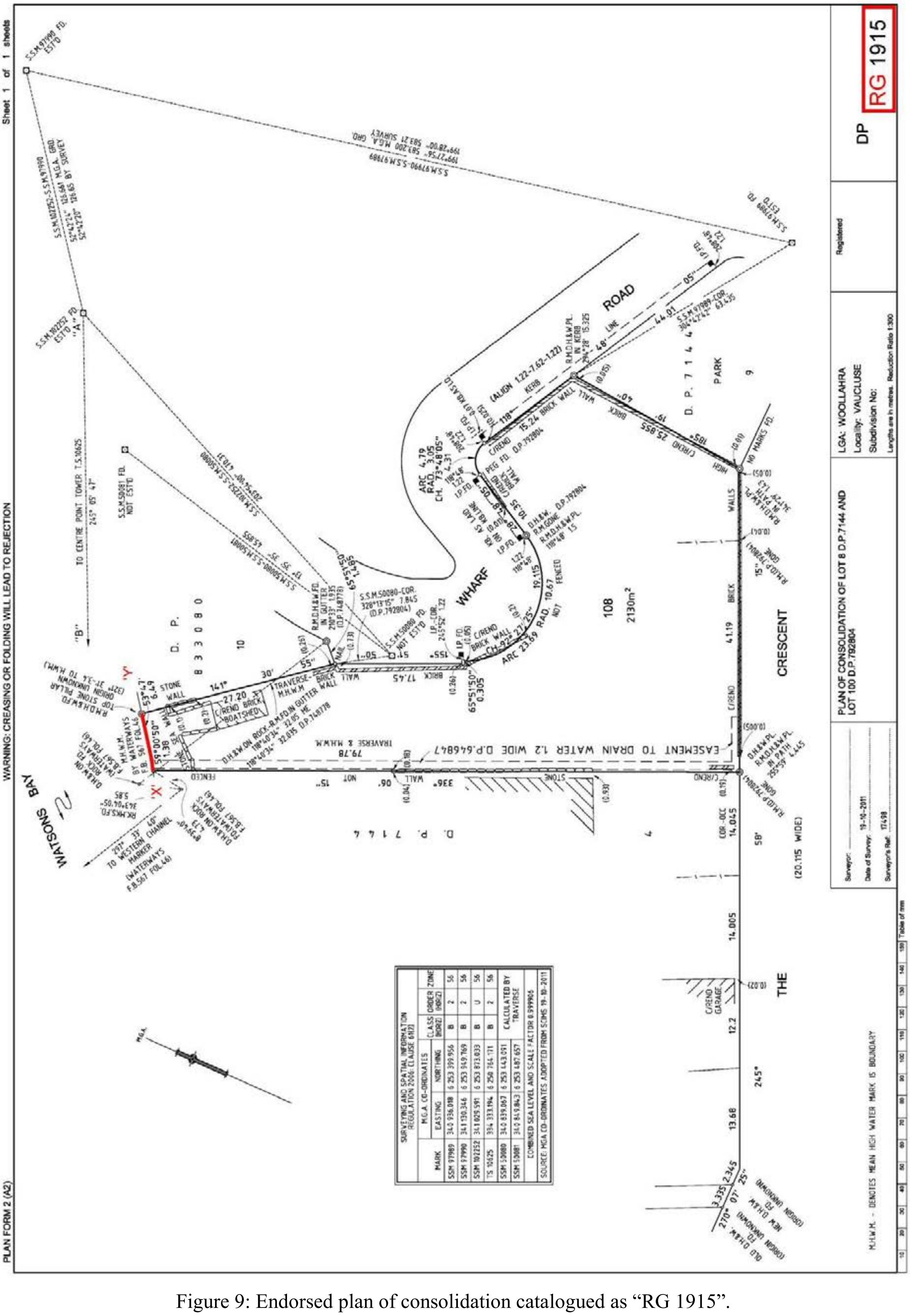
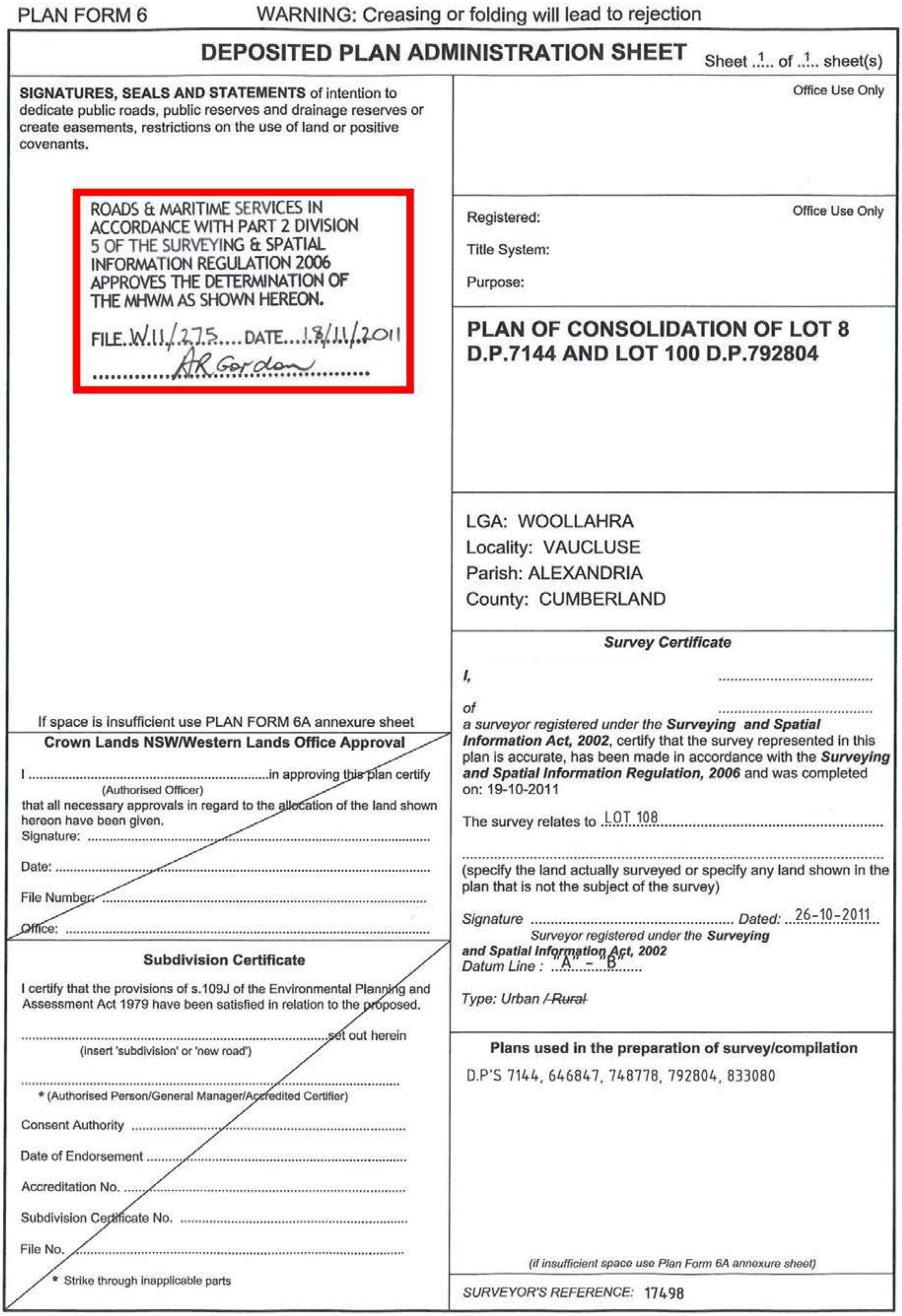


Figure 9: Endorsed plan of consolidation catalogued as "RG 1915".



PLAN FORM 6 WARNING: Creasing or folding will lead to rejection

DEPOSITED PLAN ADMINISTRATION SHEET Sheet ..1.. of ..1.. sheet(s)

SIGNATURES, SEALS AND STATEMENTS of intention to dedicate public roads, public reserves and drainage reserves or create easements, restrictions on the use of land or positive covenants.

ROADS & MARITIME SERVICES IN ACCORDANCE WITH PART 2 DIVISION 5 OF THE SURVEYING & SPATIAL INFORMATION REGULATION 2006 APPROVES THE DETERMINATION OF THE MHWM AS SHOWN HEREON.
FILE. W.11/275.... DATE...18/11/2011
.........AR Gordon.........

If space is insufficient use PLAN FORM 6A annexure sheet

Crown Lands NSW/Western Lands Office Approval

I .... in approving this plan certify (Authorised Officer) that all necessary approvals in regard to the allocation of the land shown hereon have been given.
Signature: ....
Date: ....
File Number: ....
Office: ....

Subdivision Certificate

I certify that the provisions of s.109J of the Environmental Planning and Assessment Act 1979 have been satisfied in relation to the proposed.
.... set out herein
(insert 'subdivision' or 'new road')
....
* (Authorised Person/General Manager/Accredited Certifier)
Consent Authority ....
Date of Endorsement ....
Accreditation No. ....
Subdivision Certificate No. ....
File No. ....
* Strike through inapplicable parts

Office Use Only

Office Use Only
Registered:
Title System:
Purpose:

PLAN OF CONSOLIDATION OF LOT 8 D.P.7144 AND LOT 100 D.P.792804

LGA: WOOLLAHRA
Locality: VAUCLUSE
Parish: ALEXANDRIA
County: CUMBERLAND

Survey Certificate

I, ...
of ....
a surveyor registered under the ***Surveying and Spatial Information Act, 2002****,* certify that the survey represented in this plan is accurate, has been made in accordance with the ***Surveying and Spatial Information Regulation, 2006*** and was completed on: 19-10-2011

The survey relates to .LOT 108........................
....
(specify the land actually surveyed or specify any land shown in the plan that is not the subject of the survey)

Signature .... *Dated:* ..26-10-2011..
Surveyor registered under the ***Surveying and Spatial Information Act, 2002***
Datum Line : ..."A" - "B"...
Type: Urban / ~~Rural~~

Plans used in the preparation of survey/compilation

D.P'S 7144, 646847, 748778, 792804, 833080

(if insufficient space use Plan Form 6A annexure sheet)

SURVEYOR'S REFERENCE: 17498

Figure 10: Endorsed plan administration sheet for "RG 1915" (Figure 9).

REFERENCES

Coastal Protection Act 1979 No 13, http://www.legislation.nsw.gov.au/viewtop/inforce/act+13+1979+FIRST+0+N/ (accessed Feb 2012).

Registrar General's Directions, http://rgdirections.lpi.nsw.gov.au/deposited_plans/natural_boundaries/tidal_boundaries (accessed Feb 2012).

Surveying and Spatial Information Regulation 2006 under the Surveying and Spatial Information Act 2002, http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+530+2006+cd+0+N (accessed Feb 2012).

Surveyor General's Directions, http://www.lpi.nsw.gov.au/about_lpi/publications/guidelines/surveyor_generals_directions (accessed Feb 2012).

High-Resolution Multibeam Surveys at the Sydney Ports Corporation

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ABSTRACT

The recent introduction of a high-resolution multibeam echosounder in the Sydney Ports Corporation Survey Services Department has provided full seafloor coverage of our ports for the first time. Results from these surveys have continually proven to meet the manufacturer's stated accuracy and repeatability. The multibeam echosounder system was more recently utilised during the construction of the Port Botany Expansion project to survey the scour rock placed to protect the quay wall from erosion. The Port Botany Expansion contract design stipulated minimum depths for the scour rock, as well as a minimum thickness of the placed rock. The contractor's resultant hydrographic surveys produced quite different results to the checking surveys conducted by Sydney Ports' hydrographic survey team. This paper presents some of the changes in equipment and procedures since the adoption of multibeam technology, and also the processes used by Sydney Ports' Survey Department to validate the reliability and the accuracy of the scour rock hydrographic surveys.

KEYWORDS: *Sydney Ports, Port Botany Expansion, hydrographic, multibeam echosounder, accuracy.*

1 INTRODUCTION

Sydney Ports Corporation Survey Services Department provides hydrographic survey information to mariners and engineers. Coverage areas include all navigation channels utilised by commercial traffic within Sydney Harbour and Port Botany (Figure 1). In the past, this information was gathered using singlebeam echosounder and side-scan sonar technology. In 2009, Sydney Ports Corporation (SPC) introduced a High Resolution Multibeam Echosounder (MBES) survey system.

The MBES system has greatly improved the efficiency of the survey section as well as increasing the seafloor coverage of Sydney Ports charting. Results from these surveys have continually proven to meet the manufacturer's stated accuracy and repeatability.

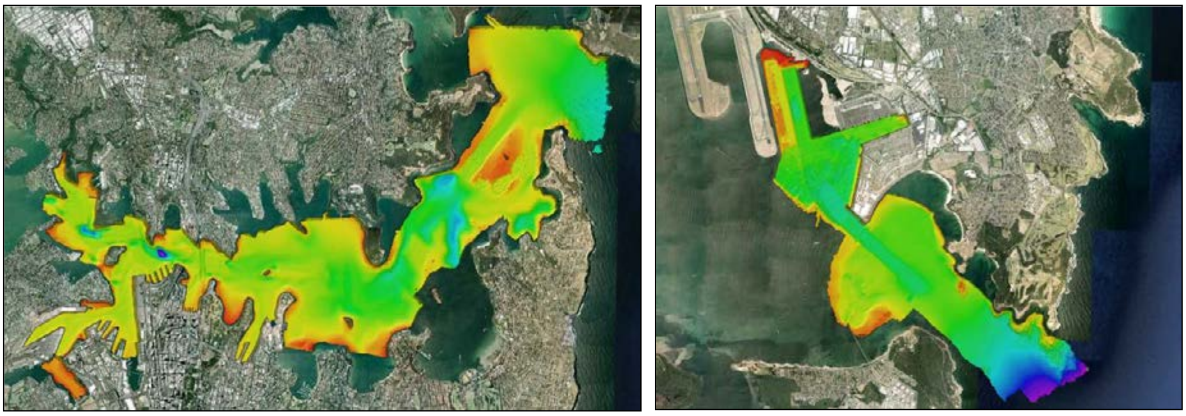

Figure 1: Sydney Ports Corporation hydrographic survey coverage areas, i.e. Sydney Harbour (left) and Port Botany (right).

2 SYDNEY PORTS SURVEY REQUIREMENTS

SPC hydrographic surveys are carried out in accordance with the Ports Australia Principles for Gathering and Processing Hydrographic Information in Australian Ports (Ports Australia, 2008). These principles are primarily intended for (but not limited to) use in Australian ports where shipping regularly or on occasions operates with restrictions on Under Keel Clearance (UKC) and are intended for use in ports, supplementing the International Hydrographic Organization (IHO) SP44 Standards for Hydrographic Surveys (Table 1). IHO Special Order Survey specifications are used as nominal standards for all hydrographic surveys performed by SPC.

Table 1: IHO S-44 Standards for hydrographic surveys (International Hydrographic Bureau, 2008).

ORDER	Special	1	2	3
Examples of typical areas	Harbours, berthing areas, and associated critical channels	Harbours, approaches, recommended tracks and some coastal areas with depths up to 100m	Areas not described in Special Order and Order 1, or areas up to 200m water depth	Offshore areas not described in Special Order, and Orders 1 and 2
Horizontal accuracy (95% confidence level)	2m	5m + 5% of depth	20m + 5% of depth	150m + 5% of depth
Depth accuracy for reduced depths (95% confidence level)†	a = 0.25m b = 0.0075	a = 0.5m b = 0.013	a = 1.0m b = 0.023	Same as Order 2
100% bottom search	Compulsory	Required in selected areas	May be required in selected areas	N/A
System detection capability	Cubic features >1m	Cubic features >2m in depths up to 40m; 10% of depth beyond 40m.	Same as Order 1	N/A
Maximum line spacing	N/A	3x average depth or 25m, whichever is greater	3-4x average depth or 200m, whichever is greater	4x average depth

$$\pm v[a^2+(b x d)^2]$$

where:

a = constant depth error, i.e. sum of all constant errors
bxd = depth dependent error, i.e. the sum of all depth dependent errors
b = factor of depth dependent error
d = depth

2.1 Achieving Survey Requirements before MBES

Prior to the purchase and installation of the new MBES system, SPC met the IHO Special Order survey specifications through the use of singlebeam echosounder (SBES) and side-scan sonar (SSS). Depth soundings were measured using the SBES, with the SSS enabling the compulsory 100% bottom search and identification of features and/or targets larger than 1 m^3 which would then be re-surveyed using the SBES and possibly removed by divers at a later date.

The SBES used by SPC was the ATLAS DESO 25 with a dual-frequency transducer (33 kHz and 210 kHz). At the higher frequency the echosounder measured the minimum seabed depth within the eight-degree transducer beamwidth, with an approximate footprint diameter of 1.4 m at 10.0 m depth, and 2.1 m at 15.0 m depth. Because of the size of this transducer footprint the true position of the measured depth can never be known with certainty.

The SSS used was a Klein 3000, with a maximum across-track range of 600 m at 100 kHz and 150 m at 500 kHz operating frequency. However, line spacing never exceeded 150 m, as SBES line spacing was run at 2 m within berth boxes, up to a maximum of 20 m in deeper channel areas. The SSS was generally run at 50 m range setting, allowing for at least 200% seafloor ensonification (total coverage of survey area that is acoustically imaged in the course of a sonar survey) in all areas. The SSS along-track beam width was 0.7° at 100 kHz, or 0.21° at 500 kHz, enabling multiple strikes on a 1 m^3 target at a vessel speed of 5 knots.

Trimble HydroPro® software was used for the online acquisition of the SBES data, and SonarPro® for the SSS. Office-based processing of SBES data was also completed using Trimble HydroPro® software, and SSS data in CARIS SIPS®.

Horizontal accuracy requirements were met through the use of Real Time Kinematic (RTK) GPS, which SPC has adopted since 1995.

SPC owns and operates two GNSS base stations, located at Sydney Harbour and Port Botany. These SPC base stations are coordinated:

- Horizontally in Map Grid of Australia 1994 (MGA94) coordinates, which is the Universal Transverse Mercator (UTM) projection based on the Geocentric Datum of Australia 1994 (GDA94, see ICSM, 2006).
- Vertically in the chart datum, Zero Fort Denison Tide Gauge (ZFDTG), i.e. 0.925 m below the Australian Height Datum 1971 (AHD71, see Roelse et al., 1971).

Differentially adjusted values measured the height of the antenna on the vessel. Combined with its fixed offset to the transducer and the depth measured by the echosounder, a reduced value for each sounding could be determined. The general survey vessel setup for a SBES survey is shown in Figure 2.

Bar checks were carried out before and after the survey to ensure the SBES was performing effectively and taking into consideration daily metocean conditions such as water temperature and salinity which in turn alter the speed of sound through water. The bar check is carried out by lowering a bar underneath the SBES transducer. This bar is attached to wire rope that has accurate metre markings and is held at various interval depths to calibrate and check the accuracy of the echo sounder measurements. The process is essentially the same as checking an Electronic Distance Measuring (EDM) instrument over a known baseline. Repeatability,

however, was difficult to assess with singlebeam as coverage of the seafloor is actually quite sparse. Survey cross-lines were run at 50-metre spacing over the site. Comparisons were carried out between subsequent surveys using contour comparisons to assess changes to the seabed.

This equipment, as well as SPC's well founded methodology, achieved the Special Order survey standard requirements, set by IHO in SP44 (International Hydrographic Bureau, 2008).

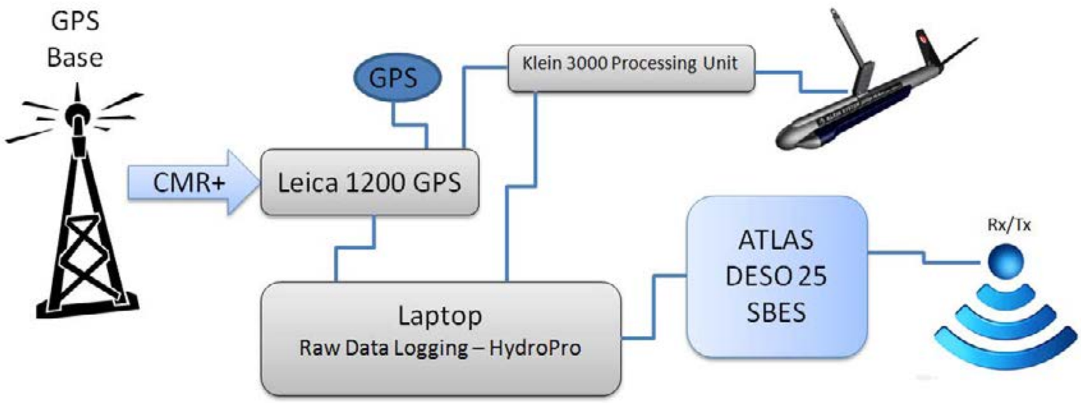

Figure 2: General survey setup for SBES surveys on SPC vessels.

2.2 Achieving Survey Requirements with MBES

In August 2009, SPC invested in a Reson 7125 SV MBES system. The Reson 7125 is a multibeam system with 256 beams, with individual beam widths of 1° along track and 0.5° across track. Using advanced beam-forming algorithms, this can be increased to 512 beams and can "ping" at up to 50 Hz. The swath width is 128°, allowing for across-track coverage of up to four times the water depth. The MBES system also records backscatter data (intensity data for each beam), enabling the creation of mosaics as previously created with the SSS and allowing for seabed classification and improved target identification.

The MBES system receives the vessel position and attitude data from an Applanix® Position & Orientation Solution for Marine Vessels (POSMV 320), an inertially-aided RTK system. The POSMV is capable of measuring vessel roll and pitch to 0.01°, yaw to 0.02° and heave to 0.05 m. The general survey vessel setup for a MBES survey is shown in Figure 3.

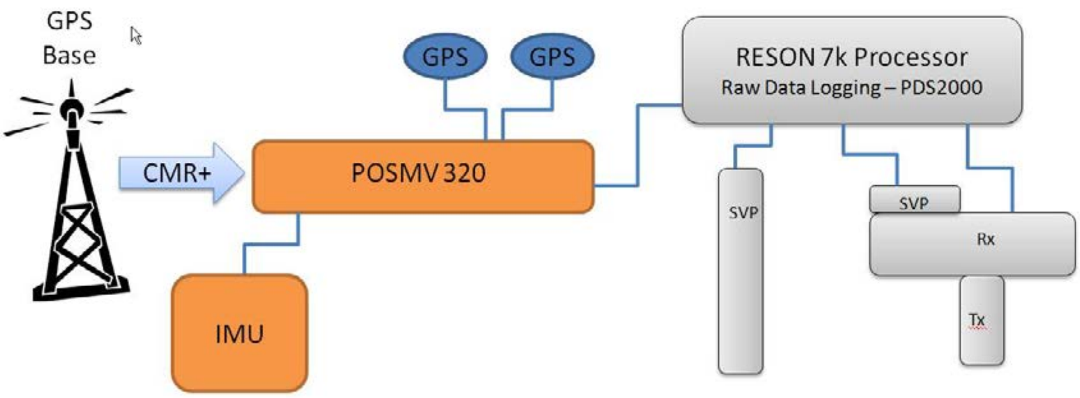

Figure 3: General survey setup for MBES surveys on SPC vessels.

Horizontal and vertical datum and all project geodesy remain the same as with previous SBES surveys, though with Applanix® POSPac software it is now also possible to calculate an inertially-aided, post-processed kinematic solution back in the office and reapply this to the sounding data during processing. This is ideal for periods of RTK drop-outs whilst acquiring data in the field, and allows for more rigorous quality control (QC) of positioning data applied to finally reduced soundings.

The MBES setup onboard the vessel is regularly and periodically calibrated to ensure calibration values are valid for the vessel and that final data quality meets survey requirements. This is done in order to calculate alignment offsets between the motion sensor and gyro (in SPC's case the POSMV) and the Reson 7125 sonar head, plus any latency within the system setup. The patch test routine which SPC follows is a very well documented procedure, more details regarding these calibration tests can be found in the Caris HIPS/SIPS User Manual (Godin, 2003).

Field procedures for MBES surveys include real-time comparisons of RTK tidal values against measured tide gauge data, line planning to ensure at least 200% seabed coverage and ensuring that target detection criteria are met (three soundings across-track and three soundings along-track on a 1 m^3 target). With the implementation of MBES comes the requirement for increased measurements of the speed of sound through the water column, both spatially and temporally, within the survey area using a calibrated Sound Velocity Profiler SVP.

Office-based data processing of the MBES data involves the QC of all position and attitude data, sound velocity data and the merging of this data with the raw soundings from the echosounder. Once this is complete, a point cloud of all reduced data is created (much like terrestrial LiDAR and/or laser scanner data). Various filters, such as spike filters and removal of outer beams can be run automatically before the manual data analysis, data cleaning and data QC is carried out by one of the SPC hydrographic surveyors. The entire processing procedure adopted by SPC involves many different steps, though the process is fairly standard to all MBES surveys irrespective of equipment and/or processing software. This office-based data processing procedure is illustrated in Figure 4.

This equipment and methodology has continually proven to achieve the Special Order survey standard requirements, set by IHO in SP44 (International Hydrographic Bureau, 2008).

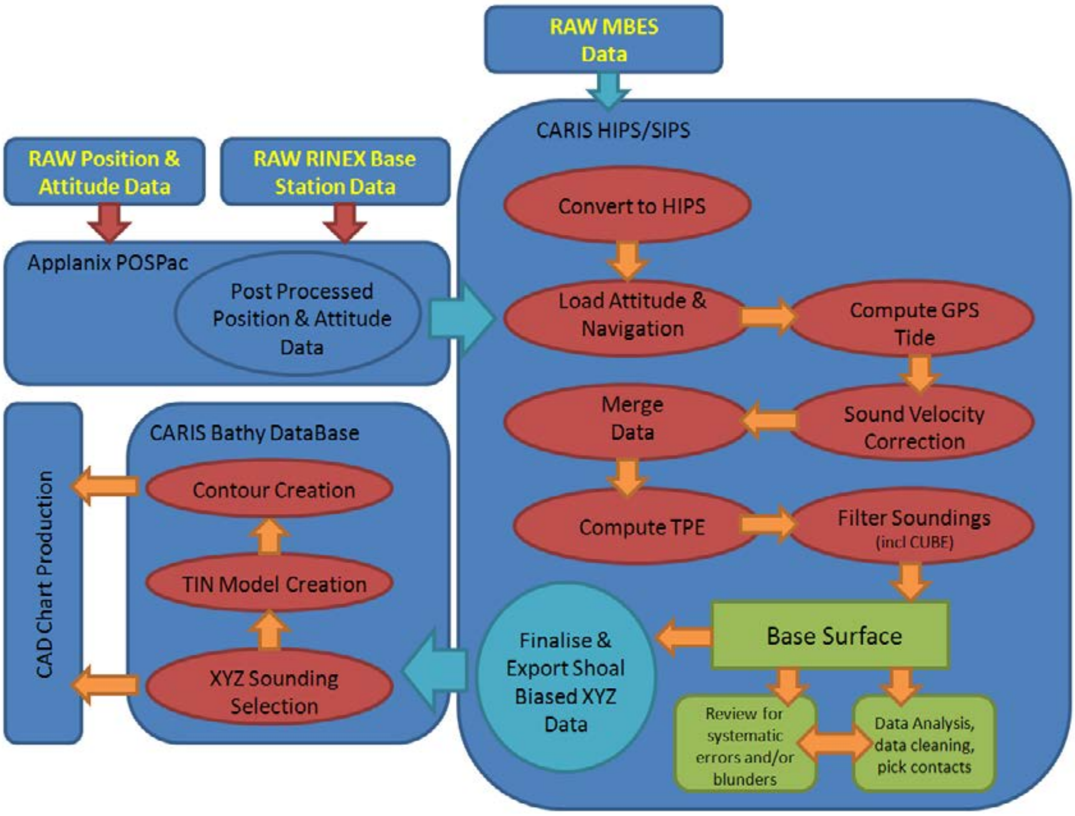

Figure 4: Office-based data processing procedure for MBES surveys at SPC.

2.3 Benefits of MBES to SPC

Whilst the adoption of multibeam technology has meant an overhaul of SPC's hydrographic survey procedures, and a massive increase in data storage requirements, there are many benefits to its implementation. These include:

- Real-Time digital terrain model (DTM) view of data, allowing for more rapid identification of hazards to navigation.
- 100% seabed bathymetry, allowing for increased coverage and less acquisition time in the field. However, office-based processing times have increased.
- Improved target detection capabilities, especially with regards to those posing potential hazards to navigation. More reliable detection and identification of smaller targets allows for more informed decisions on whether diver inspections and/or target removals are required.
- Improved quality of wreck investigation surveys, for archaeological purposes, as well as safety of navigation. This is due to higher density, more accurate soundings, allowing higher definition imagery of objects found on the port bed.
- Improved quality of coastal engineering surveys, such as quay wall inspections, bridge foundation monitoring and general scour monitoring surveys. This is achieved because of the ability to measure more accurately and densely all underwater structures, then enabling comparison of their position of over various surveys.
- More accurate volume calculation for all aspects of proposed and ongoing dredging projects.
- The ability to bid competitively for hydrographic survey contracts, as most survey specifications usually state a requirement for MBES.

- 3D interactive visualisations for engineering works and ease of interpretation of hydrographic data.
- More accurate temporal comparisons between successive surveys, allowing for better monitoring of erosion and deposition of seabed sediments.

3 ACCURACY AND PRECISION OF MBES DATA

The primary purpose of SPC's hydrographic data is safety of navigation, and hence it is important to quantify accuracy (closeness to the true depth) and precision (repeatability of depth sounding) of acquired data.

The increased density of the sounding data acquired with MBES also allows a better statistical analysis of the reduced soundings, specifically with regards to the accuracy and precision of the data with respect to survey standards and specifications. Standards used within this paper for the assessment of hydrographic data precision accuracy will be referred to IHO S44 Special Order survey tolerance values (International Hydrographic Bureau, 2008).

During 2011, SPC completed several surveys adjacent to the new Port Botany Expansion (PBE) over areas of scour protection rock. This scour rock was placed by the engineering contractor in the newly constructed berthing areas adjacent to the dock. The purpose of these surveys was to ensure that the construction of the berths had been completed within project design specifications, specifically minimum scour rock layer thickness and minimum berth depth clearance with respect to the chart datum.

SPC MBES data from these surveys were compared with as-constructed survey data as supplied by the PBE construction engineering contractor. Analysis of these datasets revealed some discrepancies between surveys which needed to be quantified before the work could be signed off. Of most interest were individual scour rock targets, which were showing as above the design depth in SPC surveys, but often not shown in the contractor's surveys.

In order to quantify the accuracy and precision of MBES survey data, a reference surface is created from the survey data and then subsequent survey line data is statistically analysed against this surface. The area chosen for the reference surface would usually be an area of relatively benign seabed which has been ground-truthed in some way.

The reference surface for this study was created using survey data collected over the scour pad area and produced with a bin size roughly equivalent to the average diameter of the scour rock boulders, i.e. about 0.50 m. Results of this analysis are shown in Table 2.

Table 2: SPC and contractor MBES survey stats over SPC scour rock reference surface.

Survey Method	**SPC MBES Survey**	**Contractor MBES Survey**
Number of points in comparison	945,449	364,425
Mean Difference from Reference (m)	-0.005	0.008
Standard Deviation (m)	0.062	0.100
95% confidence interval (m) [mean + (2 x standard deviation)]	0.129	0.208
IHO Special Order error limit	0.270	0.270
IHO Special Order survey	ACCEPTED	ACCEPTED

The data shows that, statistically, both the SPC surveys and the contractor surveys are within IHO Special Order specifications, although SPC data shows a closer fit with the reference data. However, many isolated scour rock targets were evident above the design level (-16.5 m) in the SPC survey, but not in the contractor surveys (Figure 5).

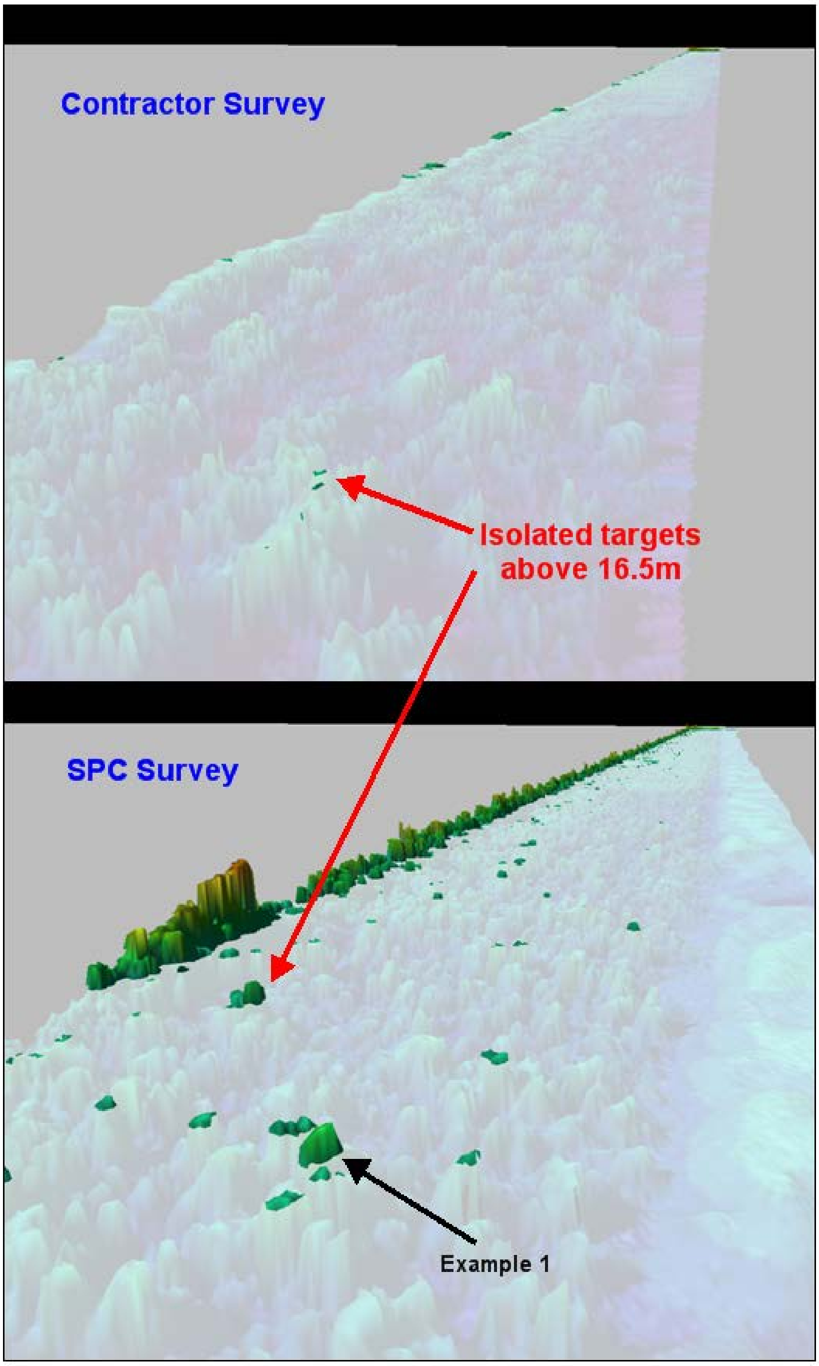

Figure 5: Targets remaining above 16.5 m depth in contractor and SPC MBES surveys.

To ensure that these shoal depths were 'real' SPC carried out repeated surveys on consecutive days (and also from differing vessel surface position/heading) to confirm repeatability. Because the contractor's equipment was not identifying these individual rock shoals with any consistency, it was their position that the shoals were in fact 'phantoms'. Repeated MBES surveys of the same areas indeed showed that many, if not all, of the targets shown in the data definitely existed (Figure 6).

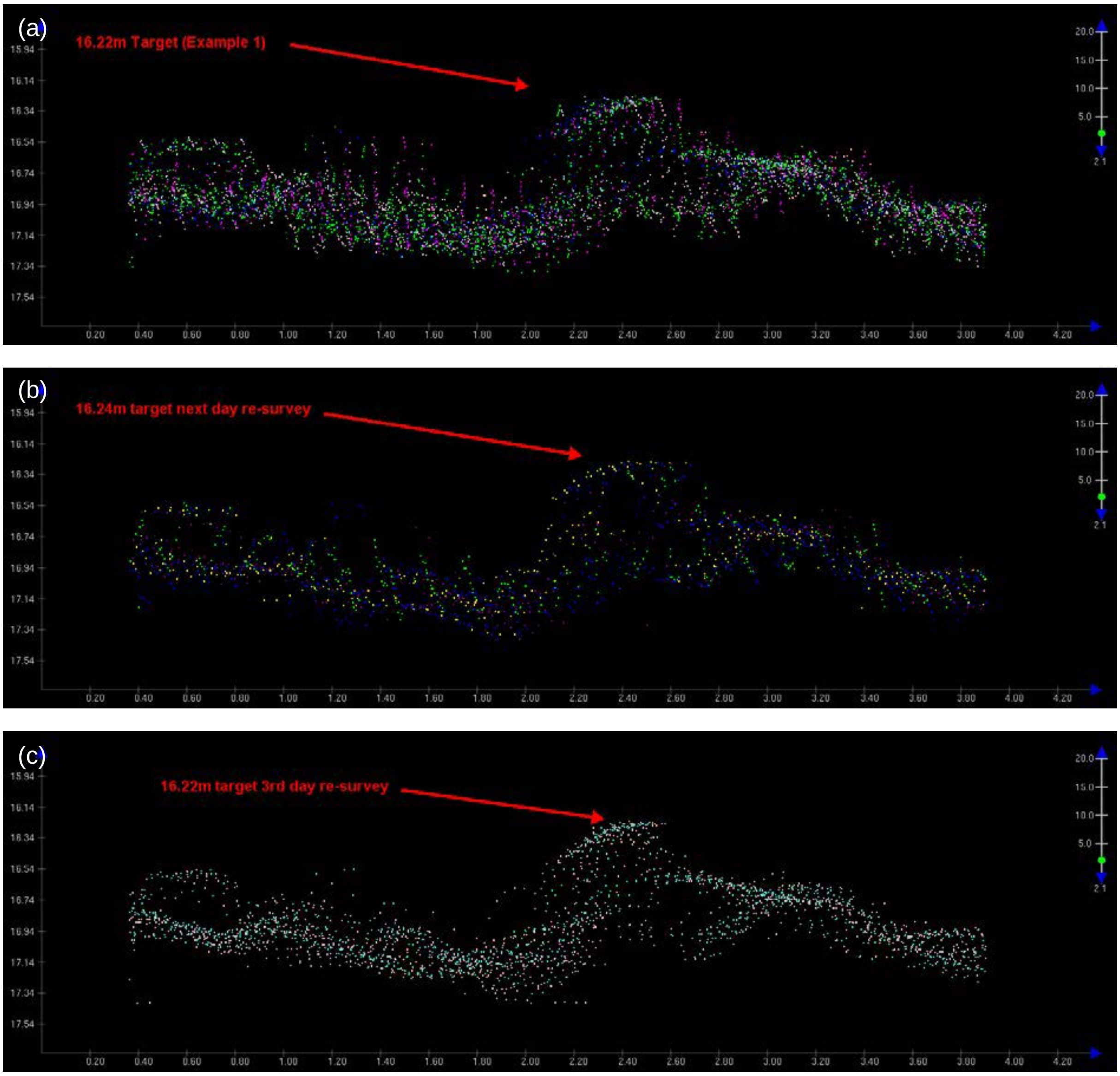

Figure 6: Example target surveyed by SPC on (a) 1 August, (b) 3 August and (c) 4 August 2011.

The contractor was using a Kongsberg EM3002 MBES system with 254 beams at 1.5° by 1.5° beamwidth, whereas SPC uses a Reson 7125 SV with 256 beams at 0.5° by 1° beamwidth. The higher resolution SPC Reson 7125 MBES data showed the targets much clearer, and with more defined shoal points than the contractor data (Figure 7).

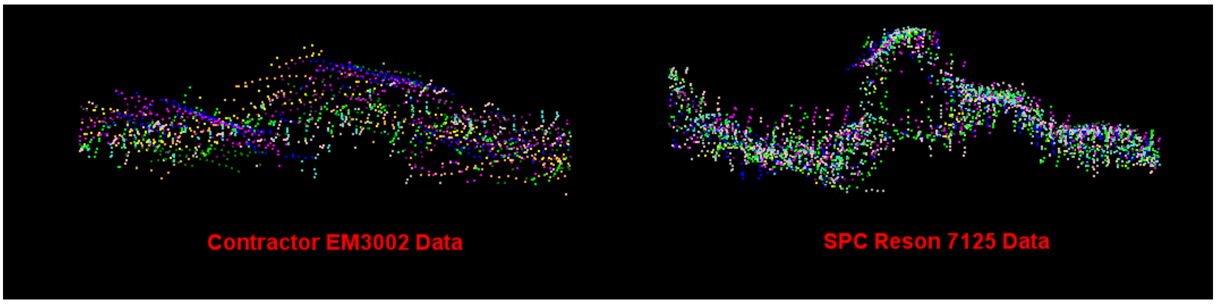

Figure 7: Comparison of contractor and SPC point cloud data over an example target.

After showing that the precision of the SPC Reson 7125 data was not in question, it was then required that the absolute accuracy of the SPC data be ground-truthed in order to resolve the conflicting survey (least depth) results over these isolated targets.

Firstly, the RTK-derived tidal reductions used by SPC were compared with the Port Botany tide gauge. Results showed that the RTK-derived tidal adjustments applied to the data were within 0.03 m of the Port Botany tide gauge. This is part of regular SPC survey checks and procedures, and hence was never considered a real source of error.

SPC then performed SBES surveys over the selected shoal targets in order to verify the minimum depths recorded by the MBES system. A bar check was performed for SBES calibration, and a statistical analysis of SBES data compared with a MBES reference surface over an area of relatively flat, benign seabed was carried out. The results of this comparison are shown in Table 3.

Table 3: Comparison between SPC SBES survey and MBES reference surface.

Survey Method	**SBES**
Number of points in comparison	869
Mean Difference from Reference (m)	-0.033
Standard Deviation (m)	0.089
95% confidence interval (m) [mean + (2 x standard deviation)]	0.212
IHO Special Order error limit	0.260
IHO Special Order survey	ACCEPTED

The SPC Deso 25 SBES has a beamwidth of 8°, i.e. the footprint at 16.5 m depth is 2.30 m in diameter. As a result, it was seen that the SBES gave more consistent results with the MBES data over isolated targets in the middle of the berth box, rather than on the berth fender line, where shoal soundings from behind the fender line are identified. This means that a shoal target surveyed as adjacent to the berth fender line by SBES could in fact have its true position up to 1 metre behind the fender line.

SBES surveys over the isolated shoal targets identified by MBES generally showed a good depth correlation, generally within ±0.15 m. Due to the much higher data density of the MBES data, and the relatively large beamwidth of the SBES, there is no benefit in running any statistical analysis of the depths of the isolated targets when surveyed with MBES against SBES, as the inherent discrepancies in horizontal positioning produce incorrect depth comparisons. Instead, it is best to investigate each target separately (Figure 8).

At this time the contractor was still disputing the survey results and conducting their own soundings using a dipping pole and land survey techniques in order to establish the true depth over the shoal point in dispute. The results of the contractor's dipping pole surveys are shown in Table 4. As can be seen, when compared statistically to both the SPC and contractor MBES surveys over the same area, the dipping pole surveys are shown to be outside of IHO Special Order survey tolerances. This may be due to the non-verticality of the pole, causing errors in horizontal positioning of the bottom of the pole, and hence recorded depth.

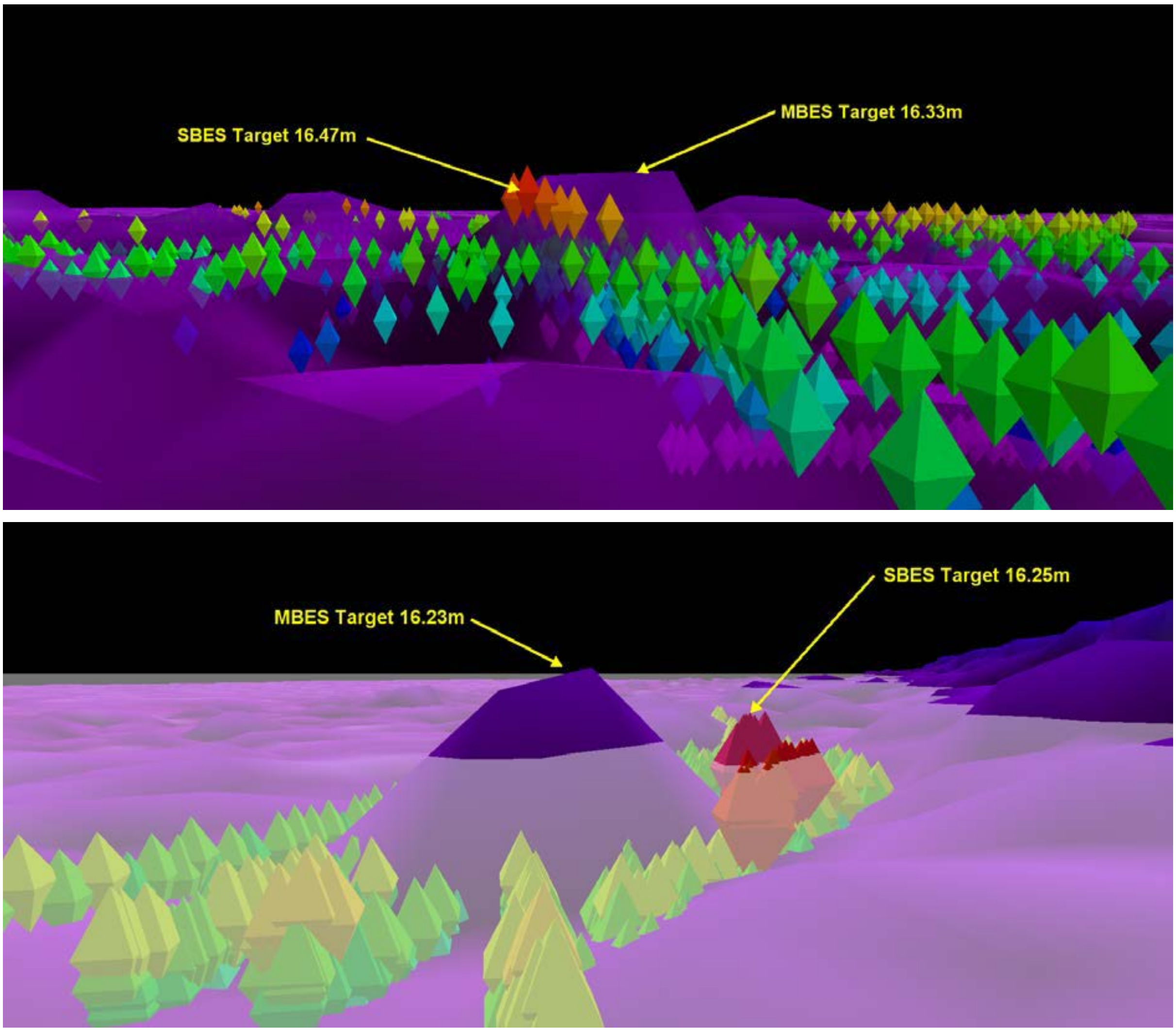

Figure 8: Comparisons of MBES and SBES soundings over isolated shoal targets.

Table 4: Comparison between the dipping pole survey and the SPC/contractor MBES surveys.

Survey Method	**SPC MBES Survey 14/04/2011**	**Contractor MBES Survey 30/03/2011**
Number of points in comparison	209	207
Mean Difference from Reference (m)	0.203	0.223
Standard Deviation (m)	0.162	0.149
95% confidence interval (m) [mean + (2 x standard deviation)]	0.526	0.521
IHO Special Order error limit	0.280	0.280
IHO Special Order survey	REJECTED	REJECTED

Further comparisons and verifications of the MBES data were carried out using a calibrated pressure sensor. The sensor has a quoted pressure accuracy of 0.001% (i.e. 0.0165 m at 16.5 m depth). Final depth calculations using the UNESCO standard formula for converting pressure to depth were tested by SPC and found to be within 0.02 m of the actual depth when lowered to different depths on a calibrated steel wire. Following this calibration, the pressure sensor was held on location above selected shoal targets by divers. Soundings were reduced by noting the time of measurement and subtracting the tidal value recorded at the Port Botany tide gauge. Results of these pressure soundings are shown in Tables 5 and 6.

Table 5: Pressure gauge survey results.

PBE - Pressure Gauge Soundings						
Target Number	**MBES Depth (SPC)**	**SVP Depth (SPC)**	**SPC MBES - SPC SVP**	**MBES Depth (contractor)**	**SPC - Contractor MBES**	**Contractor MBES - SPC SVP**
1	16.18	16.42	-0.24	16.70	-0.52	0.28
2	16.23	16.19	0.03	16.65	-0.42	0.46
3	16.18	16.17	0.01	16.78	-0.60	0.61
4	16.30	16.31	-0.01	16.82	-0.52	0.51
5	16.29	16.30	-0.02	16.51	-0.22	0.21
6	16.33	16.36	-0.04	16.52	-0.20	0.16
		Mean	**-0.042**		**Mean**	**0.372**
		StDev	**0.100**		**StDev**	**0.181**

Table 6: Pressure gauge survey comparison with SPC and contractor MBES surveys.

Survey Method	**SPC MBES Survey**	**Contractor MBES Survey**
Number of points in comparison	6	6
Mean Difference from Reference (m)	-0.042	0.372
Standard Deviation (m)	0.100	0.181
95% confidence interval (m) [mean + (2 x standard deviation)]	0.242	0.732
IHO Special Order error limit	0.280	0.280
IHO Special Order survey	ACCEPTED	REJECTED

The results of the pressure test show that the derived soundings are within survey tolerance specifications when compared with the SPC survey, but not with the contractor survey. It should be noted that this is a very small data sample for statistical analysis and so may be distorted and must be treated with caution.

4 CONCLUDING REMARKS

With the adoption of MBES technology and increasing amounts of hydrographic data being logged comes the necessity for more complex processing procedures and the need for extra attention to quality control of data throughout the process, from the field right through to the finished product.

It has been shown that by using MBES, SPC has increased the amount of hydrographic data collected, the quality of that data and also the number of uses for which this data can be put towards. Differing survey methods, such as using different equipment and/or different procedures, may provide differing survey results, yet with both being technically and statistically "within specification".

This may become a sticking point, especially in areas whereby a specified minimum depth requirement has been defined and is required to be ascertained over a specific survey area. One of the main issues is that realistic and obtainable survey accuracy and precision capabilities are rarely taken into account during the design stages of such coastal engineering works. Factors affecting the precision and accuracy of survey results include the choice of survey equipment, the acoustic environment within which the survey is to be carried out and differing survey procedures – both during the data acquisition and data processing stages.

Often the survey equipment best suited for the job and the equipment available are two very different things. However, the equipment setup used for the job should always be assessed by its fitness for purpose for each individual project and its results eligible for statistical evaluation for precision and accuracy.

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Cadastral and Spatial Information Systems in Local Government: From Maps and Tables to eSystems

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ABSTRACT

Local New South Wales councils deal in rafts of information relating to land parcels and, as in all cases for government authorities, the quantum of information, and demand for immediate access to accurate data, have increased significantly over the last two decades. This information is essential for a range of processes and services including rating, property transactions, development approvals and strategic planning. Up to the late 1980s this information was sourced from hard copy maps and simple textual databases. Maps were chronically out of date and hard to read, and the textual databases notoriously inaccurate. While early Geographic Information Systems (GIS) were available to larger councils, these were user-unfriendly and significantly lacking in functionality. In the 1990s, the ready availability of the state-wide electronic cadastre and the desktop computer revolution, accompanied by the advent of user-friendly and functional GIS software, provided an opportunity for Local Government to significantly improve its land information systems and services. Post 2000, growing acceptability of the internet for provision of information and services, coupled with a cultural change in government bureaucracies towards an "open door" approach to information, provided further opportunities for councils to offer information services over the internet. Since 1995, Pittwater Council has been a leader in the development of reliable and accurate cadastral and spatial information data sets and provision of planning and land information and services via the internet. Fundamental to Pittwater Council's development of these systems and services was a clear understanding of the cadastre, map projections, and accuracy and precision requirements for spatial information, all fundamental skills for a surveyor but significantly lacking in the conventional Local Government skill set. This paper provides a light-hearted case study of the evolution of Pittwater Council's land and planning information systems and services from a set of unreliable maps and databases to an integrated electronic internet available platform.

KEYWORDS: *Cadastre, council, GIS, spatial, planning, surveyor.*

1 IN THE BEGINNING

Pittwater Council (Pittwater) was the last new council to be created in New South Wales (other than through amalgamation). Pittwater came into being in 2003 as a result of considerable community pressure related to inequitable expenditure of rate income and poor planning decisions by Warringah Shire Council (Warringah). It is interesting to note that Warringah had been "sacked" on a number of occasions previous to the secession and has since had a period under administration.

A key element of the secession process was the "Declaration" by the Governor which included a "meets and bounds" description of the new local government area expressed as:

"Land taken from the Shire of Warringah and constituted as a separate municipality known named the Municipality of Pittwater."

"Area about 125.02 square kilometres: Commencing at the intersection of the generally northern shore of Narrabeen Lakes and the shore of the South Pacific Ocean and bounded thence by the latter shore generally northerly to the eastern extremity of Barrenjoey Head; by that head generally westerly to its western extremity; by a line westerly to West Head; by the right banks of Hawkesbury River and Cowan Creek upwards to its confluence with Coal and Candle Creek; by that creek, Akuna Bay and an unnamed creek flowing into Akuna Bay upwards to Coal and Candle Creek Drive; by that drive generally south-easterly, West Head Road generally south-westerly and McCarrs Creek Road generally south-easterly to Wirreanda Creek; by that creek upwards to the generally western boundary of Portion 83, Parish of Narrabeen, County of Cumberland; by that boundary and its prolongation generally southerly to Mona Vale Road; by that road generally north-easterly and Powder Works Road generally south-easterly to the northern prolongation of the generally eastern boundary of Lot 2, D.P. 233351; by that boundary generally southerly, a line, part of the northern and the easternmost eastern boundaries of Portion 76 easterly and southerly, a line, and part of the generally northern boundary of Portion 77 and its prolongation generally easterly to Deep Creek; by that creek downwards to the generally northern shore of Narrabeen Lakes, aforesaid, and by that shore generally north-easterly to the point of commencement." (Governor's Declaration, 24th April 1992, Local Government Act 1919 – Proclamation *New South Wales Government Gazette No.51*)

This "Declaration" leads to some interesting questions:

1. What exactly is the "shore of the South Pacific Ocean"? Is it high water mark, does it include the bays, where does the State's responsibility for administration begin and end?
2. What precisely is "the northern shore of Narrabeen Lakes"? Narrabeen Lagoon is clearly a non-tidal lake intermittently open to the sea. Is the boundary the shoreline at the date of grant or the edge of the water?

As a result of the Governor's "Declaration" 250, odd staff from a broad cross-section of Warringah Council packed up their goods and chattels, relevant documents and personal equipment one Friday afternoon in May 1992, and moved into premises at Warriewood with a view to the commencement of operations the following Monday. The only premises available were a warehouse in an industrial area within which temporary customer service and office facilities had been provided. All the new Council's corporate information was either accessible through a "link" to an old "green screen" mainframe system at Warringah, or documents, maps, plans and hard copy files shipped up to the new offices as part of the secession process. Cooperation levels between staff at the new Council and Warringah staff were low to say the least, and the general consensus in local government circles was that the new council would quickly fail.

Successful operation almost immediately was a survival imperative. This included the ability to be able to provide accurate and complete information to the staff and to the public at a time when every failure of the new Council in terms of service delivery and efficiency would be subject to the scrutiny of those people opposed to the secession itself.

2 THE CADASTRE – THE FUNDAMENTAL BASIS FOR LAND ADMINISTRATION SYSTEMS

The terms 'Cadastre' and 'Cadastral' were introduced to many of us (surveyors) in our first year of University by 'Henry' Werner and at that time, for those who understand surveying to be an applied mathematical concept of bearings, distances and heights above sea level, and (despite Henry's exhortations to understand that the Cadastre had a wider purpose) the term 'Cadastre' was a mathematical concept, rather than the basis of an administrative system for land.

Not generally recognised is the fact that local government is essentially a land manager of both private and public land, its functions relate in large part to administration of information and processes relating to land parcels. These processes rely on cadastral information and in many councils those professionals that have an understanding of the Cadastre are not generally involved in information management. While this is changing with the increasing trend towards comprehensive use of the electronic Cadastre, reliable land information databases did not exist in 1992.

In order to get up and running, the newly formed Pittwater relied on Cadastral information provided through a series of hard copies of maps from Warringah and land parcel and planning information relating to those land parcels contained in the mainframe computer system (which was located at Warringah and accessed by a "phone line link").

At its most fundamental level, the Cadastre provides a record of who owns what (land) and where it is, together with additional site information related to the individual parcel that might be relevant to the administrative authority, such as size and slope, land use and value. The reason for such records is pretty fundamental: taxation**.**

Forms of taxation have been applied to land and land owners throughout history. All substantive civilisations have imposed some forms of taxation relating to land ownership. Our society and its local councils are no different. The basis of Australian local government financial viability is a system of "taxing or rating" land parcels within their respective local government areas.

This fundamental use of the Cadastre is extended to many other purposes by councils and for each land parcel the following information is required:

Legal and Land Description Information:
- Lot and DP/parish and portion/volume and folio
- Valuer General's property details
- Ownership details
- Street address

Planning Information:
- Zones
- State Environmental Planning policies
- Local Environmental Plan information
- Development Control information

Hazard Information:
- Flood hazard
- Bushfire hazard
- Geotechnical hazard
- Coastal hazard
- Climate change impact

What do councils use this information for?

Record Systems:
- Property file
- Road file
- Some subject files (virtually all of these files relate to a property or land parcel)

Rating and Ownership Details:
- Billing and collection
- Transfer of ownership
- Registers – Council's Land Register

Planning Information:
- Development management
- Local Environmental Plan information
- Development Control Plan information
- Hazard information
- Planning certificates

Quite clearly within councils the vast majority of administrative processes rely on the underlying cadastral information. Systems are largely based on property or land parcel information with virtually every file document (file notes, approvals, etc.) at Council being able to be related to a single land parcel or group of land parcels with correspondence linked to a person, also linked to individual properties through ownership or address.

Additionally Asset Management Systems originally maintained in hard copy are now increasingly maintained as electronic systems which are spatially referenced, with property details being the link between the coordinate references and a "man in the street's" understanding of where things are. Imagine the response to the referencing of the location of a pothole outside No.46 Queens Road as a coordinate in a letter to a ratepayer.

3 THE RAPID EVOLUTION OF CADASTRAL (LAND INFORMATION SYSTEMS) IN LOCAL GOVERNMENT – PAPER TO GIS

The formation of Pittwater Council in 1992 provided a unique opportunity to obtain a snapshot of land information systems in local government at the time, for no other reason than the relevant information had to be identified and shifted to the new Council and made operational. Pittwater inherited from Warringah a series of property files, street files, DA files (Figure 1), slip maps (Figure 2), zoning maps (Figure 3), charting maps (Figure 4), flood maps, contour maps, air photos, engineering plans, as well as a 'mainframe' property database based on Valuer General information.

Figure 1: Old DA files.

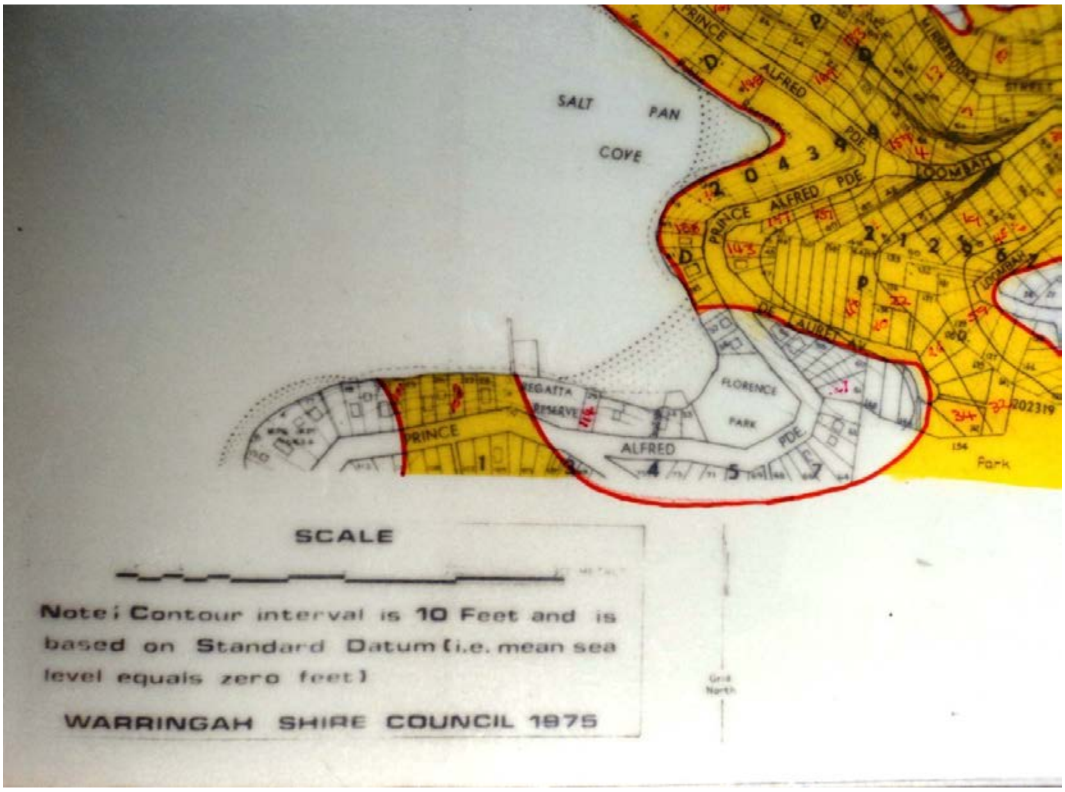

Figure 2: Slip map.

Figure 3: Zoning map.

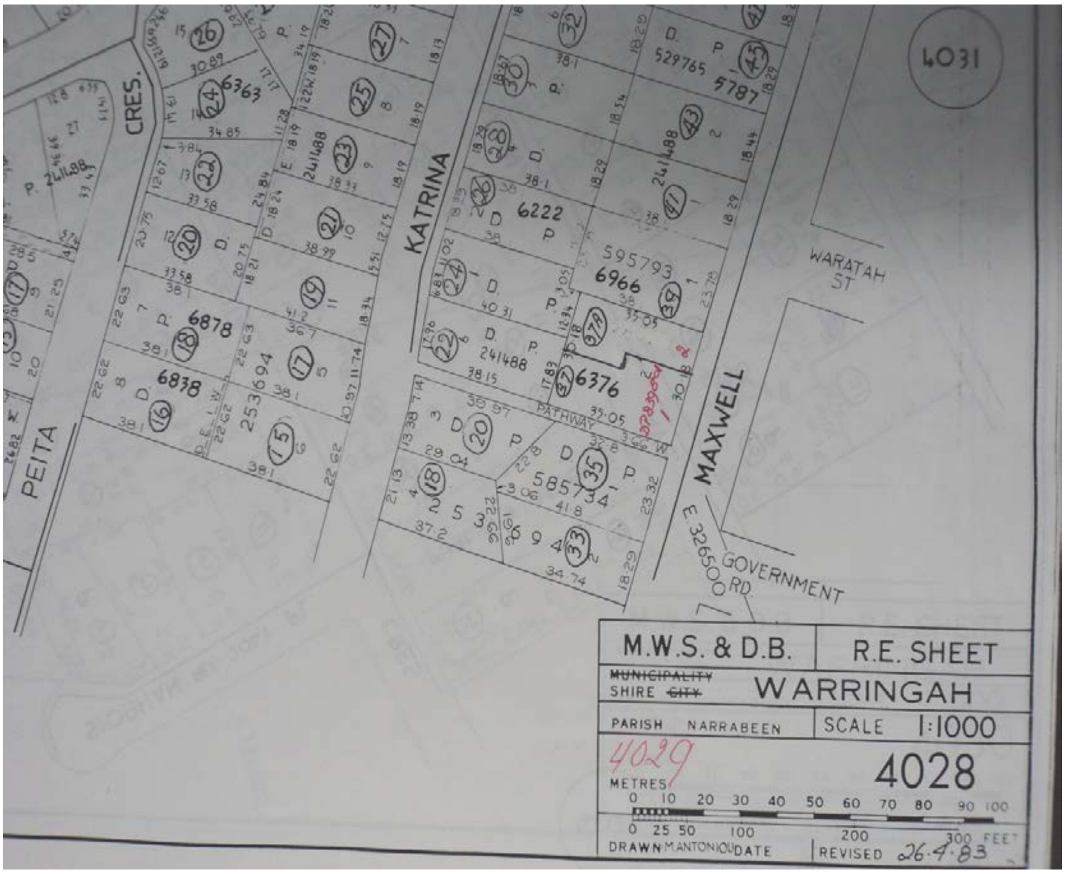

Figure 4: Charting maps.

As can be clearly seen, these maps were out of date and hard to read with the exception (perhaps) of the zoning map. The information on the maps and within the mainframe computer databases contained significant errors in relation to parcel identification, i.e. wrong lot numbers or DP numbers, incorrect dimensions and areas as well as errors in the planning attributes necessary for the production of planning certificates derived from hard copy maps. At that time, Council had placed little emphasis on the risk aspects of poor information management and poor cadastral and spatial information systems, relying on the experience of staff to identify problems and minimise errors. (Subsequently, it would be determined that errors existed in at least 70% of the land parcel information contained in the computer system.)

Additionally, the time taken to determine the information by inspection of records, checking and viewing hard copy maps was extensive. In 1992, a customer enquiry as to the factors one should take into account when making a Building or Development Application on a property required counter staff to examine a series of hard copy maps and gather other information from the mainframe computer system. This process (if it was carried out extensively) took approximately two hours to complete with a high likelihood that, during that process, an error either resulting from original information being incorrect, or misreading, would occur.

Likewise, in order to issue a Planning Certificate, each was printed on a draft based on the data contained on the mainframe computer and then laboriously checked by reference to hard copy maps. This process took several days and certainly did not provide a reasonable level of customer service. While highly experienced and expert staff members carried out the task of preparing a Planning Certificate, this process was still prone to error and there was and remains a history of significant damage cases in New South Wales as a result of inaccurate Planning Certificates being issued.

In short, the new Pittwater Council (as had been Warringah) was at risk because it had poor cadastral and planning information systems. Pity the new Manager who had to satisfy a 100.00% accuracy requirement as part of his performance agreement in the issue of Planning Certificates. As for Planning Certificates, provision of inaccurate information by staff in response to public enquiry (counter, telephone and letters) also exposed Council to risk and in fact legal actions were brought against Council on a number of occasions because of alleged inaccurate or incomplete information being provided by staff. If ever there was a reason to examine and develop a more effective cadastral and land information system, the levels of risk in providing incorrect information was it.

4 THE WINDS OF CHANGE

Prior to 1993 so-called Geographic Information Systems (GIS) were mainframe-based, complicated and user-unfriendly, however they were gaining recognition within the Local Government industry. The well publicised effective emergency application of GIS following the Newcastle earthquake did a lot to raise awareness. (It was perhaps no accident that a surveyor, Mr John McNoughton who was Mayor of Newcastle Council at that time, had championed the development of a GIS as an essential tool for local government.)

Coinciding with the formation of Pittwater Council was the “affordable” personal desktop computer (PC) revolution, which was accompanied by a proliferation of “off-the-shelf” user-friendly software packages. Rather than “stick” with a mainframe computer system so

prevalent in other councils, Pittwater Council quickly moved to a networked PC system, making software choices free of the information technology/mainframe “god” and the resultant decentralisation of data management. This freedom to use “off-the-shelf” software allowed Pittwater Council staff to invest in GIS systems for specific purposes. At the same time, the electronic cadastre became purchasable at a reasonable price from the State Government. Given the risks associated with the paper-based and inaccurate land information system Pittwater had inherited from Warringah, transition to a Land Information System based on an electronic cadastre, using desktop computer software systems was a logical step.

5 USING THE ELECTRONIC CADASTRE TO DEVELOP A COMPREHENSIVE LAND AND PLANNING INFORMATION SYSTEM

In 1994, Pittwater Council purchased the “Map Info” GIS software for a specific task associated with the Ingleside Warriewood Land Release Project. This was a joint project with the Department of Planning and involvement of State Government stakeholders. Notwithstanding the State’s role in the process, it would not make the Cadastre, even for the land release area, available in electronic form and there remained resistance within Council to expenditure on something its higher level management did not understand. Rather than “stick” with the paper-based mapping systems so prevalent in the planning industry for the land release process, Council staff digitised the Cadastre for the land release area and used that as a basis for production of a series of environmental and planning maps which were printed in 1995 as the basis of the Planning Strategy. The public, government departments, Council’s General Manager and the Councillors were impressed by the standard of mapping contained in the documents to an extent where, by 1995, funding had been made available for the purchase of the electronic Cadastre from State Government.

Up to this point in time, the term “Cadastre” was virtually unknown in the organisation with the closest the General Manager could get to an understanding, was to compare it with the cartoon character “Nasty Canasta”. So, having bought the “nasty” Cadastre, Pittwater was able to start the process of developing a fully electronic cadastral land information and planning system.

During 1995, two things happened which catalysed this GIS programme. A new General Manager arrived. Angus Gordon knew what the Cadastre was and why it was a fundamental building block for an electronic land and planning information system. Additionally, the land information management process was decentralised from the traditional owners of data (the information technology people) and placed in the hands of those responsible for data output, including Planning Certificates and planning information, these being the most vulnerable area for Council in terms of damage claims for provision of inaccurate information. The Manager of this area of operations was a surveyor and therefore had the required skills to develop the system.

6 JUST HOW MUCH INFORMATION ARE WE TALKING ABOUT?

In 1995 there were approximately 100 different characteristics that might, or might not, apply to a parcel of land required to be kept by Council for the provision of information to the public and for internal use. This has now expanded to approximately 500 possible characteristics per parcel. Not only was it necessary to get this information right in the first place, it needed to be maintained.

In 1995, two fundamental procedures were commenced:
1. **Validation** of property and parcel information.
2. **Mapping** of all relevant property-related data.

7 VALIDATION: WHAT AND WHY?

Council's electronic cadastral information contained in its databases was based on Valuer General information, lot/DP, parish/portion, etc. Additionally, owner and property details were attached to this. Council had 25,000 properties and, on initial comparison, only 70% were able to be precisely matched to parcel information contained in the electronic Cadastre. This was not unusual, with some councils in rural areas having more mismatched information.

Why was this information so poor? The Valuer General system was property-based and did not necessarily relate to individual land parcels. Much of the information was out of date and had certainly not been maintained, this not being considered important by the previous managers of the databases. Additionally, the Valuer General information did not contain any reference to most Council-owned and Government-owned land.

Council commenced the validation process based on prioritising privately owned land, then looking at Council and State owned land. The initial phases of this were completed by 1998, with all privately owned land in the local government area being clearly linked between the electronic Cadastre and the textual database systems. During this process, a system for maintaining the database was also implemented, to ensure that information remained 100% correct.

It is interesting to note that the validation process is still going with some 25 parcels (generally small residues) still remaining to be identified. This process identified a number of land parcels that Council thought it owned but in fact it did not. Most of this land was in drainage reserves or public reserves, some of it extremely valuable land (just how much is a 1,000 m^2 lot overlooking Bilgola Beach worth). An off-shoot of the validation process was Council began a process of applying through the various mechanisms open to it, to become the owners of that land. Some 1.6 ha of land, not previously formally "owned" by Council, has thus been transferred to its ownership. It is hard to imagine the public uproar that would have occurred if these parcels of land (which form an important part of Council's reserve system) had been lost from public ownership.

8 MAPPING

Rather than wait for the validation process to be completed, in 1995 Council simultaneously commenced the mapping of all relevant spatially based land data. This includes:
- Zoning
- Hazards
- Local Environmental Plan (LEP) clauses
- Development Control Plans (DCP)
- Biodiversity data

By 1996, there were runs on the board. In the simple "work space" created by overlaying these map layers over the electronic Cadastre, staff could "interrogate" any land parcel in Pittwater to determine its zoning, the hazards that affected it and the planning information which related to it. Associated with this information set was a printout of the zoning map.

This process could now be achieved by staff at their desk, or at the counter, in response to an enquiry in less than two minutes, achieving a considerable reduction from the 2-hour process that previously existed. Customer satisfaction was immediate. Local valuers and architects began to provide comments to Councillors and the General Manager as to just how effective this system was. Customer service had made a huge leap forward as rapid and accurate supply of information was now available.

9 A NEW SYSTEM BASED ON THE CADASTRAL DATABASE

In 1997, Pittwater Council installed the "Proclaim" system which significantly increased the capacity to electronically utilise land parcel database or cadastral information in various applications including automatic production of Section 149 Planning Certificates, building and development processes and planning processes, and links to record systems.

10 DIGITAL AIR PHOTOGRAPHY WITH A CADASTRAL OVERLAY

In 1998, Council received the first digital rectified aerial photography which could be utilised in conjunction with the Cadastre for a range of purposes. As has subsequently been demonstrated by the success of Google Earth and Google Map, staff and the general public had no trouble at all relating to an aerial photograph and, when overlaid with Cadastral information with a reasonable degree of accuracy, this becomes a really useful tool, both within Council and for its external customers.

11 AN ELECTRONIC ZONING MAP IS GAZETTED

By 1999, Council had produced an electronic version of its Local Environmental Plan (LEP) map and had that gazetted, thus replacing the original pencil and coloured-in map that it produced in a hurry in 1993 and had relied on since.

12 ELECTRONIC PLANNING CERTIFICATES, FILES AND INTERNET MAPPING

By early 2000-2001, Pittwater was producing Planning Certificates totally reliant on electronic data with no manual checking or input. Electronic file management had commenced. "Encounter" was introduced, making GIS mapping publicly available via the internet. Valuers, architects and the like did not even have to come into the Council to obtain accurate land and planning information on a parcel by parcel basis. All of these systems relied on the underlying electronic Cadastre.

By this time all privately owned land was 100% validated in both the textual and GIS systems, electronic record systems were linked to properties and the organisation had learned to trust its electronic Cadastre and land information system.

13 CATHARSIS IN PLANNING

Just after the beginning of the new millennium, there was a considerable dissatisfaction arising at Pittwater and across the State with the NSW Planning System. Planning departments were being termed "toxic environments", there was a shortage of planners and turnover was high. Average employment periods for planners was less than two years and the current belief was that a new Town Planner would take at least six months to become operational. Why?

Many reasons were provided as to why the planning system was failing and the environment for planners unacceptable, however my view is that the complexity and inability to easily access planning information was a major contributor. In Pittwater, there were 25,000 parcels upon which a landowner might be able to do some of 100 possible development types. For each land parcel (depending on where it was) State and Council planning controls and hazards applied up to 400 controls that may or may not apply to a particular development on a particular site. This matrix gives a range of approximately one billion possibilities. Planners were expected to be able, without error, to assess and determine a development on a parcel of land taking into account these factors. Clearly, an almost impossible task resulting in errors, delay, frustration and dissatisfaction.

Additionally, councils held planning and development information close to their chest for years, often preferring to sell hard copies of planning controls in an effort to recover the cost of their productions rather than make them readily available. With the tools that it had amassed through the validation and mapping processes, Pittwater Council realised that it had the opportunity to develop what is now referred to as "e-Planning Systems". It was simply a matter of finding a software provider.

14 DA TRACKING

In 2003, Council met and formed a relationship with "Infomaster" and, within five months, had an internet-based development application tracking system available on the internet (Figure 5).

This system was a "first" (Figure 6) and is now considered best practice in local government but, at the time, was a brave step with Council criticised for making available information that should, in some people's minds, remain behind locked doors.

The immediate benefits of this system were:

- Reduced telephone calls.
- Improved performance by staff who now were transparently responsible for the process.
- Better liaison between applicants and their neighbours: With applicants now knowing that their neighbours could easily scrutinise their development, there was far more likelihood that there would be consultation prior to, or in the early stages of, the application leading to a reduced number of objections and better overall customer satisfaction.

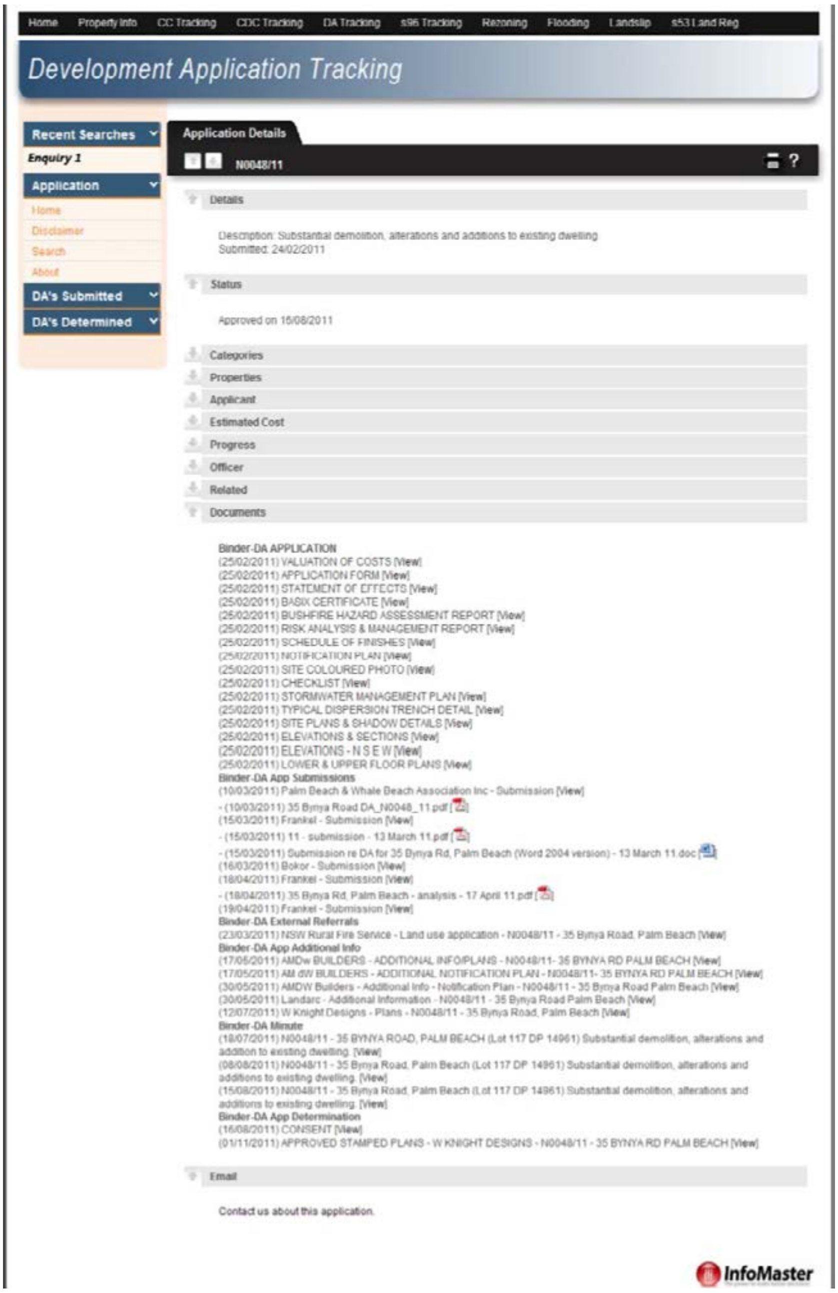

Figure 5: DA tracking.

It is no secret, however, that various people tried to have this system pulled down on the basis of privacy legislation. Whilst steps were taken to overcome this, there remained significant disparity between obligations to Council under various Acts including the Environmental Planning & Assessment Act which requires development information to be public, the Local Government Act and privacy legislation which place embargoes on provision of information. It was a matter for State Government surely to recognise that the e-world has arrived, and refresh its legislation accordingly (I am still waiting).

Figure 6: API award to Pittwater Council.

15 PLANNING CERTIFICATES ONLINE

Simultaneously, and utilising other internal systems, Council made its Planning Certificates available in real time by internet application. Pittwater Council was the first to do so and, within a relatively short period, over 50% of 149 Certificates were being issued in real time over the internet. As of this date, 70% of Certificates are issued in this way with not a single action being taken against Council in relation to the issue of a single Certificate on the basis of inaccurate information. Each of these Certificates is issued in relation to an individual lot and a Deposited Plan, again reinforcing the fundamental basis that the Cadastre performs in these electronic services.

It is interesting to note that on commencing the process, a person from another council rang up and asked "how could we sleep at night" knowing that certificates were not being manually checked prior to issue? That council still has not developed the capacity to issue electronic certificates and relies on manual checking. The response is clear. How can they "sleep at night" taking the risks they do with record systems so inaccurate that they have to manually check the certificates prior to issue, sometimes taking two to three days, and surely far more susceptible to error than certificates electronically produced using information systems which are well maintained?

16 INTERACTIVE PLANNING INFORMATION (ENQUIRER)

The other major complaint about planning was that no one could ever find out what information they needed to take into account in lodging an application. In February 2004, Pittwater Council launched its internet "Enquirer" service whereby an applicant could nominate a property by lot number and DP number or address, select the development type that they wished to carry out from a list, and receive a property/development specific list of the controls that applied together with the information they needed to submit with the application. Again, this was a "first" in e-Planning Systems (Figure 7).

The 'toxic environment' was starting to break down as not only did the applicant receive this information, the same information source was used by staff who would carry out the assessment: a level playing field between applicant and Council assessment staff was in place.

Figure 7: PIA award to Pittwater Council.

The concept of a planner having to spend six months learning "rafts" of paper-based planning information prior to becoming effective had been "put to bed". New planning staff were now able to rely immediately on the electronic system in terms of the controls that they had to take into account in an assessment and did not have to learn "reams" of hard copy Development Control Plans. Additionally, all staff could be certain that, if they addressed the controls specified for the site/development specific application, they had not missed anything out. This significantly reduced the "toxicity" of their work environment and, together with the improved customer satisfaction and communication provided by the DA tracking services, the enmity between Council staff and customers was decreasing, making the work environment significantly more pleasant.

17 QUALITY ASSURED ELECTRONIC ASSESSMENT

In 2005, Council carried e-Planning a step further. It introduced a complete electronic assessment process for use by staff whereby the controls that applied were generated for each specific development and staff could work through a sequence of "screens" to complete their assessment. At the end of this process, staff could readily check that they had addressed all relevant issues and a report and conditions, and consent (or refusal) was automatically produced. This electronic process was in fact a quality assurance system which could never be equalled in the manual systems (Figure 8). This system has been working effectively for approaching seven years and, again, significantly improved the work environment of staff.

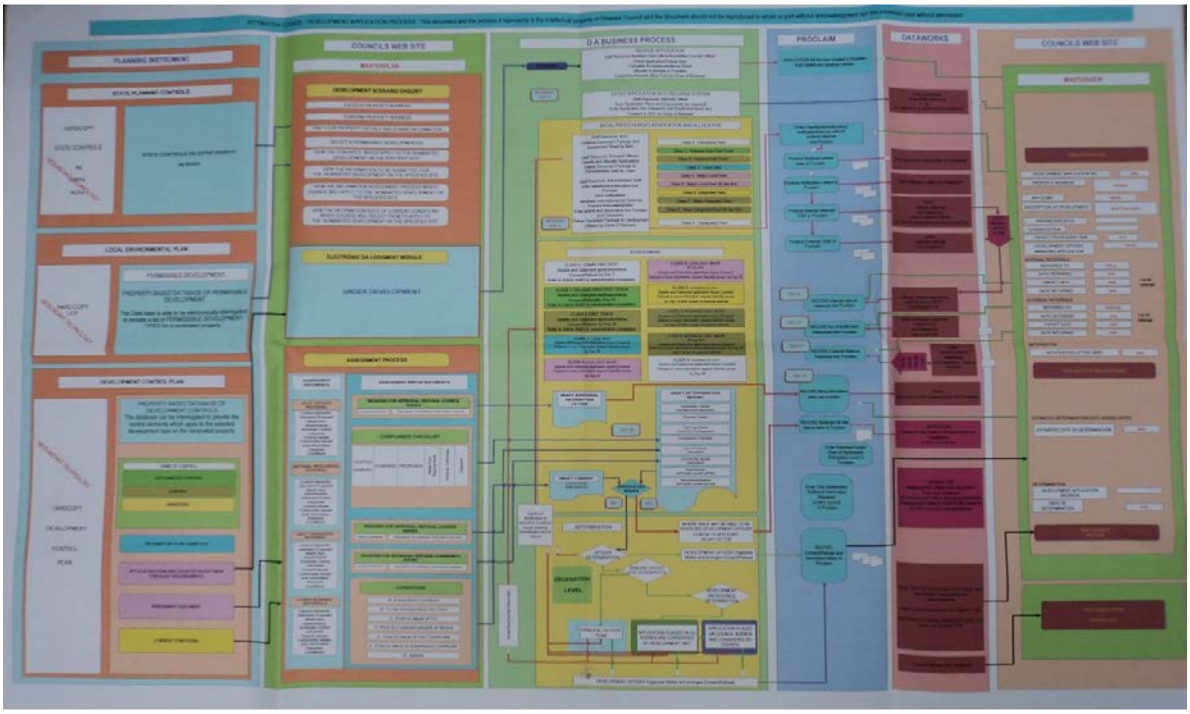

Figure 8: Old manual system.

18 ELECTRONIC LODGEMENT

In 2006, Council introduced an electronic application system which allowed applicants to in fact forward an electronic application into Council for a particular development.

19 THE ROLE OF SURVEYORS

All of these e-Planning Systems as well as many other Council functions rely on the underlying cadastral and land information systems. From inception in the mid-1990s to present, management of the development of these processes and maintenance of the information has been overseen by a surveyor and specialised staff under direct management. Without a comprehensive understanding of what constitutes the Cadastre and how it needs to be maintained, these systems would quickly become unreliable. It is not difficult to imagine the consequences of *not* having a surveyor involved in these processes.

20 CONCLUDING REMARKS: WHERE TO FROM HERE?

With increasing State involvement in planning through Exempt and Complying Development provisions, a raft of State Environmental Planning policies and other statutory requirements, together with a clear need to improve the planning system including the introduction of new legislation, it is clear that refined electronic planning systems should be available across the State. This cannot be achieved without an agreed Cadastre commonly available through a variety of portals.

With possibly hundreds of planning attributes applying to each parcel of land in NSW, the concept of a fully maintained centralised system is simply not achievable. However, if one accepts the concept of data being managed in a variety of sites and viewable through a common "window", it is simply a matter of organising access to various information layers and establishing a way that those responsible for creating and maintaining that information can do so at their site while making it available through an overall portal(s).

The SIX system (LPI, 2012) already provides such an avenue. Individual councils could elect to use whatever layers of the SIX database they wish, and then provide other layers of information into a single State Planning suite of layers. Anyone wishing to view the information would obtain that information, regardless of where in the State it lay. Using such a system, one could enter property details (lot number and DP number or address) and obtain a list of the land and planning characteristics for the land together with a range of development options, either State specified or locally Council specified. On choosing the development type in which they are interested, they could then determine the appropriate controls and requirements and progress to an electronic lodgement system.

Post approval management and recording could likewise be achieved. A basis for such a system would be an agreed "State Planning Cadastre" and an appropriate administration process. Various sections of the Cadastre could be administered by the State at local council level, depending on the level of attached information Planning "layers" administered by the relevant authority, for example:

- Rural Fire Services NSW would administer the Bushfire Hazard layer.
- Department of Planning & Infrastructure would administer State Policy layers.
- Councils would administer layers applying to their local area.

The benefits of such a system go well beyond planning development, but that's a good starting point.

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Helping to Rebuild Queensland with Survey and Spatial Data

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ABSTRACT

In 2011 many parts of eastern Australia were affected by natural disasters such as flooding and tropical storms. Timely, accurate and comprehensive spatial data was required to help government representatives to assess the damage, prioritise resources, and help to rebuild infrastructure, communities and homes. This paper reviews some of the technologies used to perform these tasks across Queensland.

KEYWORDS: *Yasi, infrastructure, Queensland, Aerial Imagery, Web Mapping Services.*

1 INTRODUCTION

AAM Pty Ltd is a company which supplied rapid-response aerial imagery to the Queensland Government for a number of natural disasters that occurred in Queensland (Qld) in 2010 and 2011. From inland floods to post Tropical Cyclone Yasi, rapid response image products were captured within hours of the disasters and supplied within several days for the priority areas.

These rapid-response, post-disaster products were one of the vital foundation datasets embraced for immediate disaster assessment and prioritising emergency response efforts by Qld Fire and Rescue Service, Emergency Management Qld, Police and other agencies. A combination of sequential and parallel team work, in association with leading-edge technologies for data capture and data distribution, ensured post-disaster aerial imagery was in the hands of the key personnel in the devastated areas within several days of the events.

2 CYCLONE YASI OVERVIEW

Tropical Cyclone Yasi (Figure 1) was a tropical cyclone that made landfall in northern Queensland in the early hours of Thursday, 3 February 2011. Yasi was the size of the East Coast of Australia, and caused an estimated $3.6 billion in damage, making it the costliest tropical cyclone to hit Australia on record. Cyclone Yasi made landfall at Mission Beach and wind gusts were estimated to have reached 290 kilometres per hour, leaving significant and widespread damage. A storm surge estimated to have reached 7.0 metres destroyed structures along the coast and pushed up to 300 metres inland.

In the hours after the storm's passage, police were unable to venture beyond their station grounds as the situation had yet to be declared safe. Beaches had lost sand and most structures at Mission Beach were damaged. Residents described the aftermath as a scene of mass destruction and an unknown number of homes were completely destroyed. Due to the

available preparation time and mass evacuations, fortunately Yasi was not directly responsible for any fatalities.

Figure 1: Satellite image of Yasi off the east coast of Queensland on 2 February 2011 (Photo Source: NASA).

2.1 AAM's Planning Input to the Yasi Project

AAM's input to the project context was:

- Short notice for flight planning and system mobilisation.
- Extremely challenging weather conditions for aerial survey.
- Specific requests for image capture, i.e. immediately after disaster or at peak flood.

Table 1 lists examples of the short response times essential during this project.

Table 1: Example of short response times for Post Tropical Cyclone Yasi project.

DERM released request for quote	Wed Feb 2, 10am
Tropical Cyclone Yasi hit land	Thurs Feb 3
AAM awarded contract	Thurs Feb 3, 5.15pm
Successful aerial capture of priority areas	Sat Feb 5
First imagery delivered to Qld Govt	Mon Feb 7

Teams of AAM personnel worked long hours for several weeks. The aerial survey teams worked in difficult conditions to successfully exploit the small gaps in the poor weather conditions to capture imagery, while office-based teams worked in parallel to process the data for delivery within two days of capture for the priority areas. Figure 2 illustrates the conditions faced during data capture.

Figure 2: Very low cloud bases, high winds and steep terrain were some of the conditions faced by the aircrews during the post Yasi data capture over 23 sites.

2.2 AAM's Data Capture and Processing for the Yasi Project

From the diverse collection of digital cameras owned by AAM, a large format, Zeiss Intergraph Digital Mapping Camera (DMC) was selected based on the need to:

- Fly slow under a very low cloud base.
- Deliver high-resolution imagery with minimal or no clouds.
- Supply mosaics within a few days of data capture.

The use of multiple 64-bit workstations and experienced data analysts ensured the provision of multi-resolution, compressed products for distribution via the ftp and HDD mechanisms. Figure 3 provides an example of the 50 cm rapid mosaics created from the 5 cm imagery captured (Figure 4). Ground photography only captures part of the picture (Figure 5).

Given the initial priorities of the users were assessing the extent and severity of the damage / event, rapid mosaics were compiled and dispatched. In parallel production, the more time-consuming tasks involving aesthetics (colour balancing) and precision orthocorrection were undertaken. These rapid image products were generated at multiple resolutions and multiple compression formats (ecw, jpg2000) to aid distribution to agencies with a range of software environments and data preferences.

Within 10 days of project commencement AAM collected:

- Data over 23 sites.
- More than 500 km^2 of data.
- More than 6000 frames of almost cloud-free imagery.
- Most capture at 5 cm GSD (i.e. just below the clouds).

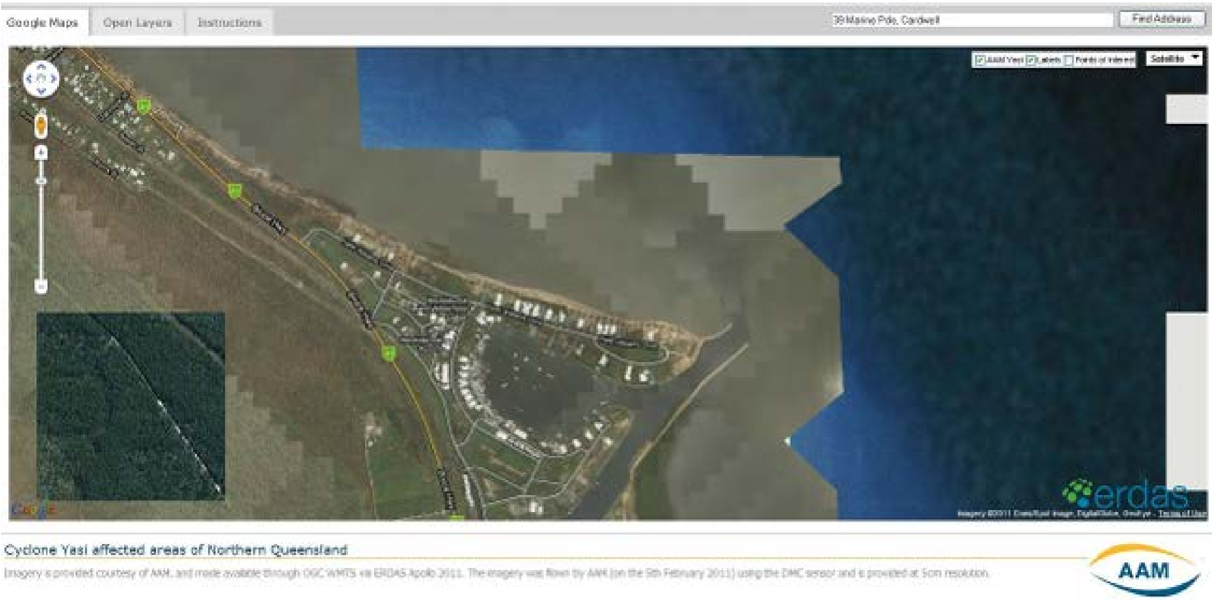

Figure 3: AAM imagery as supplied by Web Mapping Service in the ERDAS Apollo Environment.

Figure 4: Example of the Cardwell 5 cm imagery that was acquired.

Figure 5: Ground photography of the same site does not capture the complete picture (sourced from the Courier Mail website).

3 USES OF IMAGERY

AAM imagery formed the foundation dataset for a range of applications to which many agencies value-added, e.g.

- Qld Fire and Rescue Service (QFRS): Iimmediate assessment of damage (Figures 6-9).
- Centrelink: Confirmation of claims made for disaster relief funding in areas impacted by the disaster.
- Tax Office: Confirmation of which properties were impacted, so claims such as "I lost all of my receipts" and "all of my tax paperwork was destroyed" can be validated, as well as identification of individuals that may need more time to pay tax bills as their properties were affected by the disaster.
- Qld Reconstruction Authority: The communication tool and planning base for prioritising reconstruction of buildings, roads, rail, etc. (Figure 10).

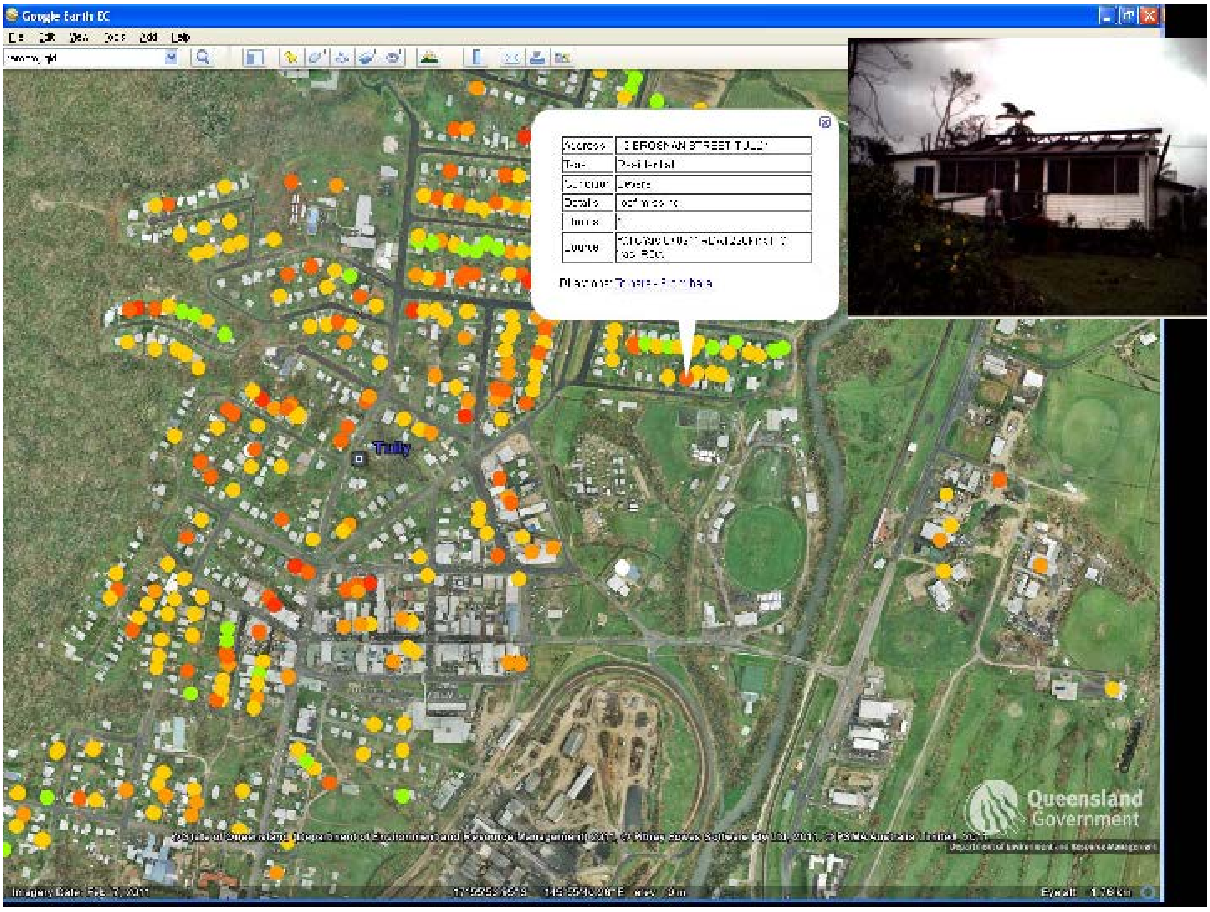

Figure 6: AAM imagery utilised to aid on ground damage assessment (Photo Source: DERM).

Figure 7: Emerald imagery showing rapid damage assessment information collected by QFRS. Data as viewed from Emergency Management Qld internal mapping system.

Figure 8: St George imagery showing rapid damage assessment information collected (Source: QFRS).

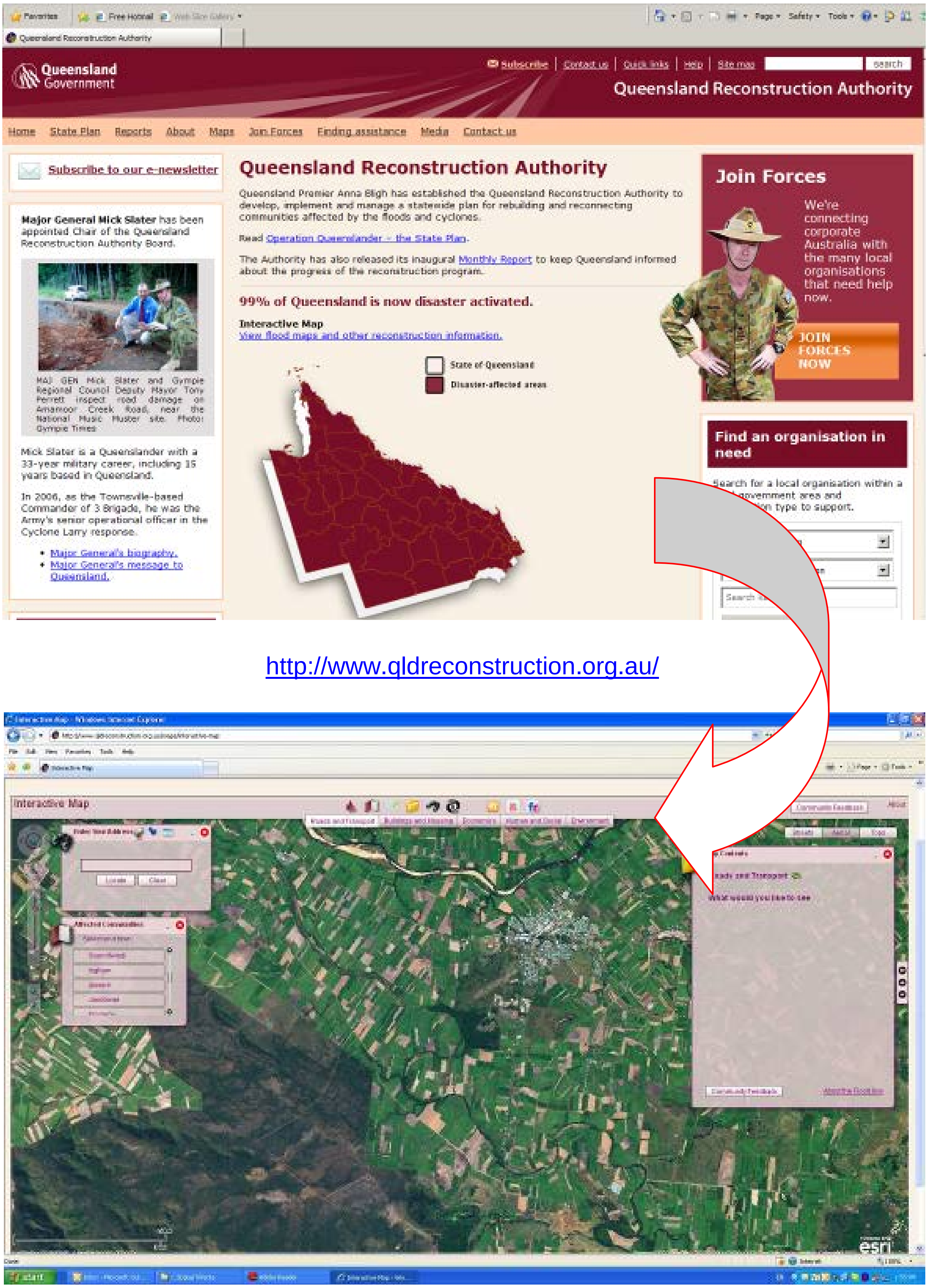

Figure 9: AAM imagery as the foundation dataset within the Qld reconstruction website.

4 BENEFITS OF RAPID AERIAL IMAGERY SERVICES

Queensland Emergency Services personnel had not received rapid response data before AAM's provision of flooded inland towns or post Cyclone Yasi. Accurate imagery of the extent and severity of the damage was a vital tool which ensured a common understanding of the situation and solid base for an informed response.

Teams of specialist AAM staff worked long hours to accelerate the flight planning, image capture, image processing, mosaic creation and delivery of datasets to the Qld Department of Environment and Recourse Management (DERM) and Emergency Management Qld.

Having captured imagery within hours of the disasters, the data had immense value to disaster relief planning, and damage assessment in addition to government planning regulations which will influence a range of government policies, future disaster strategies and continued prioritisation of resource allocation.

The AAM products and services supplied confirmed the capacity, capability and maturity of Australian companies to undertake aerial survey services under difficult circumstances and to create teams to support rapid response work using the latest generation of digital imaging technology.

On-the-fly data processing capabilities and data distribution applications illustrated the power of web mapping services (WMS) such as ERDAS. The old but reliable ecw data compression via the old and reliable ftp technology also aided the rapid transmission and receipt of data in numerous regional locations.

The image base provided a unique and common foundation for communication amongst all parties involved in numerous tasks associated with disaster response, e.g. damage assessment, prioritisation of scarce resources.

The synergy between the imagery and the subsequent on-the-ground input from Emergency Services personnel and others allows the Government and major commercial agencies in the region to aid in the allocation of resources and prioritisation of vital reconstruction.

5 COMMUNITY BENEFITS

Emergency personnel were impressed with the unprecedented speed and quality of image data available to them. The AAM methodology permitted the widespread use, access and enhanced understanding of how leading-edge geospatial digital products can better support our Emergency Response Agencies and SES volunteers.

AAM recently received a highly commended nomination at the recent Queensland Spatial Excellence Awards. The AAM contribution was informally acknowledged by personnel from the Department of Community Safety / Emergency Management Queensland and formally acknowledged in a letter shown in Figure 11.

Queensland Government — **Department of Environment and Resource Management**

24.3.2011

Mr Brian Nicholls
General Manager
AAM Pty Ltd
152 Wharf St
Brisbane Qld 4000

Dear Mr Nicholls,

I would like to thank your company for the tremendous effort put into the imagery projects required by my Department for the recent natural disasters that Queensland has experienced.

Your company played a major role in the acquisition and prompt delivery of essential aerial imagery. The imagery is now being employed in the response and recovery efforts across the Queensland Government including the newly established Queensland Reconstruction Authority.

The Department of Environment and Resource Management recognises that, not only was the imagery acquired under very difficult circumstances but the image quality and timely delivery of the data could not have been better. It is not often that government agencies give praise for work well done by the private sector, but these excellent outcomes reflect very highly on your company and in particular the dedication and experience of AAM's air crew, technical and support staff. Without their endeavour, the imagery would not have been available for the critical work required by the Government and the community for the disaster response.

For your interest I have included some screen shots of AAM's imagery being utilised by the department when integrated with other departmental datasets for disaster response activities.

Could you please convey my sincere thanks to all involved? The department looks forward to working with AAM in the near future and in the longer term in other spatial data projects.

Yours sincerely

Steve Jacoby
General Manager
Spatial Information Group

Figure 10: Evidence of client endorsement.

6 CONCLUDING REMARKS

In short, the imagery was one vital input to view and assess the damage of natural disasters and then determine which geographic areas required the most support. New benchmarks were met by the rapid imagery projects with the Queensland government in 2010 and 2011. These were:

1. The almost immediate capture of high-resolution, post-disaster imagery for numerous locations. Mosaics of the major areas of devastation were created and delivered within two days of capture. Some previous disasters in Qld were not imaged until months after the event, e.g. Cyclone Larry.

2. Access to the imagery was possible via several mechanisms:
   - Emergency Management Queensland secure ftp site.
   - DERM secure ftp site.
   - Backup delivery on HDD.
   - Imagery was quickly made available via web mapping imagery services.

3. The Qld Government embraced a flexible and collaborative arrangement in the capture of aerial imagery to ensure its rapid capture and delivery. The Government is now reaping the rewards of imagery capture immediately after (or during) the disasters' peak levels. The imagery is now contributing to the accurate mapping of floods heights and cyclone damage extents, which are vital to long-term damage assessment and will influence a range of government policies, future disaster strategies and continued prioritisation of resource allocation.

ACKNOWLEDGEMENTS

AAM gratefully acknowledges the following:
- Web mapping services supplied by Robert Clout & other colleagues at ERDAS.
- GIS screenshots from E-Tom, supplied by Emergency Management Queensland.
- GIS screenshots supplied by the Department of Environment and Resource Management.
- AAM photos of aircrew and flying conditions: Dider, Matthius.
- AAM staff, their families and partners for working long nights, weekends and multiple public holidays to provide our capture and processing services.

Average Speed Safety Cameras

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ABSTRACT

In 2009, the NSW government enacted legislation to enable the detection and subsequent penalising of drivers of heavy vehicles speeding over a distance as opposed to instantaneous (fixed point) detection. To achieve the requirements of the legislation and to present evidence at court to inform participants of the nature of the site, various surveys need to be undertaken. Such surveys need to be of varying accuracy. This paper presents the method of determination and certification of the Shortest Practicable Distance (SPD), the methods used to detect vehicles and the various surveys needed to provide supporting information. The legislation requires that the distance so determined must be accurate to 0.01 kilometres, i.e. 10 metres. Various methods were considered to achieve this accuracy in a timely and accurate manner. In considering any method of measurement, the method of detection of a vehicle at the terminals of the SPD length is useful to understand.

KEYWORDS: *Average speed camera, surveying, shortest practicable distance.*

1 INTRODUCTION

The Road Transport Legislation Amendment Act (Traffic Offence Detection) Act 2009 (No. 50) has being introduced in NSW to prosecute drivers that exceed the legal "average speed limit" within a designated Point-to-Point (P2P) Speed Enforcement Zone. Each P2P length will have a measured "Shortest Practicable Distance" (SPD). The SPD is that distance between each detection point which is the shortest possible path that a vehicle can legally travel along the road, i.e. crossing over broken lane/centre lines.

The terminals of the P2P length will be within a detection area linked to a detection sensor (e.g. loops, radar 'video'). The sensors will detect each vehicle, identify it and record the registration numbers. Any offending vehicles will then be infringed.

2 LEGISLATION

The Road Transport (Safety and Traffic Management) Act 1999 No. 20 was amended with the inclusion of section 43A. The legislation specifies that only heavy vehicles are to be infringed and outlines the method for calculating the average speed for single or multiple speed zones. There are also further infringements that can occur within a P2P zone. A P2P zone is defined in the Act as being within approximately 300 metres of the cameras. Such an infringement is attempting to avoid detection, e.g. crossing to other side of road or driving around the site.

43A Average speed of heavy vehicle is evidence of actual speed in certain circumstances

The pertinent clauses that impact the type of survey are:

(a) *the average speed of the heavy vehicle* calculated in accordance with this section is admissible and *is prima facie evidence of the actual speed at which a driver of the vehicle drove the vehicle on a road between the detection points*, and

(b) *the heavy vehicle and any of its drivers are*, for the purposes of calculating the vehicle's average speed and any average speed limit, *taken to have travelled between the detection points by means of the shortest practicable distance between those points regardless of the actual route taken by any of the drivers between the points.*

(4) **How average speed is to be calculated**

The average speed of a heavy vehicle between detection points is to be calculated in accordance with the following formula (and expressed in kilometres per hour rounded down to the next whole number):

$$\frac{D_T \times 3600}{T} \tag{1}$$

where D_T is the total shortest practicable distance (expressed in kilometres and rounded down to 2 decimal places) that could have been travelled by the vehicle on a road between the detection points. T is the journey time (expressed in seconds) of the vehicle between the detection points.

(5) **How average speed limit is to be calculated**

The average speed limit for a driver of a heavy vehicle on a road between detection points in circumstances where more than one speed limit applied to the driver between those points is to be calculated in accordance with the following formula (and expressed in kilometres per hour rounded up to the next whole number):

$$\frac{D_T}{\frac{D_1}{S_1} + \frac{D_2}{S_2} + \dots \frac{D_n}{S_n}} \tag{2}$$

where D_T is the total shortest practicable distance (expressed in kilometres and rounded down to 2 decimal places) that could be travelled by the vehicle on a road between the detection points. S_1, S_2 … S_n are each of the speed limits (expressed in kilometres per hour) that would have applied to a driver of the vehicle if the vehicle were travelling along the shortest practicable distance D_T on a road between the detection points. D_1, D_2 … D_n are each part of the total shortest practicable distance D_T between the detection points (expressed in kilometres and rounded down to 2 decimal places) for the different speed limits S_1, S_2 … S_n that would have applied to a driver of the vehicle between the detection points.

3 DETERMINING THE SPD

When considering how to measure each P2P length, it was recognised that the road surface (not the horizontal) distance will be that travelled by a vehicle. The distances involved for the 22 P2P lengths vary from 6 to 70 km. They traverse varied terrain from very hilly to very flat and straight to very windy.

Normal methods of measuring were considered for the task of measuring the SPD but were found to be extremely costly and dangerous for the personnel. Therefore, the method that Roads & Maritime Services (RMS) adopted to measure the SPD is to use the GIPSICAM (Global-Inertial Positioning Systems Image Capture for Asset Mapping) van.

This paper will not go into the intricacies of GIPSICAM. Suffice to say that it captures images (jpegs) as it travels the road. It is equipped with two GNSS receivers, inertial systems, odometers, computers and cameras; and software for processing the raw data and images collected by the vehicle. The images are able to be geo-referenced. GIPSICAM is calibrated on an established test site within two months prior to and after a SPD survey. The baseline has been measured and certified by a registered land surveyor using GNSS equipment, total station and 100-metre band all calibrated to Australian standards.

During a SPD survey, GIPSICAM has a daily calibration procedure and runs the length three times in both directions. From the data extracted, the surface distance can be obtained and spot coordinates obtained (Figure 1).

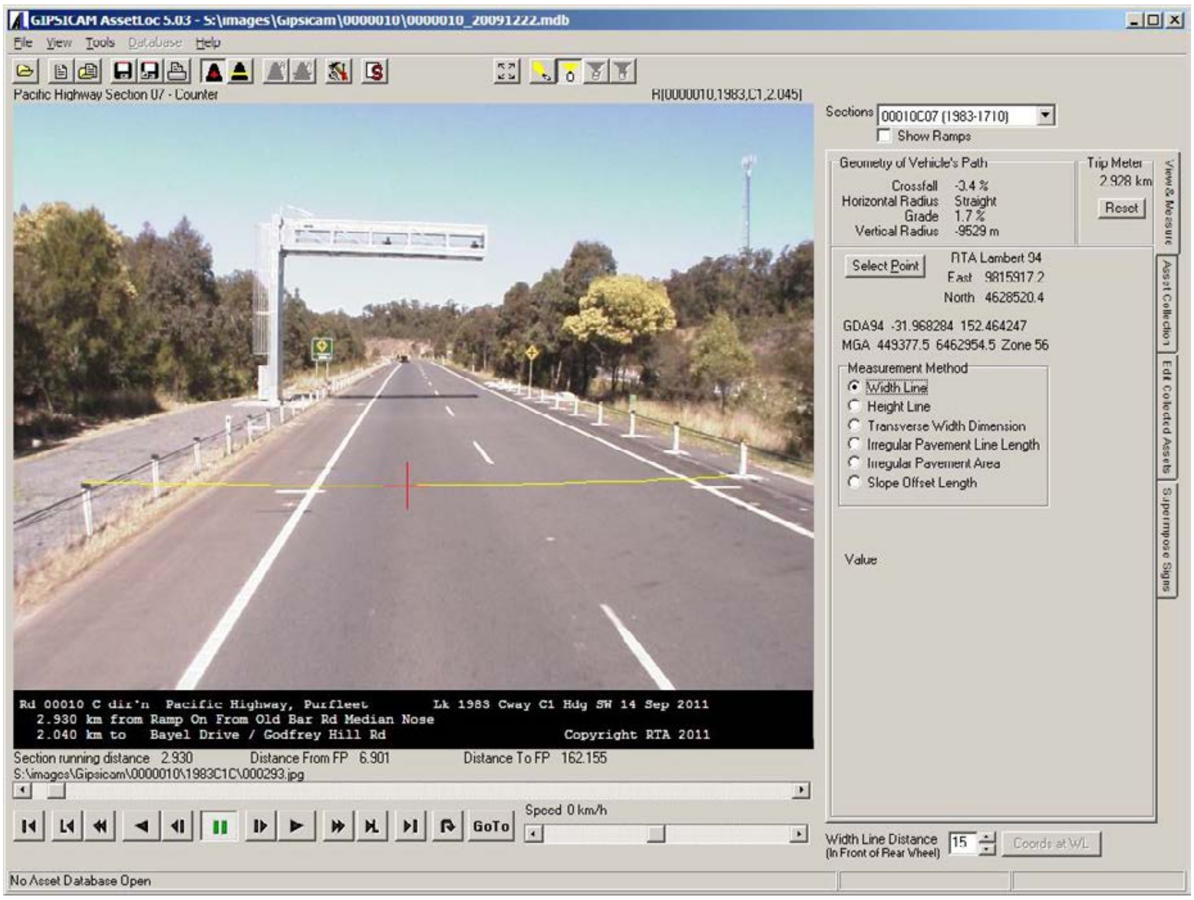

Figure 1: GIPSICAM image showing cursor position.

The SPD is to be taken as the distance of the shortest travel path of a vehicle. This can be determined on screen by the operator, less all possible distance and positioning measurement errors to ensure that there is no possible path length shorter than that determination. It can be seen from Figure 2 that the deflection in the vehicle path is not the same as the road curve deflection, and may be zero in some cases.

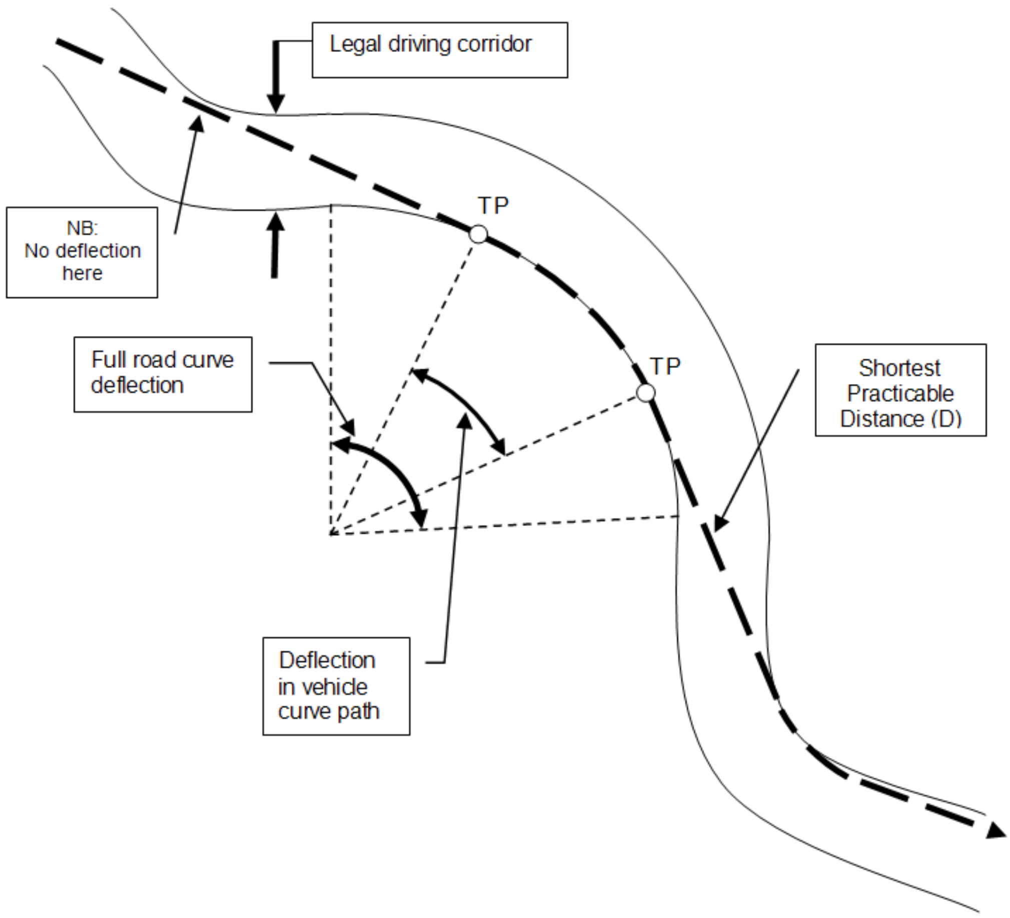

Figure 2: Deflection in the vehicle's path.

4 METHODS OF DETECTION

There are currently three methods that vehicles are detected entering and exiting these lengths. These are discussed in this section.

4.1 Inroad Sensors

This type of detection is used for fixed digital speed cameras, traffic lights, etc. The type used to date in this program is known as Loop-Loop as there are two loops a set distance apart (Figure 3). These are able to perceive the magnetic signature of a vehicle twice. The second time is to confirm that it is the same vehicle.

Figure 3: Inroad sensor loops seen in the road.

4.2 'Video' Technology

'Video' technology uses infrared cameras to detect 'hot' pixels on a vehicle – in particular the number plate. A number of images are taken in a short period of time (sub-second), compared and the clearest image adopted as the vehicle being detected. Figure 4 shows the corners of the footprint of each of four infrared cameras at this site. The detection point for the purposes of certifying the SPD is taken as the last moment that a vehicle enters the length and the first moment that a vehicle leaves the length. This is to ensure that the driver is not disadvantaged.

Figure 4: Corners of the footprint of each of four infrared cameras at this site.

4.3 Radar

To date radar is not in use on any site in NSW. That will change when a length south of Sydney comes online. Radar is self explanatory. The difficult part is determining where the point of detection will be so as to certify the SPD. The point of detection is affected by the speed of the vehicle.

5 OTHER SURVEYS

5.1 Location

A location sketch (A4 size) is prepared of the overall length to show its geographic location (Figure 5). Importantly, on this sketch the locations of all regulatory speed signs are shown, including the signs immediately before and after the length. This is to establish, at court, exactly what and where each speed sign showed the speed limit. This is to avoid the argument that the driver was unaware of the limit, especially if there are multiple speed zones.

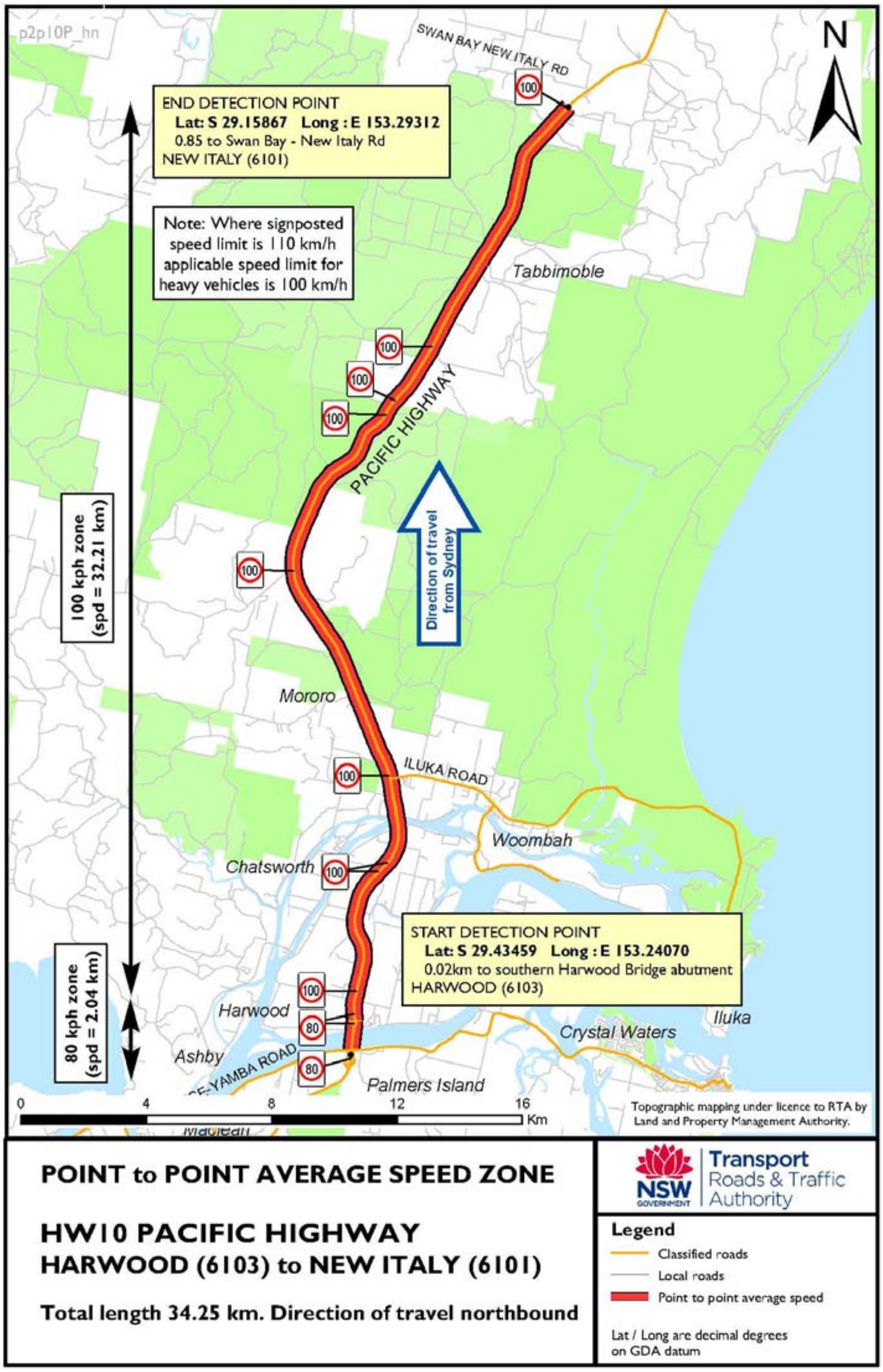

Figure 5: Location sketch showing the overall length of the Harwood to New Italy site (Pacific Highway).

5.2 Detail Survey

Warning signs are placed about 150 metres either side of the detection area. It is between these signs that vehicles can be infringed for other matters, e.g. avoidance or wilful damage. Therefore, a detail survey is prepared of the site that includes these signs and is generally fence-to-fence wide (Figure 6). The purpose of this plan is to present an image of the site for those that do not visit it, e.g. the court.

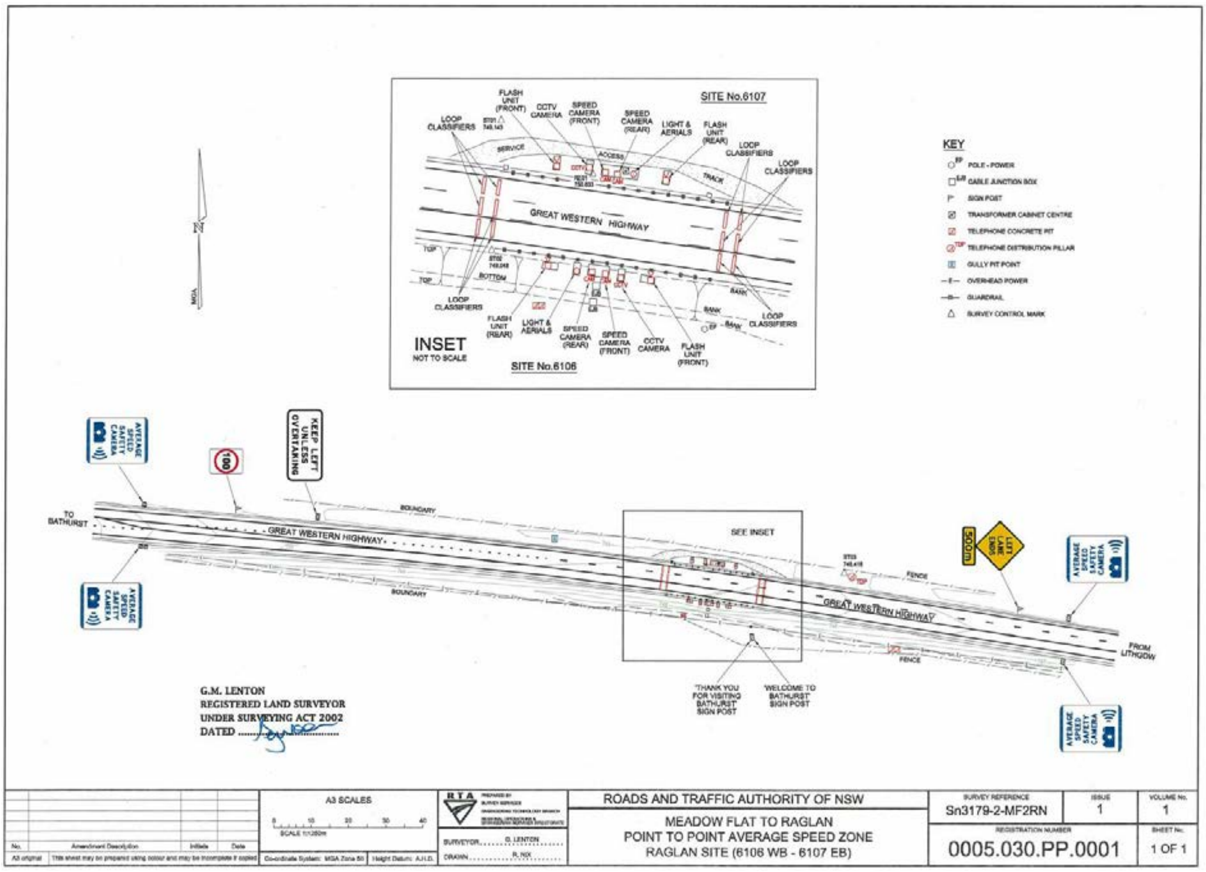

Figure 6: Detail survey plan for the Raglan site (Great Western Highway).

6 CONCLUDING REMARKS

The survey branch of Roads & Maritime Services was presented with the task of establishing a process of surveying and documenting the requirements of new legislation. This paper has described the survey work involved.

List of Attendees

(at 5 March 2012)

Surname	First	Organisation
Ablett	Chris	Ablex Pty Ltd
Addison	Rob	Property Manager
Ahearn	Daniel	Wyong Shire Council
Athorn	Mick	RailCorp
Avery	Mark	Ausgrid
Barnes	Craig	Department of Primary Industries
Begg	Don	Tattersall Lander Pty Ltd
Beljanski	Steven	Clarke & Di Pauli Surveyors
Bennett	Anthony	Usher & Company Pty Ltd
Bennett	Neil	Office of Environment and Heritage
Berrisford	Simon	Usher & Company Pty Ltd
Birse	Bob	Crown Lands, DPI
Bolte	Mark	Roads & Maritime Services
Bowler	Geoff	Cowra Shire Council
Brown	David	RailCorp
Brown	Kevin	NSW Office of Water
Bruhn	Norm	RailCorp
Burbidge	Brian	Geoscience Australia
Burgin	Peter	Ultimate Positioning
Burke	David	Roads & Maritime Services
Burke	Martin	Brown Consulting
Burns	Graham	GBA Consulting
Burton	David	Aspect Development & Survey
Butler	Mark	Parsons Brinckerhoff
Calvin	Grant	Greater Taree City Council
Cannings	Jarad	NSW Public Works
Carr	Paton	AWT Survey
Casey	Tom	Casey Surveying
Catzikiris	Jamie	Upper Hunter Shire Council
Chi	David	NSW Public Works
Chia	Liang	Sydney Catchment Authority
Chidzey	Ross	RailCorp
Clifford	Gary	RailCorp
Collier	Greg	Land & Property Information
Commins	Russell	Land & Property Information
Connolly	Paul	Roads & Maritime Services
Conway	Chris	Conway Burrows & Hancock
Cooper	Barry	G & G Surveying Pty Ltd
Cornish	Peter	Hard & Forester Pty Ltd
Corry	Paul	City of Sydney
Cox	Glenn	Lockley Land Title Solutions
Cram	Patrick	TAFE
Cumming	Graham	CR Kennedy & Company
Davis	Wayne	City of Sydney
de Belin	Fred	Ryde City Council
Dearsley	Mark	Meadows Consulting Pty Ltd
Delbridge	Michael	ADW Johnson
Diaz	James	AEC Systems
Dickson	Greg	Land & Property Information
Doyle	Greg	Wyong Shire Council
Dubyk	Paul	Ausgrid
Dunn	Michael	Roads & Maritime Services
Dunstall	Bill	CDE Survey
Dunstan	Richard	Ausgrid

Surname	First	Organisation
Durtanovich	Jim	Ex City of Sydney
Dyce	Lindsay	Pittwater Council
Edwards	Joel	Land & Property Information
Ellerton	Graeme	RailCorp
Ellis	Dick	Land & Property Information
Emmerick	Chris	CR Kennedy & Company
Evans	Gavin	Environment & Sustainable Development
Evans	John	Port Stephens Council
Fattore	Carlo	RailCorp
Feeney	Stephen	City of Sydney
Fenwick	Wayne	Crown Lands, DPI
Filocamo	John	Crown Lands, DPI
Foster	Greg	Crown Lands, DPI
Friend	Matthew	RailCorp
Gaggin	Graeme	RailCorp
Gardner	Les	Land & Property Information
Gilmour	Raymond	Roads & Maritime Services
Goodman	Greg	Land Team
Gordon	Allan	Maritime Services Division
Gordon	Mark	Roads & Maritime Services
Gore	Troy	Ausgrid
Gowans	Nicholas	Land & Property Information
Gowen	Brian	Brian Gowen Surveying
Gregor	John	Geomatic & Property Services Aus P/L
Griffiths	Bob	Griffiths & Rose
Grinter	Thomas	Land & Property Information
Groves	Glendyn	Esler & Associates
Haasdyk	Joel	Land & Property Information
Hammer	Murray	RailCorp
Harcombe	Paul	Land & Property Information
Hartmann	Kevin	Ex RTA NSW
Hartzenberg	Pieere	Hard & Forester Pty Ltd
Harvey	Malcolm	Thiess
Hasen	Ross	Parramatta City Council
Haynes	Sean	Brown Consulting
Hehir	Warwick	President, SSSI
Hern	Greg	Newcastle City Council
Higgs	Charleie	AAM Pty Ltd
Hilder	Glenn	GlobalPOS Pty Ltd
Hopson	Matthew	Crown Lands, DPI
Hurcum	Bert	Catchment & Lands, DPI
Hurcum	Michele	Catchment & Lands, DPI
Iredale	Ian	Iredale & Associates
Janssen	Volker	Land & Property Information
Jap	Charles	Land & Property Information
Job	David	Land & Property Information
Johansen	Walter	Environment & Sustainable Development
Jones	Ian	RailCorp
Jung	Steve	Aurecon Group
Justine	Paton	Crown Lands, DPI
Kelly	David	Sutherland Shire Council
Kelly	David	Ballina Shire Council
Kennedy	Dan	Crown Lands, DPI
Kilpatrick	Grant	Roads & Maritime Services
Kinlyside	Doug	Land & Property Information
Kocoski	Micheal	Blue Mountains City Council
Lahood	Robert	Land & Property Information
Lander	Bob	Tattersall Lander Pty Ltd
Lang	David	RailCorp

Surname	First	Organisation
Langdon	Rob	Greater Taree City Council
Leggatt	Geoff	Hornsby Shire Council
Lenton	Geoff	Roads & Maritime Services
Lewsam	Darren	Newcastle City Council
Liddell	Mitch	Tweed Shire Council
Livingstone	Greg	City of Sydney
Lock	Robert	Land & Property Information
London	Michael	Land & Property Information
Long	Adam	TransGrid
Longhurst	Steve	City of Sydney
Lutton	Col	Tweed Shire Council
Markham	Robert	TransGrid
Martin	Alf	R.W. Martin & Associates
Masters	John	NSW Public Works
McAnespie	Andrew	OSL, Dept of Planning and Infrastructure
McElroy	Simon	Land & Property Information
Mcilwaine	Greg	Ex Public Works
McNiven	Scott	SDMA Survey
Mitchell	Stephen	Mitchell Land Surveyors Pty Ltd
Mooney	Des	Land & Property Information
Moss	Peter	Roads & Maritime Services
Naebkhil	Sam	RailCorp
Najjar	George	G&R Surveying Services Pty Lty
Neate	Michael	Trey Ingold Neate
Nilon	Peter	RailCorp
O'Connell	Venessa	Sydney Ports Corporation
Palmer	Craig	Land & Property Information
Panya	Kit	Roads & Maritime Services
Paterson	Graeme	Blue Mountains City Council
Petrow	Ales	Office of the Surveyor-General, ACT
Pettit	Greg	Usher & Company Pty Ltd
Plokstys	Richard	RailCorp
Porter	Neil	State Water Corporation
Pritchard	Rob	Ausgrid
Ragen	Peter	Crown Lands, DPI
Reddington	John	CR Kennedy & Company
Rees	David	RailCorp
Riddell	Matthew	Ausgrid
Rigelsford	Andrew	RailCorp
Robinson	Stephen	Roads & Maritime Services
Rose	Tony	Tony Rose Surveying Pty Ltd
Rumble	David	Ex Pacific Power
Sadler	Daniel	Land & Property Information
Samundsett	Colin	Retired
Saunders	Stephen	NSW Public Works
Sledge	David	Eurobodalla Shire Council
Sluys	Dennis	Land & Property Information
Smith	Bruce	CEH (Dapto) Pty Ltd
Smith	Darryl	NSW Public Works
Smith	Matthew	CEH (Dapto) Pty Ltd
Songberg	Geoff	Crown Lands, DPI
Stankiewicz	Czeslaw	Parramatta City Council
Steuart	Phil	NSW Department of Trade and Investment
Stewart	Graeme	Land & Property Information
Stivano	Paul	Aurecon Australia
Sutton	Stephen	Blacktown City Council
Thai	Huy	RailCorp
Thomas	Warren	State Property Authority
Thompson	Kevin	Crown Lands, DPI

Surname	First	Organisation
Thompson	Nathan	CR Kennedy & Company
Tierney	John	Ex TransGrid
Tucker	Brian	UTS
Usher	Andrew	Usher & Company Pty Ltd
Veersema	Adam	Usher & Company Pty Ltd
Vollmer	John	J. J. Volmer
Wadley	Scott	LCPL
Wady	Vaughan	Ausgrid
Wallis	Grahame	President, IS NSW
Watt	Simon	Ryde City Council
Waud	Michael	NSW Public Works
Wearne	Rodger	TransGrid
Webb	David	TransGrid
Wells	Phil	Newcastle City Council
Wilkinson	Paul	RailCorp
Williams	Mark	RailCorp
Wood	Keith	Keith H Wood - Surveyors
Wormald	Geoff	Land & Property Information
Yan	Thomas	Land & Property Information