

## NorthConnex: Subsurface Stratum Acquisition

**Kit Panya**

Roads and Maritime Services

[Kit.Panya@rms.nsw.gov.au](mailto:Kit.Panya@rms.nsw.gov.au)

### ABSTRACT

*NorthConnex is a proposed 9 km tunnel motorway designed to link the M1 Pacific Motorway in Wahroonga to the Hills M2 Motorway in Pennant Hills. The tunnel is part of the NSW Government's State Infrastructure Strategy forming an essential link in the Sydney Orbital Network and expected to cost \$3 billion. In January 2015, NorthConnex received official project approval by the NSW Government. The earliest access date required for tunnel construction was July 2015. The NorthConnex project team engaged the Roads and Maritime Services (RMS) Cadastral Survey Unit for the stratum acquisition of approximately 900 lots. The acquisition was predominantly subsurface, but also included surface land, strata title, and community title acquisition. Between the project approval date and the tunnel access requirements, we had a timeframe of two months to acquire the first 80 lots in the initial stage. This paper outlines how the RMS Cadastral Survey Unit was able to respond, using a plan production and lodgement strategy unique to previous motorways. With Land and Property Information (LPI), we developed the Subsurface Stratum Definition Strategy to allow for the compilation of boundaries for subsurface acquisition plans. Once the strategy was in place, the extent of acquisition was determined from analysis of spatial data and the tunnel model. Compiled plan production, and occasionally field surveys, could then take place to complete the acquisition process. The strategy and spatial analysis were fundamental to a plan production program that will consist of at least 100 compiled and surveyed Deposited Plans used to acquire the tunnel stratum. With the help of the NorthConnex project team, and LPI, we have delivered six of the seven stages of acquisition, all within the key project timeframes.*

**KEYWORDS:** *Stratum, subsurface, NorthConnex, acquisition.*

### 1 INTRODUCTION

NorthConnex is a proposed 9 km tunnel motorway designed to link the M1 Pacific Motorway in Wahroonga to the Hills M2 Motorway in Pennant Hills. The tunnel is part of the NSW Government's State Infrastructure Strategy forming an essential link in the Sydney Orbital Network. The project is expected to cost \$3 billion. Of that, \$2.65 billion is allocated to construction costs with the remainder set aside for land acquisition and project delivery (NorthConnex, 2016).

In January 2015, NorthConnex received official project approval by the NSW Government. In February 2015, the construction contract with the Lend Lease Bouygues (LLB) Joint Venture was finalised. The earliest access required for tunnel construction was July 2015.

The NorthConnex project team engaged the Roads and Maritime Services (RMS) Cadastral Survey Unit for the acquisition of subsurface stratum affecting approximately 900 lots. The

acquisition process also included surface acquisition, Strata Title acquisition and Community Title acquisition. Between the project approval date and the tunnel access requirements, the RMS Cadastral Survey Unit only had a timeframe of two months to acquire the first 80 lots in the initial stage. Further property acquisition was required in stages governed by a series of key access dates required by the LLB Joint Venture.

The objective of this paper is to describe the process of the NorthConnex subsurface acquisition. Firstly, the paper outlines the basic concepts of subsurface acquisition, as well as the challenges and complexities inherent to the NorthConnex project. Secondly, the methodology of the acquisition process is explained. This is followed by short case studies of particular surveys that challenged the acquisition process. The paper concludes with a summary of the project progress and the effect of this project leading into the development of future motorways and tunnels.

## 2 PROJECT CONCEPTS AND COMPLEXITIES

### 2.1 The Nature of Subsurface Stratum Acquisitions

In the past, RMS developed a general configuration for subsurface stratum acquisitions for tunnels. Usually, RMS will acquire a lot that extends infinitely in height, and down to the centre of the Earth. Imagining a vertical slice of the land that has been acquired for a tunnel, the components of the acquisition comprise three lots (Figure 1):

- Surface lot.
- Tunnel stratum lot.
- Support lot.

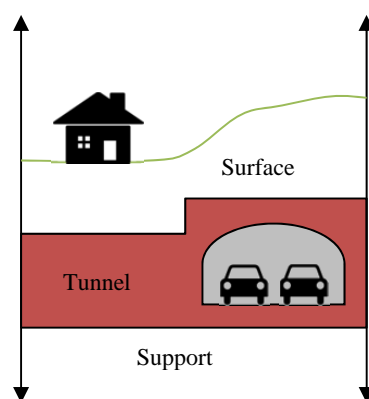


Figure 1: Stratum acquisition section.

The surface lot extends infinitely in height to a depth limited in stratum to a chosen Reduced Level (RL). The surface lot remains in the ownership of the current title holder (i.e. the owner in the title's first schedule). The limitation of the surface lot in depth is governed by the RL of the top of the tunnel stratum.

The tunnel stratum lot is a subsurface lot limited in depth and height by levels governed by the design of the tunnel. The stratum lot is also limited horizontally, with the horizontal configuration depending on the complexity of the tunnel structure as well as supporting structures. For instance, the tunnel stratum lot must contain not only the tunnel, but also any rock anchors, shafts, tunnel utilities and ramps. The tunnel stratum lot is initially acquired by

RMS, but will usually be leased to a tollway management company at a later stage once the tunnel is operational. Care must be taken to ensure that the tunnel stratum is deep enough below the surface. This is to provide enough space for the owner of the surface lot to use the land.

The support lot is limited in height to the bottom of the tunnel stratum lot, but extends infinitely to the centre of the Earth. This lot is acquired and owned by RMS. The intention is to limit the ownership of land under the tunnel stratum. This also allows for acquisition flexibility should the tunnel require upgrades, or if a future infrastructure project requires the space.

## **2.2 Project Scope**

The 9 km NorthConnex tunnel spans across approximately 900 existing lot parcels, from Pennant Hills to Wahroonga. The types of lots affected include private subdivisions, publicly owned lots, strata schemes, community schemes, motorways and public road lots. The aim was to acquire land for the purposes of constructing the NorthConnex tunnel.

In order to enable the acquisition of land, the following tasks had to be performed for each affected lot:

- Determine the level of the ground surface.
- Determine the upper level of the tunnel stratum.
- Calculate the depth from the ground surface to the top of the stratum.
- Calculate the position of the boundaries (horizontally and vertically).
- Survey or compile the boundaries for plan production.
- Produce a Deposited Plan for acquisition, and lodge with Land and Property Information (LPI).

## **2.3 Timing**

The general property acquisition process for NorthConnex is as follows:

1. Determination of subsurface stratum location.
2. Preparation and lodgement of Deposited Plans.
3. Proposed Acquisition Notices distributed to property owners.
4. Approval by the Minister for Gazettal and construction access.

Project approval for NorthConnex was granted in January 2015. The deadline for property acquisition was July 2015. This meant that by July the tunnelling joint venture (LLB) should have unrestricted access to the land for construction. Considering the timeframes for ministerial approval and Proposed Acquisition Notices, this left the RMS Cadastral Surveying Unit with two months for the production of Deposited Plans for lodgement (a deadline of February 2015). Fortunately, the acquisition programme could be separated into stages that reflected the tunnelling access requirements. Even then, the workload was still extremely demanding, as shown in Table 1.

Table 1: NorthConnex subsurface stratum acquisition schedule.

Stage	Plan Lodgement Date	Proposed Tunnelling Access	No. Deposited Plans
1	6 February 2015	July 2015	14
2	8 March 2015	August 2015	24
3	24 April 2015	October 2015	13
4	30 July 2015	November 2015	16
5*	30 September 2015	January 2016	20
6	8 February 2016	May 2016	8
<b>TOTAL<sup>1</sup></b>	--	--	95
<sup>1</sup> Final count of plans may depend on additional plans in reaction to amendments and/or design changes. * Stage 5 also included additional plans to amend or change acquisitions in previous stages.			

## 2.4 Technical Constraints

As mentioned in the previous section, the first step in the acquisition process was to determine the location and extent of the subsurface acquisition. To do this, the spatial extent of the tunnel had to be determined.

The LLB Joint Venture provided the design constraints for the tunnel, accounting for road design and geotechnical investigation. The stratum envelope to contain the tunnel has to conform to the following rules:

- Horizontally, the subsurface stratum must be offset 12 m from the sides of the main tunnels, or offset 20 m in locations that are shallow, of geotechnical risk or near shafts and dive structures.
- Vertically, the upper surface of the tunnel stratum is 20 m above the control line of the tunnel (Figure 2). However, it must not be less than 3 m below the ground surface. The lower surface is undefined for the location of the RMS support lot below (generally 20 m below the control line of the tunnel).

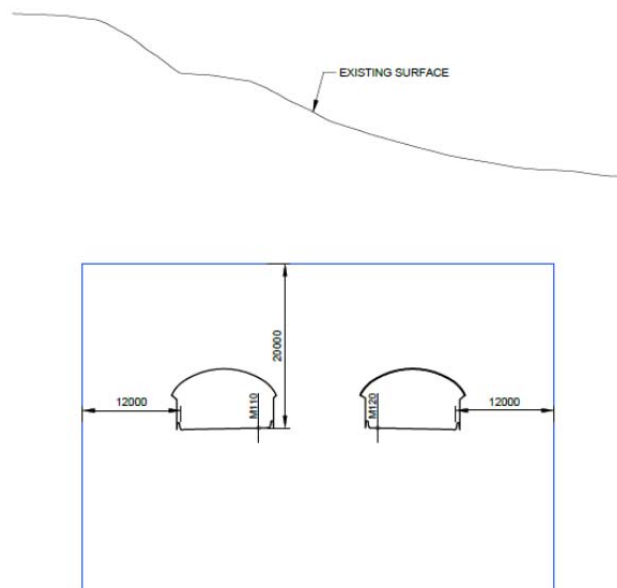


Figure 2: Typical cross section schematic of the tunnel stratum (courtesy LLB and Aurecon-SMEC).

There are also technical constraints related to survey and plan production. To produce plans based on traditional survey for the entire length of the project would not be feasible within

project timeframes. The geometry of the tunnel stratum dictates the need for plans of survey. The tunnel stratum contains level changes that reflect the vertical and horizontal curves of the tunnel structure. Ramps that incline or decline also complicate the situation.

Compiled plans would simplify the acquisition process greatly. However, in most cases, compiled boundaries are only accepted by the Registrar General in cases where the boundary determination is very simple (straight line boundaries, no more than four lots, etc.). In order to progress, RMS needed to resolve this issue (see section 3).

Lastly, there are technical constraints inherent to the NorthConnex project and its location. While the intention was to compile most of the acquisition, it was necessary to identify areas where plans of survey were absolutely required. Over the length of the project, there were some areas that required special attention:

- Where surface acquisition is required, particularly near ramps, shafts, and where NorthConnex merges with existing roads. In this case, surface acquisitions refer to the acquisition of land extending from the centre of the Earth to infinity.
- Where the entry ramps to the tunnel descend below the surface. The tunnel geometry was likely to be exceedingly complex to be suitable for acquisition by compiled plan.
- Where acquisition is required over Strata Lots (not just Common Property). RMS has never before acquired a Strata Lot by survey.
- Where acquisition is required over lots in a Community Title scheme (not just the Community/Neighbourhood Lot). RMS has never before acquired a Community Scheme Lot by survey.
- Where any other stratum boundaries have been identified, particularly the North West Rail Link.

The methodology behind the acquisition process had to take into account these technical constraints in order to provide Deposited Plans for acquisition that were suitable for the construction of the tunnel and lodged with LPI within the key deadlines. The methodology for plan production is explained in greater detail in the next section.

### **3 METHODOLOGY**

The RMS Cadastral Survey Unit was able to develop a solution to facilitate the acquisition of land for the NorthConnex tunnel. This approach can be broken down into the following components:

1. Developing the Subsurface Stratum Definition Strategy.
2. Analysis of spatial data using a Geographic Information System (GIS).
3. Surveys and compiled boundary calculations.
4. Deposited Plan preparation.

#### **3.1 Subsurface Stratum Definition Strategy**

The development of the strategy was crucial to the success of the project. The Subsurface Stratum Definition Strategy is an agreed set of conditions used to facilitate compulsory subsurface stratum acquisitions and the eventual registration of a tollway lease for NorthConnex. The first Strategy meeting between RMS Survey and LPI occurred on 15 September 2014. This was in expectation of the incoming wave of stratum acquisitions for NorthConnex (initially predicted to be around 1,000 lots and 150 plans). A conclusive

meeting was held on 9 February 2015, with the strategy finally developed and signed by all parties on 4 March 2015.

The key benefit of the strategy was that it allowed for compiled plans to be used for the acquisition of NorthConnex. This will reduce the timeframe for complete acquisition of the NorthConnex tollway from 10-15 years to 1-2 years. The strategy was also given the exemption number '2015M7100(119)RMS' for use on NorthConnex compiled acquisition plans.

For the Strategy to work, RMS and LPI had to agree on a number of important conditions, as summarised below (RMS and LPI, 2015):

1. The plans will be compiled Deposited Plans only (not surveyed).
2. All stratum planes shown on the compiled plans must be horizontal planes.
3. Two established control marks must be shown on the plan, as a guide to relative depth to the stratum.
4. The notation "Compulsory Acquisition purposes only and will be subject to final survey" is not a requirement for the compiled Deposited Plans.
5. Traditional cadastral survey is required where the motorway structure is close to the surface, where inclined planes or benches are required within properties, or where critical properties are affected.
6. RMS Survey will undertake control or cadastral mark recovery to establish the network prior to any construction work.
7. Where minimal effect (<50%) acquisition is determined and/or a large parent parcel is partially affected, a vertical stratum boundary will be calculated. The new boundaries will be calculated between existing corners or designated rounded offsets (nearest metre) along existing property boundaries.
8. Definition will include subsurface lots across all affected public roads. These acquisitions can be calculated and depicted on the acquisition Deposited Plans that affect private lots. The public road area above the tunnel stratum will also be defined by calculated lots and remain as public road in Council ownership.
9. No Certificates of Title will be created or issued on any of the acquisition plans at registration. Titles will be created (but not issued) following gazettal action and lodgement of 31A(3) (Real Property Act 1990) applications.
10. Consolidate all subsurface lands once acquired, then create and issue titles. These consolidation plans will be compiled.

With the strategy in place, it was possible to proceed with the preparation and lodgement of acquisition plans.

### **3.2 Analysis of Spatial Data**

While the strategy outlined in section 3.1 was being finalised, the RMS Cadastral Unit also had to develop a solution to facilitate the creation of dozens of plans within the timeframes set for each acquisition stage. The basic process can be seen in Figure 3.

Before determination of the acquisition extent can begin, models had to be created in order to organise and illustrate the existing information that was available, and make it easier to analyse. The models created had to show RLs of the upper and lower surface of the tunnel stratum, lot and Deposited Plan details, and additional tunnel stratum geometry for any complex tunnel locations.

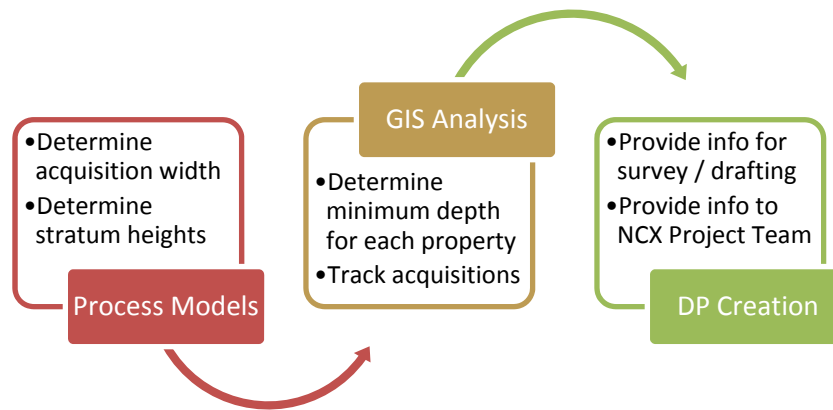


Figure 3: The basic process for subsurface stratum acquisition.

### 3.2.1 Initial Input

At this stage, the structural design of the NorthConnex tunnel was also in its infancy. The only design input available, at the time, consisted of:

- 2D model showing the horizontal tunnel widths and Master Control Lines (generally the centre line of each carriageway).
- Plan showing the approximate horizontal location of the tunnel stratum (based on the 12-20 m offsets mentioned in section 2.4)
- Plan of longitudinal sections along the Master Control Lines.

With the NorthConnex project approval (the official start date) approaching, and the acquisition deadline following soon after, determination of the tunnel stratum location had to be based on the information available.

### 3.2.2 Processing the Model – Horizontal

By combining the input data, a 3D model was created to be suitable for approximating the position of the tunnel stratum (Figure 4). The MXROAD software platform was used to create the model in this instance. Horizontally, the originally neat 12-20 m buffer around the tunnel had to be reworked to a ‘sawtooth’ configuration to meet the conditions of the Strategy, i.e. minimally affected lots (<50%) remain as partial acquisition and greatly affected lots (>50%) are acquired in stratum to the full horizontal extent of the lot. Wherever allowable by design, some minimally affected lots could be ignored altogether (no stratum acquisition).

### 3.2.3 Processing the Model – Vertical

Once the horizontal dimension of the stratum was determined, the level of the horizontal stratum footprint was ‘draped’ to follow the levels of the Master Control Lines. This created a base 3D surface at the level of the tunnel control. By copying and offsetting this initial surface 20 m higher and lower, the first approximation of the upper and lower surfaces of the tunnel stratum was made.

By combining the model with topography (and later, LiDAR contours), the tunnel stratum could be compared to the ground surface. Some locations required ‘massaging’ of the upper stratum surface to correspond to the 3 m minimum depth requirement below the surface (see section 2.4).



Using MXROAD, the depth from the ground surface to the upper tunnel stratum surface was determined using volume contours (Figure 5). The volume contour model could be transferred GIS analysis software (ArcGIS) for further analysis with the cadastre.

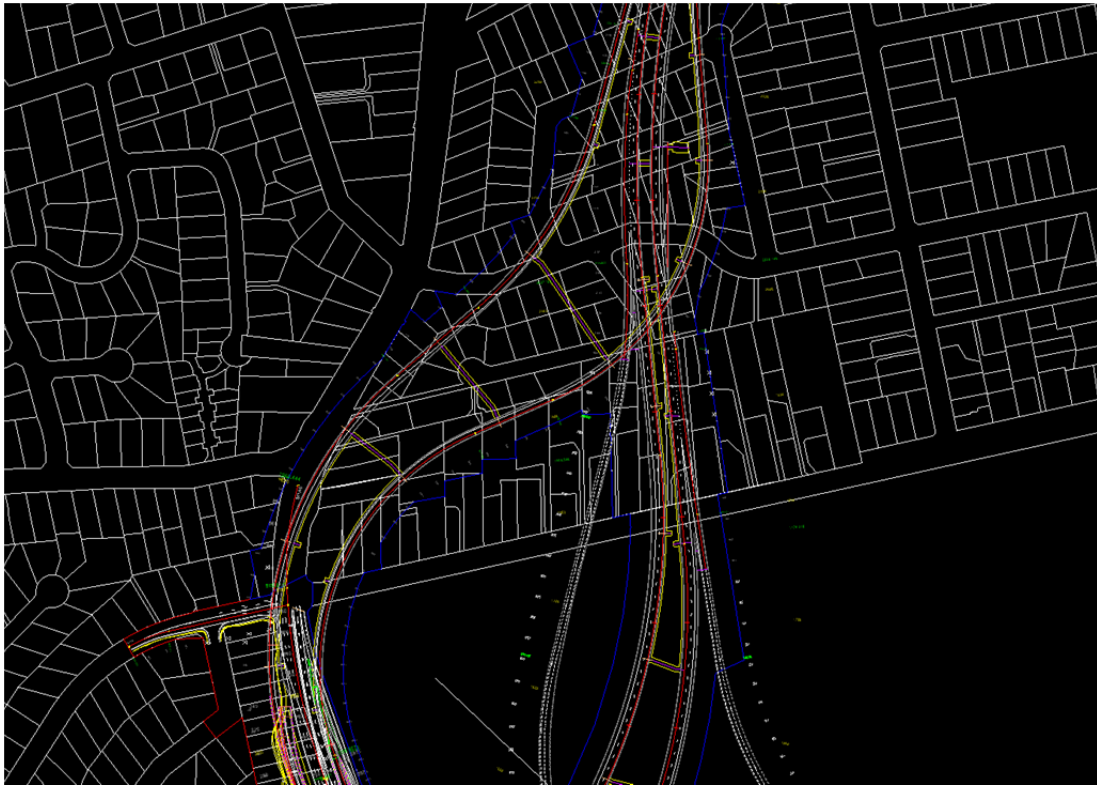


Figure 4: Model showing the Master Control Lines (red), tunnel design, and 'sawtooth' boundary (blue).

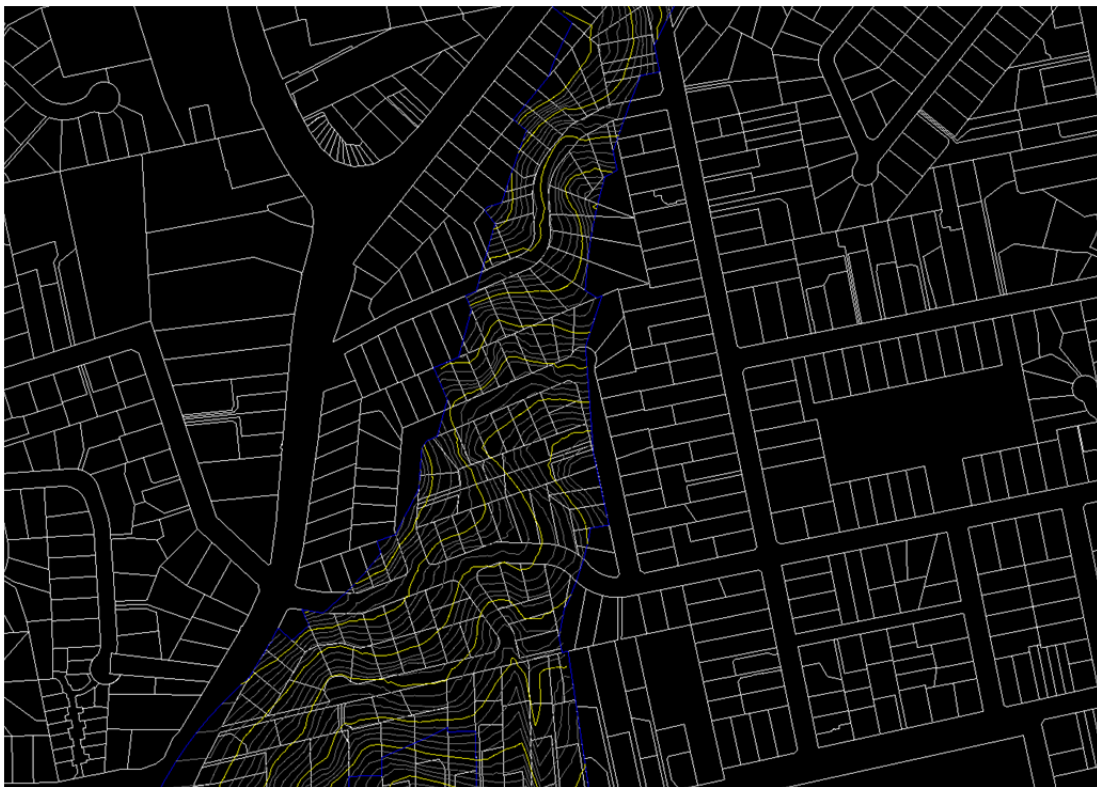


Figure 5: Screenshot showing volumetric contours.



### 3.2.4 GIS Analysis

Using ArcGIS, the volume contours (indicating depth) were overlaid on top of the cadastre. To meet another requirement of the Subsurface Stratum Definition Strategy, it was required to determine only one upper surface stratum level for each acquisition lot. As a quick way to determine this for 900 lots, the 'spatial join' tool for ArcGIS was used. Using this tool, two datasets (depth values and lot boundaries) were combined by calculating the smallest depth value inside each lot parcel. This provides the shallowest depth for each lot, highlighting any locations where the tunnel stratum comes close to the ground surface.

Extending this further, the highest RL for each lot parcel (using the shallowest depth in the previous combined dataset) was determined. The result of this was the creation of a map of the entire NorthConnex tunnel showing the affected lots and the upper (and lower) RLs for each lot, as shown in Figure 6.

The depths and levels can be cross-checked against updated information and cross sections as provided by the tunnel designers. In addition, the levels are also checked prior to plan lodgement. With the GIS analysis above, and combined with the search for DPs, titles and survey control sourced from the Survey Control Information Management System (SCIMS – see Kinlyside, 2013), the creation of acquisition plans could begin.

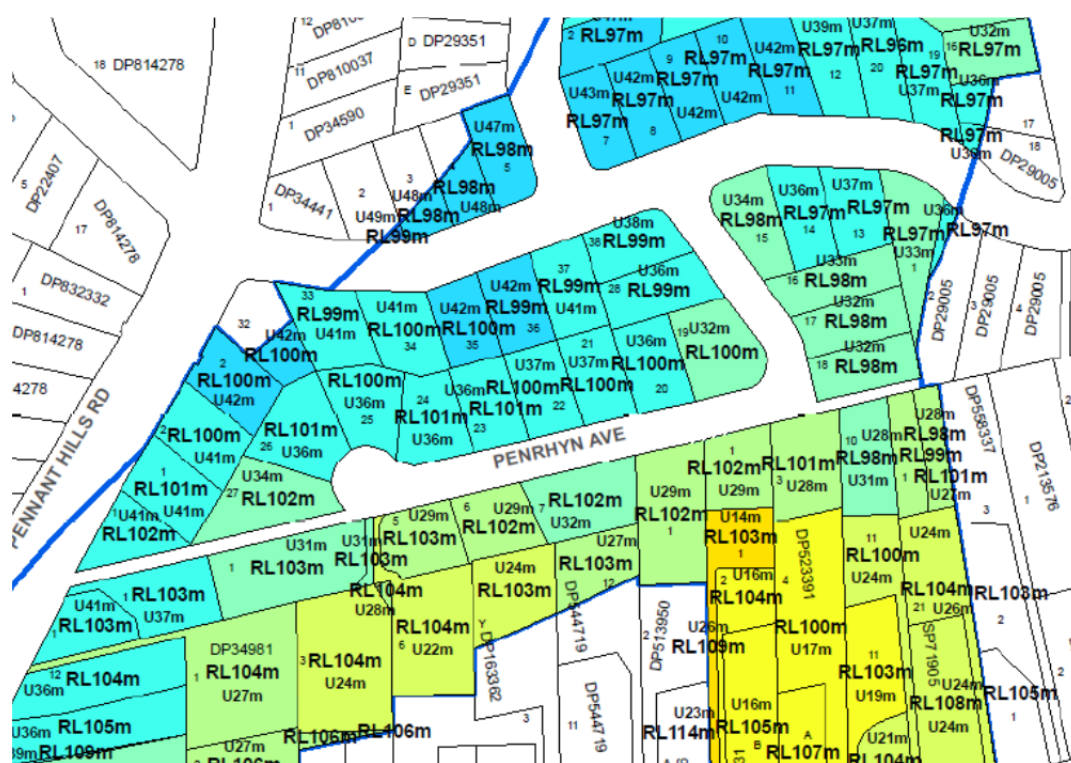


Figure 6: Map of affected lots showing depth to the upper surface of the tunnel stratum and its RL.

### 3.3 Plan Preparation

The preparation of the subsurface stratum acquisition plans began with calculations to locate the existing boundary. Most of the boundary calculations were straightforward at this stage. The calculations were put together based on logical relationships between the lots, e.g. lots using the same base Deposited Plan or plans that can be rotated onto a more encompassing parent plan. Some of the Deposited Plans prepared were more complex or contravened the

strategy for compiled boundaries and, as such, were treated as special cases. These cases will be discussed in further detail in section 4. Once the boundaries had been calculated, they were sent to the cadastral draftsman with the other relevant search information.

The distinctive features of the acquisition plans are listed as follows:

- Three plan views: ground level view, upper stratum level view, and a lower stratum level view.
- Cross section diagrams spanning as many lots across the plan as possible.
- Stratum statements for every lot, describing their relative position above/below other lots, and their absolute position above/below stratum RLs.
- Partial acquisition boundaries below the surface – shown as a dashed line on the ground level plan view, but a thick solid line in the stratum views.
- Acquisition lot and Certificate of Title schedule (RMS standard for all acquisition plans).
- Motorway access restrictions along only the exterior of the NorthConnex stratum corridor (some plans show boundaries exterior and interior to the tunnel corridor).
- Any existing stratum boundaries (e.g. North West Rail Link).

Once the initial draft is completed, it is checked by the Senior Cadastral Information Officer. It is then checked by a Senior Surveyor for signature, and then forwarded to the Principal Surveyor for final approval as a plan for acquisition. The plan is then lodged by the Senior Cadastral Information Officer by electronic plan lodgement (known as ‘ePlan’ by LPI). This triggers the release of Proposed Acquisition Notices to the property owners, upon receipt of the Deposited Plan number.

## **4 CHALLENGING CASES**

This Section highlights some of the interesting components of the NorthConnex acquisition project.

### **4.1 Grace Avenue and the North West Rail Link**

Deposited Plan: DP1208231

This Deposited Plan was one of the most complicated compiled acquisition plans created by RMS. The plan contains a total of 98 lots with a combination of total (horizontal) subsurface stratum and partial subsurface stratum acquisition. In addition, the North West Rail Link (NWRL) subsurface stratum corridor crosses the NorthConnex subsurface stratum corridor at a higher elevation. A conscious decision was made to abut the upper stratum surface of NorthConnex to the bottom of the NWRL stratum, in order to avoid any hiatus between the two corridors (which, given time, would be lost forever).

### **4.2 Pennant Hills Golf Course Survey**

Deposited Plan: DP1207275

The Pennant Hills Golf Course acquisition was completed using a plan of survey by RMS surveyor, David Burke. In this case, 6.4 ha of NorthConnex stratum were contained within 39 ha of the single golf course lot. Due to the size of the acquisition lot, the acquisition had to be accomplished by traditional means. Furthermore, this lot is adjacent to the M2 interchange,

and therefore the tunnel structure in this area consists of two separate declining carriageways of differing elevations.

The final subsurface stratum containing these carriageways is comprised of hinge joints connected by inclined planes, elevation benches between the two carriageways (as seen in the cross sections), and horizontal curves to accommodate for the tunnel/ramp geometry. The boundary definition involved the survey of the entire golf course block, fixation of Pennant Hills Road, as well as the location of survey marks inside the golf course proper. The plan also created a separate stratum limited easement for rock anchors over the golf course near Pennant Hills Road.

#### **4.3 Kingsley Close Community Scheme**

Deposited Plan: DP1208012 and DP1209861

The stratum acquisition for the Kingsley Close Community Scheme consists of two plans. The acquisition was separated into two plans because in the first instance subsurface stratum was for the majority of the lots, and in the second instance NorthConnex required the surface acquisition of the Neighbourhood Property (which is the Kingsley Close road and park area).

The first case was a compiled plan that neatly acquired the tunnel stratum underneath the lots in the Community Scheme whilst avoiding the Neighbourhood Property lot. This allowed for Proposed Acquisition Notices to be issued to the private owners within the timeframe demanded by the project. It also prioritised the acquisition, buying time for the second plan.

The second case was a traditional plan of survey by RMS surveyor, Michael Waud. The survey affected only the Neighbourhood Property lot, being the road Kingsley Close. On one end of Kingsley Close the lot was to be acquired purely in subsurface stratum. On the other end of the road, closest to the M1/F3 interchange, was full surface acquisition of the Neighbourhood Property lot. Once the Certificate of Title is created for the acquired surface lot, this triggers an action to add additional sheets to the Community Plan showing the changes.

### **5 CONCLUDING REMARKS**

The request for the NorthConnex subsurface stratum acquisition was demanding on the RMS Cadastral Survey Unit. It required the acquisition of land for 9 km of tunnel, in a timeframe that would be considered impossible in the past. Acquisition for shorter tunnels such as the Cross City Tunnel and Lane Cove Tunnel took years to complete (and was finalised post-construction).

Five of the six stages of NorthConnex acquisition have now been completed (at the lodgement stage). At the time of writing, this equates to 96 Deposited Plans lodged in 12 months. During this time, RMS had initially exceeded its \$100,000 lodgement fee cap with LPI. Lodgement fees at the time of writing currently stand at \$460,000. The final stage of acquisition will be completed two months ahead of schedule, with the final plan to be lodged before Christmas 2015 (but is due February 2016).

The continuing success of the NorthConnex subsurface acquisition contributes to the delivery of an important link to the Sydney Orbital Network strategy – by providing the cadastral envelope that encompasses the construction, tunnel structure and supporting structures. The most significant effect of this project comes from the agreement to the Subsurface Stratum Definition Strategy, between RMS and LPI. The intention of the strategy was not only to develop a flexible solution for the compulsory acquisition for NorthConnex, but to provide the blueprint for future subsurface stratum projects. The strategy will be reviewed on a project-by-project basis, which will provide opportunities for improvement. As RMS and LPI work with the strategy, it can evolve into a set of conditions that provides for rapid, efficient, and responsible subsurface stratum acquisition.

From a boundary surveying perspective, stratum boundary definition will be increasingly important. As our cities continue to develop vertically, there is a need to look for alternative engineering and planning solutions to build infrastructure in challenging environments. The NorthConnex subsurface stratum showcases a number of different subsurface stratum situations. The RMS Cadastral Survey Unit has been contacted to apply this expertise to a number of new purposes, such as the enclosure of bridge structures, advertising signage and the disposal of land with high vertical development potential (e.g. RMS-owned land within Sydney CBD).

Due to the success of NorthConnex, the RMS Cadastral Survey Unit has been engaged by the WestConnex Delivery Authority to assist with the subsurface acquisition for the WestConnex motorway. The principles and lessons from NorthConnex will be carried into future projects. This has been recognised by project managers from other departments and alliances. Surveyors in RMS are working hard to develop efficient and flexible solutions using the resources available. An acquisition strategy combined with the assistance of cadastral surveyors industry-wide will help meet the infrastructure demands of NSW. Projects like NorthConnex and WestConnex bring to light the necessity of surveyors to any infrastructure project, particularly cadastral surveying and the role they play in the acquisition process.

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