



Precise positioning services in the surveying and land management sector

An estimate of the economic and social benefits of augmented positioning services in the surveying and land management sector



Prepared for the Department of Industry, Innovation, Climate Change, Research and Tertiary Education

June 2013

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Executive summary

The surveying and land management industry is a broad based, multi-disciplinary industry that is technologically advanced in its use of geospatial information systems. It operates in a wide range of sectors including, land development, mining engineering, property development and agriculture. Its activities also extend to hydrographic and geophysical surveys for the petroleum and mining sectors.

The position requirements of surveying are one of the most demanding of all of the land related activities. The cadastre, which is the spatial, textural and temporal record of property in Australia, requires centimetre accuracy. Similar levels of accuracy requirements arise for surveying and setting out of infrastructure and in land development.

Some surveying requirements are less demanding. Identification of points of interest or general location of property services and as built infrastructure may accept accuracies at the decimetre level. High levels of reliability and integrity are not as important for land surveying as in navigation applications. However high levels of reliability are required for offshore geophysical surveys where position is required in real time.

The surveying sector has been an early adopter of augmented GNSS. Surveyors use augmented GNSS in combination with other geospatial technologies to support accurate location of points in setting out engineering and other infrastructure. This saves significantly on labour costs reducing the number of surveyors and technical staff required on site.

In addition, position data that is embedded in digital mapping data supports the construction phase of projects and also supports maintenance and management of the infrastructure once built.

Important applications of augmented GNSS include regional surveys where the availability of control benchmarks is limited, engineering surveys, accurate sea level monitoring, infrastructure condition surveys and sub-divisions. Augmented GNSS is also actively used by the offshore sector in geophysical surveys.

Productivity improvements are significant in surveying and land management, ranging from about 20 per cent to 40 per cent in 2012 with a further 20 per cent likely by 2020.

Levels of adoption of augmented GNSS in the surveying sector are estimated to have been around 20 per cent in 2012. Future levels of adoption will depend on the availability of augmentation services across the country. They could be as high as 70 per cent or more by 2020 with further expansion of CORS networks for example.

The report estimates that in 2012, augmented GNSS had delivered cost savings to the surveying and land management sector of between \$30 million and \$45 million.

These savings are projected to increase to between \$100 million to \$150 million by 2020. These estimates are based on conservative assumptions on the rate of development of CORS networks.

Key findings

- Surveyors' use of augmented positioning tends towards the precise end of the spectrum, with precision at the centimetre level normally required. Whilst some surveying applications require lower precision, for example in the order of a decimetre, generally this precision requires specialist tools and techniques.
- The use of augmented GNSS is extensive in the surveying industry. Augmentation signals are provided through stand-alone RTK systems, CORS networks and space based augmentation services.
- Precise GNSS is already being applied in engineering and construction surveying and is finding further applications in regional surveys, infrastructure surveys, sea level monitoring, and sub-division and land development activities.
- The use of precise GNSS with innovations in geospatial technologies is delivering significant productivity gains for surveying of infrastructure. Tasks that traditionally took weeks can now be completed in days. These productivity gains also deliver economic benefits to a number of other sectors including the construction, mining and utilities sectors.
- Future levels of adoption will depend on the extension of augmentation services across the country. This could include both further developments of CORS networks as well as space based positioning services.
- Development of GNSS compatible positioning services for areas where GNSS cannot effectively penetrate such as indoors and underground could also contribute to expansion of the use of augmented GNSS by the surveying sector.

1 Introduction

ACIL Allen Consulting, in partnership with SKM and Lester Franks Surveyors and Planners, has been commissioned by the Department of Industry, Innovation, Climate Change, Science, Research and Tertiary Education to assess the value of augmented positioning services in Australia.

The purpose of this report is to provide an understanding of the economic and social benefits of precise positioning information within the surveying and land management sector. This information is to allow better informed decision-making and assist in identifying areas for growth and investment from both the private sector and government. It will also provide context to the National Positioning Infrastructure Plan being developed by Geoscience Australia.

2 The surveying and land management sector

2.1 Background

The surveying and land management industry is a broad based, multi-disciplinary industry that is technologically advanced in its use of geospatial information systems. It operates in a wide range of sectors including, land development, mining engineering, property development and agriculture. Its activities also extend to hydrographic and geophysical surveys for the petroleum and mining sectors.

Surveying is the determination of the position of the boundaries of public or private land, including national and international boundaries and the registration of those lands with the appropriate authorities. The creation of titles relies on the output of surveyors in the subdivision process throughout Australia.

The provision of three dimensional spatial data services by surveyors is drawn on by developers, architects and engineers and forms the base data for conceptual and detail design for major infrastructure projects. Surveying also involves the construction phase and plays a role in the creation and formatting of spatially accurate and reliable 'as constructed' and asset management records.

Land management encompasses a broad range of activities including measurement, recording and laying out of land development. The advent of precise surveying technology has not removed the requirement for the application of land law and administration, however the manner in which ownership is depicted and recorded has the potential to change significantly with the emergence of geospatial data bases and precise positioning using techniques that include augmented GNSS.

Geophysical surveys are the foundation on which exploration programs for petroleum and minerals are planned and executed. Exploration is a high risk activity and information from such surveys is fundamental to the ongoing effectiveness of exploration programmes.

2.2 Surveying and land management sector's positioning requirements

The position requirements of surveying are one of the most demanding of all of the land related activities. For example the cadastre, which is the spatial, textural and temporal record of property in Australia, requires centimetre accuracy.

Topographic mapping and all surveying data relies on survey control marks that form the basis of Australia's geodetic framework. This framework provides the underlying control of position and elevation on which all surveying reference points are based. Fundamental geodetic data is required at the millimetre level and is determined from astronomical data, laser ranging stations and GNSS systems.

GNSS is widely used in the surveying sector. From a gradual take up during the 1990s, mainly amongst larger firms undertaking project control network surveys, most surveying firms now have GNSS capability. Further improvements in positioning technology can be expected to be rapidly adopted by the surveying industry.

Most surveying applications require higher precision than can be provided by stand-alone GNSS. Although surveyors are integral to the setup and maintenance of augmented GNSS in construction, mining and agriculture, there are some areas where surveyors require the integrated use of augmented GNSS with other geospatial tools to provide accurate reference frames for these activities.

The cadastre has been developed since Federation and accordingly it contains inherent inaccuracies of spatial definition in some areas. All Australian jurisdictions have regulated accuracy for cadastral surveys of between one to two centimetres. That accuracy can only be achieved with application of precision GNSS techniques. Typically these augmentations are provided through RTK¹, differential GPS or CORS² networks. Such approaches are not suitable in some circumstances, for example when structures or vegetation interfere with the augmentation signal.

¹ RTK means real time kinematics. RTK corrections can be delivered immediately to the receiver or are applied for post for applications such as surveying and mapping where immediate corrections are not required.

² CORS refers to Continuously Operating Reference Stations

Surveyors both “identify” and “mark” property boundaries. For identification surveys, sometimes lower precision is appropriate such that single frequency or “asset grade” GNSS receivers can be employed. In this case DGPS³ is used but the precision obtained, either via “real time” augmentation, or “post processed” is in the order of one metre in the horizontal plane⁴.

As improvements to precise positioning emerge, it is likely that GNSS solutions will be increasingly used in cadastral surveying

3 Applications of augmented GNSS

Applications of augmented GNSS vary across the surveying and land management sector. Six case studies were used to illustrate different applications of augmented GNSS in the surveying and land management context. The case studies are referred to in the following sections while full details are provided at Appendix A.

3.1 Reference controls

Surveying depends on accurately positioned benchmarks for reference controls. The availability of control marks varies from jurisdiction to jurisdiction and from region to region. In some regions the availability of control benchmarks is limited and this can create problems for mapping and surveying.

Augmented GNSS can help overcome these problems by providing high level positioning accuracy over a wide area on which reference points can be based. This is illustrated in the first case study discussed at section A.1 of Appendix A.

In this example a CORS GNSS was used to overcome the lack of survey control marks for a photogrammetric survey on the Fleurieu Peninsula in South Australia. The survey was required to determine features from aerial photography such as road centre lines, kerb corners and fence posts over a wide area of the peninsula.

The necessary coverage was achieved using a GNSS system linked into a commercial CORS network. The augmented GNSS signals were used to provide greater flexibility in placing control in difficult locations where ground control did not exist.

³ Differential GPS – a form of augmented GNSS

⁴ Real time augmentation relates to the situation when correction signals are broadcast via radio frequencies, such as for RTK GPS, or via Omnistar⁴ corrections, or via CORS signals broadcast over a mobile phone network. Post processed means that data collected in the field is not corrected until returning to the office, where an internet connection is used to access base station data for software based “correction” of the raw data.

This application delivered significantly lower costs than would have arisen if conventional terrestrial survey techniques had been employed. It is difficult to envisage how this outcome would have been cost effective with conventional terrestrial surveying techniques. The wide coverage of the CORS network in the area enabled the necessary control points in a more economic and timely way.

It has been estimated that these techniques reduce the time required in the field for survey teams by around 75 per cent (Lorimer, 2007).

Such approaches would now be possible in regions of Australia where a CORS network is available. It would also be possible to do the same task with some space based commercial augmentation systems depending on the area to be surveyed and the accuracy of the service in that area.

Application of augmented GNSS services in this case delivers net savings in the cost of capturing survey market data in such areas. While the task would be theoretically feasible to do with conventional terrestrial surveys, the cost would probably make it uneconomic in most circumstances.

3.2 Engineering surveys

Engineering surveys often traverse routes in remote locations where the survey data is limited and where traditional land surveying would require time and personnel to travel the route measuring and recording route topography.

Detailed surveys of the route corridors for infrastructure such as pipelines and power lines require two centimetre accuracy and in the past this required a survey team to traverse the route. Most traditional survey teams require at least two surveying personnel which involves travel and accommodation costs as well as time to traverse the survey route. This can be both time consuming and expensive. With growing demands for infrastructure and rising costs, techniques are needed to undertake engineering surveys more efficiently and at lower costs. Augmented GNSS has been an enabling technology that reduces the number of days of professional and technical time required to undertake each project.

The use and application of augmented GNSS for the engineering surveys are illustrated in the second case study (see Attachment A). This describes a survey for a natural gas pipeline in Tasmania. In this project, real time and post processed GNSS positioning data was used to refine and prove up the route for the proposed pipeline networks that stretched from Bell Bay to Hobart in the south and Burnie in the north west. RTK GNSS was also used for set-out and completion of an as constructed survey. The as-constructed survey subsequently provided a data base for the pipeline operator to use for operations and maintenance once operational.

This approach resulted in significant improvements in the efficiency of site selection, route selection, construction and subsequent operation and maintenance of the network of gas transmission pipelines in Tasmania.

Recent developments

The pipeline was constructed in 2002-2004. Technology improvements since that time have resulted in further efficiencies in the use of augmented GNSS for engineering surveys. Detailed route surveys would now be more effectively performed with the availability of a commercial CORS network in Tasmania. Much of the primary control networks that were required in 2002 would not be needed today. The CORS network would be sufficient to cover the majority of the project footprint. RTK GNSS which requires multiple set up of base stations would no longer be required for many sections. River Crossings would still require some RTK set up and conventional survey techniques but the position corrections would be obtained from the CORS network.

If the pipeline were to be constructed today much of the route selection would be done by remote sensing. Lidar, Google and Nearmap imagery is also available for much of this work. Setout in 2012 would now be undertaken using machine control. Machine control is reliant on stable and reliable GNSS solutions that are enabled by the CORS networks. Such systems reduce the need for surveyors staking out designs by up to 90 per cent.

In the Queensland surveying market it was estimated in 2007 that productivity improvements of 30 per cent to 50 per cent were possible using the SunPOZ CORS network (Lorimer, 2007). It is clear that productivity benefits in excess of 50 per cent are possible through the use of augmented positioning with the CORS network.

In addition adoption rates are increasing. According to an SKM report prepared in 2010 into the viability of CORS in Tasmania,

“Use of precision GNSS in earth moving in construction is expected to reach a market penetration of 60% by 2020, from a current penetration level of 15%. Again, market penetration is expected to increase with GNSS equipment becoming standard in earth moving equipment” (SKM, Feasibility Study - CORS Network Tasmania 2010).

Productivity impacts

Precise positioning technology has advanced to the stage where limited survey field work is required for engineering surveys where suitable augmentation signals are available. The expansion of the CORS networks and the use of laser guided trenching machines would now result in lower costs for completion of as constructed surveys. In this case, third party surveyor verification would not be required.

Looking forward five years, strengthening of CORS networks (together with associated mobile signal coverage) will continue to remove the reliance on

surveyors for ground control and site setout. Improved communications will allow automatic updates to be sent from office to site, and fewer surveyors will be able to manage more projects simultaneously. This will be an important factor in addressing the current and projected skills shortage in surveying.

It is tempting to predict that, if the improvement in precise CORS networks continues for the next five years, as it has done for the last five, that take up for machine control will be virtually universal for projects of any significant size where CORS augmentation is available.

Productivity improvements of between 20 per cent and 40 per cent in staff and fuel costs are possible with a further 20 per cent improvement by 2020. The latter improvement would depend on the extension of augmentation services more widely in Australia. This could be either a CORS network or a space based system depending on the accuracy in regional areas.

3.3 Monitoring sea level rise

Sea level rise is a potential consequence of global warming. It threatens coastal communities and has been a focus of concern at all levels of government in Australia in recent years.

Records of tide levels are of considerable national and international importance for future research into sea level rise. Measurement of sea level rise requires stable reference points with accurate elevation data to provide reliable time series on which estimates of sea level rise can be made. Land movement at tide gauge stations must be measured accurately if useful movements in sea levels are to be obtained. An accurate time series of land movement is required for adjustments to be made to tide gauge observations.

Accuracies of less than 1 mm are required for this purpose. GNSS augmented by signals from a CORS network are ideal to provide accurate and continuous measurement of land movement at tide gauge stations. Recent studies have shown that CORS GNSS is able to provide vertical land motion monitoring with an accuracy of better than 1 mm per year (Janssen, 2013).

Tide gauge records have been augmented with GNSS CORS technology in New South Wales. Compared to traditional monitoring methods based on terrestrial surveying techniques, the use of CORS GNSS technology is reported to offer significant improvements in the measurement of land movements at tide gauges. This is described in the case study at section A.3 in Appendix A.

GNSS CORS offers continuous monitoring within a global reference frame. Precision and accuracy with a CORS GNSS is improving with time and can be homogenous across all sites. Finally labour costs are lower as the CORS GNSS reporting is automated whereas periodic terrestrial surveying requires at least two surveying staff per survey. In addition traditional terrestrial monitoring is periodic whereas the CORS GNSS provides continuous reporting.

It is difficult to estimate the savings from utilising the CORS network in such applications. Periodic measurement with terrestrial methods would not produce a continuous record so to some extent the use of CORS GNSS for this purpose has no feasible alternative approach.

Net savings would be the difference between the periodic costs of terrestrial surveys and the marginal cost of locating CORS stations close to tide gauges. While these savings are important the benefits of better data are significant in terms of informing research into and understanding of potential sea level rises on the east coast of Australia.

3.4 Infrastructure surveys

Surveying of existing linear infrastructure often requires surveys to be undertaken over long distances and in relatively remote areas. Surveying of road conditions for example is critical for assessment of maintenance needs and planning of maintenance activities but can involve long survey distances and low level survey data. Traditional terrestrial survey techniques can be time consuming and costly in such circumstances.

Augmented GNSS when linked to other geospatial technologies can significantly lower the time required and costs of infrastructure surveys and produce more useful results in some cases. This is illustrated in the case study of the Tarkine Road evaluation project discussed in section A.4 of Appendix A.

Road management authorities frequently require an evaluation of the condition of roads for assessment of maintenance needs or for consideration of upgrades to address changing user demands. The Tarkine Road in Tasmania is an example. This road required upgrading and sealing in order to form part of a tourist loop road. As part of the evaluation the road designers needed data to analyse areas that would require realignment and sight distance assessment.

A conventional survey would have been prohibitively expensive, so an innovative “Structure from Motion” technique was used. A camera was attached to a vehicle which drove the route. The resulting imagery was correlated with mapping grade GNSS to calibrate a digital model of the road from the imagery. However, the mapping grade GNSS was found to create positioning errors that propagated through the length of the road and required considerable reworking by the designers to correct these errors.

Augmented GNSS would have overcome these problems. If a CORS network had been available at the time of the survey, RTK solutions could have been employed that would have increased the accuracy and eliminate the propagation errors. Greater availability of CORS networks would facilitate greater innovation in data collection techniques. Some existing techniques are expected to be replaced by a combination of image capture and accurate

positioning resulting in significant productivity improvements in road surveying and design.

Productivity improvements estimated from such techniques are estimated to be 25 per cent less time in the field and 50 per cent less office time required. In addition accuracy of the data collected is expected to be up to 80 per cent higher with a CORS network. These improvements are considered to be representative for applications in all jurisdictions where equivalent networks are available.

3.5 Land Management and subdivisions

A significant part of the work of the surveying industry is in laying out subdivisions for new housing developments as well as rural and industrial area subdivisions. Traditionally, such surveys were carried out with electronic theodolites, or total stations, and required a minimum two person field party. This is because line of sight surveying requires stations to be occupied and traverses to be constructed linking up the various sections of the survey. Line of sight surveying is necessarily constrained by topography and vegetation. The more undulating the terrain and the denser the vegetation, the slower the progress of the survey, and consequently the greater the cost involved.

GNSS surveying is to a large degree unconstrained by these limitations. Vegetation is only an issue when the canopy is sufficiently dense to interfere with satellite signals. Topography is only an issue when intervening hills disrupt repeating radio signals. Additionally, most of the survey could be completed by a one person field party.

Traditional traversing can achieve between 800 metres and 2000 metres per day depending on the constraints earlier described. The case study of a rural subdivision examined in section A.6 at Appendix A demonstrates the savings that can be achieved with GNSS surveys.

For this project, it is estimated that an average of 1500 metres per day would have been required for a traditional terrestrial survey for a rural subdivision. With the aid of RTK GPS, this project achieved 4,544 metres per day. The time required for the survey was reduced from an estimated 15 days for a traditional technique to 4 days with RTK GNSS. This is equivalent to a productivity improvement of around 70 per cent.

With the extension of CORS networks such productivity improvements would be possible more widely in Australia.

3.6 Geophysical surveying

The oil and gas sector relies on geophysical surveys in the early stages of exploration. The types of exploration activities that are predominantly supported by augmented GNSS are offshore seismic and bathymetric surveys

which both contribute to the overall geophysical assessment of potential and existing hydrocarbon deposits⁵.

Precise position is typically required at the decimetre level utilising Differential GPS (DGPS) corrections delivered by satellite communications as opposed to the centimetre level positioning associated with RTK. Such corrections are typically supplied via private operators via satellite communications to resolve positional ambiguity.

Whilst DGPS is the primary service utilised for exploration activities, there is a small reliance on RTK systems for important shore crossing / transition zones for pipeline connectivity. The reliance of independently operated RTK base stations for such activities is particularly important given the increased requirement for accuracies for construction and management of pipelines.

Woodside Petroleum has estimated that around 10 per cent of exploration expenditure can be lost due to downtime which is in part attributable to poor navigation data and inefficiencies in steering survey vessels. Woodside invests around \$100 million per year in such activities implying an annual saving of around \$10 million a year. Augmented GNSS signals contribute to these savings (see Section A.7 of Appendix A).

3.7 Emerging developments

3.7.1 Extension of augmented GNSS coverage

Expansion of CORS networks along with further development in the accuracy of space based augmentation services will contribute to further adoption of the techniques described in this report and hence the productivity gains that are potentially achievable.

Another potential development is the emergence of non-satellite dependent augmented GNSS systems to fill in gaps where GNSS cannot penetrate reliably. Such areas are where buildings or canopy cover interferes with the satellite signal and indoors, in tunnels and in underground mines.

Developments such as the Locata localised GNSS compatible positioning technology could extend the coverage of precise positioning⁶.

Future levels of adoption of augmented GNSS will be driven by the availability and cost of augmentation signals across Australia.

⁵ Sources: Woodside

⁶ The Locata system is an Australian developed localised GNSS system that uses local transmitters to create an augmented GNSS signal. It is not dependent on satellites and can be used in urban areas and underground where satellite signals are either unreliable or not available.

3.7.2 Augmented reality

Augmented reality is an emerging innovation where accurate positioning combined with digital mapping and simulation technologies is revolutionising planning and design of infrastructure.

Augmented reality (AR) combines real and virtual information in real time or near real time in a 3 dimensional environment. In the world of surveying, AR is an emerging technology that is linked to other professional areas such as town planning, mine planning, asset management, emergency management and urban renewal.

With the advent of GNSS enabled mobile devices such as Smart Phones and Tablets, AR is on the cusp of becoming a standard tool for surveying and planning professionals. AR has uses both indoor and outdoor, so whilst augmented GNSS signals such as Locata have limited use for conventional surveying, they will be critical to the take up of AR systems indoors.

For real time use, AR relies on positioning techniques, principally at present from GNSS enabled devices. Since autonomous GNSS positions in hand held devices are generally of lower precision than those from devices capable of receiving corrected signals, the uses, at present, of AR are limited to imprecise, or indicative, applications only.

If, however, autonomous positioning improves, the usefulness of AR for precise applications will correspondingly increase. For example, if a developer wishes to show a local authority the likely impact of a proposed development, the proposed building can be loaded into a tablet device, and used at the site to view the building from any location, to a precision consistent with GPS accuracy on the tablet. This is suitably accurate for this application.

However, if a local authority asset manager wishes to locate buried assets with AR enabled glasses, then the GNSS positioning in the glasses needs to be of higher precision than currently available. Decimetre precision is required for the accurate location of buried services.

Therefore, for major design projects the use of augmented GNSS is likely to significantly improve the useability of AR systems. The surveying industry is yet to adopt AR as a working tool. However, the industry links with the construction and development sector where uptake is considered to be more likely and widespread. As in the machine control examples, the role of the surveyor will be in data management, quality assurance and reporting.

AR has the capacity to replace paper plans, and when linked to a single server, can provide real time updates on works in progress by combining data received from, for example, laser scanners attached to the front of construction machinery. These techniques are already in use in the gaming sector.

Augmented reality has the potential to significantly improve the efficiency and effectiveness of the surveying and design process for land management and

infrastructure development. A summary of the rates of adoption is provided in Appendix A.

4 Adoption rates and productivity

4.1 Estimates of rates of adoption

In order to estimate the economic benefits that have been delivered by augmented GNSS systems in Australia we used case studies of applications in the surveying and land management sectors to provide a verifiable estimate of productivity impacts. The findings of these case studies, combined with estimates of levels of adoption across the industry were used to estimate sector wide productivity and cost savings. The assumed levels of adoption were based on wider industry consultations and the knowledge held by the consulting team.

The rate of adoption of augmented GNSS is likely to depend on a number of factors including:

- the rate of roll out of the CORS network
- integration of augmented positioning with other technological innovations such as structure from motion techniques and development of augmented reality technologies.

In a study prepared in 2008, Allen Consulting estimated that the adoption of precise GNSS by the surveying sector was around 8 per cent in 2008⁷. Since that time the CORS network has been expanded in Victoria, New South Wales, Queensland, South Australia and Tasmania. Our interviews with the industry suggest that since that time the adoption level had increased to around 20 per cent by 2012. Future adoption will depend on the further extension of CORS networks and other augmentation systems.

We have assumed a continued roll out of CORS and rapid development of complementary technologies for the high scenario and a slower roll out of CORS and technological development for the low scenario. Our assessment is that adoption could reach 90 per cent by 2020 with a full roll out of the CORS network in Australia and 70 per cent with a more restricted roll out. This concurs with an assessment made by SKM's 2010 study (SKM, 2010).

4.2 Productivity

Productivity improvements are significant in surveying and land management ranging from 20 per cent and 40 per cent in 2012 with a further 20 per cent by 2020.

⁷ Allen Consulting Group, The Economic Benefits of Precise Positioning, November 2008

In addition, augmented reality has significant potential to improve the quality of planning and design of land and infrastructure developments through its potential as a 3 dimensional imagery that supports community consultation on design and planning, consultation between surveyor, engineer and architect and design decision making. This has not been included in the productivity assessments.

5 Economic impacts

In order to estimate the economic impacts of precise positioning we made allowance for the fact that without precise positioning the surveying industry had alternative but less efficient options including emerging laser and related technologies to undertake their tasks.

These estimates of costs savings were combined with estimates of rates of adoption in 2012 and 2020 to provide industry wide estimates of cost savings from the productivity improvements available from precise positioning.

5.1 Estimates of cost savings to the surveying and land management sector

Surveying is classified as under Professional, Scientific and Technical services in the Australian and New Zealand Standard Industry Classifications. There is no breakdown of the size of the surveying sector in industry statistics available from the Australian Bureau of Statistics. Based on earlier work we estimated that the surveying sector comprised around 1.3 per cent of this classification.

We assumed adoption rates of between 20 per cent and 30 per cent in 2012 and 40 per cent and 60 per cent by 2020. Savings from precise positioning use in survey work was assumed to be 30 per cent in 2012 and 50 per cent by 2020. Finally we assumed that the construction related surveys that we were addressing, represented about 50 per cent of the total market for surveying services. The estimates are summarised in Table 1.

Table 1 **Productivity improvements for surveying in the construction market**

	Assumptions			Low case	High case
		Productivity impact	Value \$million	Productivity impact	Value \$ million
2012	Cost savings of 30%. Adoption 20%-30%	3%	30	4.5%	45
2020	Cost savings of 50% Adoption 340%-60%	10%	100	15%	150

Note: Productivity ratios expressed as a percentage of cost savings.

Data source: ACIL Allen and Lester Franks research

The table shows that savings in labour costs of between \$30 million and \$45 million could have been realised by 2012 as a result of the use of precise GNSS for construction and mining surveys. With increased adoption and further

development in technology, these savings could increase to between \$100 million and \$150 million by 2020.

The increased savings accruing in 2020 also assume that the availability of augmentation services is increased particularly the RTK and CORS networks which provide the levels of accuracy needed for most surveying tasks.

It should also be noted that significant economic benefits accrue to the construction, mining, transport and agriculture sectors from the use and application of augmented GNSS by the surveying sector. These aspects are discussed in the accompanying reports and in an overview report.

Appendix A Case studies

A.1 Photogrammetry survey control

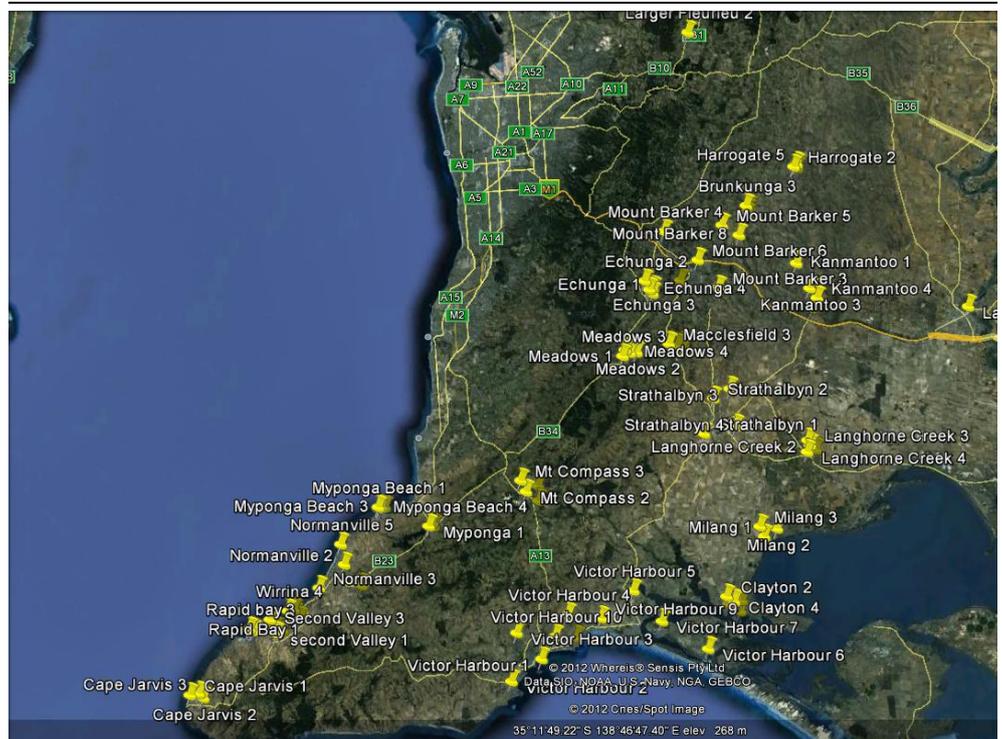
Sawley Lock Surveying, a survey firm based in Adelaide was engaged to provide photogrammetric control at locations on the Fleurieu Peninsula in South Australia. The locations generally centred on populated townships, most of which had 3rd order Tertiary Network survey marks to provide our MGA94 / AHD ground control.

The points required by the client, involved coordinating points that they could determine from aerial photography, features such as white lines on roads, kerb corners, fence posts and related infrastructure. The difficulty that presented to the surveyor was that not all areas had sufficient survey marks with 3rd order vertical control. The coverage across the wide survey area was variable with gaps in some areas of interest to the client.

To assist in covering the project more efficiently and with greater consistency an augmented GPS system from Position Partners was used that linked to the AllDayRTK broadcast CORS ground control network. This gave the surveyors greater mobility to place the required control in the difficult locations where little 3rd order control existed.

The coverage is shown in Figure 1.

Figure 1 Coverage of ground control using CORS network



Data source: Sawley Lock Surveyors

The use of the CORS network provided coverage that could only have been achieved with far more time consuming and expensive methods. It is difficult to envisage how this outcome could have been realistically achieved without the use of an augmented GNSS system.

A.2 Use of GNSS in engineering surveys

The Tasmanian Natural Gas Project involved the construction of a pipeline across Bass Strait from Victoria, to supply natural gas to Tasmania. In Tasmania, the project comprised approximately 430km of underground pipe from Bell Bay, north of Launceston, to Bridgewater, near Hobart, and across to Port Latta in the far north west. Construction for the project was completed in 2002.

This case study discusses the surveying requirements for the onshore Tasmanian component of the project as it was done, how it would be done now, and what the impact of improved precise positioning may be to a project of this nature in the years ahead to 2020.

A.2.1 How was the project undertaken in 2002?

The project comprised four surveying stages.

1. Route selection.

A trial one kilometre wide corridor was supplied by the proponents and preliminary route selection was made using state topographical series maps, and by synthesising from several sources:

- aerial photography
- 1:25,000 photomaps
- contours
- cadastre
- vegetation mapping
- geology
- land ownership records.

Surveyors then refined and proved the route in the field using mapping grade GPS capable of real time and post processed results.

2. Detailed survey of selected corridor.

Once the route was confirmed, the designers required a detailed survey of the proposed pipe centreline, and a 20 metre corridor at crossing features such as creeks and roads. Their accuracy requirement was 20 mm in all dimensions.

In order to ensure compliance, primary control marks were installed at 5 kilometre intervals throughout the corridor. Measurements were observed with dual frequency GPS over a period of three weeks.

The detailed survey was then undertaken using RTK GPS, with a base station calibrated to the control points transmitting corrected positions to the roving antenna in real time.

3. Setout

Following final design, setout was undertaken with RTK GPS. Setout information supplied to the contractor enabled trenching crews to control depth and alignment in an essentially manual environment.

4. As constructed survey

The proponent required every weld and every bend of the constructed pipe to be recorded by survey. Each weld had a reference bar code that was also recorded simultaneously.

This information was recorded with RTK GPS tied to the primary control network.

Since the pipeline traversed private as well as public lands, easements were required to be recorded as encumbrances on all affected Certificates of Title. In order to limit both the field and office components of this element, special instructions were approved by the Lands Titles Office and the Office of the Surveyor General permitting the utilisation of GPS equipment and a relaxation of the marking requirements of the survey regulations.

Nevertheless, all the easement processes were related back to and hinged on the primary control network and subsequent RTK GPS techniques.

A.2.2 How would the project be undertaken today?

1. Route selection

With the advent of improved aerial and satellite imagery, and the increased use of LIDAR technology, route selection for such a project requires far less ground survey. Approximately 95% of route selection for this project could now be completed using remote sensing techniques.

Of course, there is a significant cost to acquisition of LIDAR data (for example), however, consider that now there is recent Google and Nearmap imagery available for the cost of licensing and delivery. These avenues significantly enhance project planning. Also, LIDAR acquisition is increasingly being commissioned for multiple purposes during one mission, so as we move towards 2020 it can be reasonably assumed that more and more areas of the country will be accumulating terrain information.

2. Detailed survey of route

With the recent availability of CORS networks, also now just available in Tasmania, the creation of primary control networks which were required for

this project could be avoided. The CORS coverage is presently sufficient to accommodate the entire project footprint.

Some infill control will always be required, however it is estimated that approximately 60% of the control network would no longer be required.

Therefore the detailed survey could be conducted utilising CORS solutions rather than RTK GPS, which requires the setting up of base stations and localised radio broadcast corrections.

In addition, if RTK is not required, the base station can be converted (switched over) to become another rover unit, thereby doubling productivity from a GPS kit, or halving the entry price depending on from which aspect this is examined. That is, only one rover is required with CORS, whereas a rover plus base is required for RTK.

Detailed survey at river and road crossings and for difficult terrain would be undertaken using RTK GPS, with position corrections obtained through the CORS network.

In addition, for the majority of the route, data available from LIDAR would be sufficient for design. However, designers are still in transition to their use of LIDAR data, partly due to concerns with accuracy. The planning and execution of LIDAR and aerial photography missions is heavily correlated with their usefulness for design.

For example, it is possible deliver terrain model products from aerial surveys that almost match the accuracy of ground based surveys. However the design of the flights and the associated ground control requirements are critical. A route selection series of rectified images is not the same as a fully controlled series of design images.

A further point to note is that the usefulness of CORS systems is significantly dependent upon the coverage of mobile phone signals, since this is the prime source of correction signal delivery. Therefore it is apparent that the densification and enhancement of CORS networks relies on cooperation with other agencies and technology suppliers, and commercial entities.

3. Setout

Today, setout would be undertaken using machine control. Surveyors are required onsite to set up the equipment, prepare and activate design data, and provide quality assurance and trouble shooting.

Machine control (MC) techniques depend upon stable and reliable GNSS solutions, and have developed rapidly since the advent of CORS networks. Whilst the hardware requires a significant initial outlay, MC systems reduce the need for surveyors staking our designs by up to 90%.

Similarly to the detailed survey elements of this project, productivity gains from CORS networks have a similar impact, in that a former RTK kit can be converted to two rovers for MC use.

There are limitations to the accuracy of GNSS CORS systems that still require infill solutions with traditional techniques. However those limitations would not significantly affect the execution of this pipeline project, if it was being conducted today.

According to a SKM report into the viability of CORS in Tasmania,

“Use of precision GNSS in earth moving in construction is expected to reach a market penetration of 60% by 2020, from a current penetration level of 15%. Again, market penetration is expected to increase with GNSS equipment becoming standard in earth moving equipment”

(Source, SKM, Feasibility Study - CORS Network Tasmania 2010).

4. As constructed survey

GNSS and laser guided trenching machines now record position of trenches as they are excavated. Therefore third party (surveyor) verification is mostly not required. The data can then be provided to a surveyor to produce as constructed plans.

So the increase in precise positioning available through MC systems greatly reduces the need for surveyors on site. Their role changes from construction setout to data management and quality assurance.

A.2.3 How will the availability of higher resolution positioning affect the methodology in the future?

As documented in this case study, precise positioning technology has already advanced to the stage where limited survey field work is required for such a project.

Looking forward five years, strengthening of CORS networks (together with associated mobile signal coverage) will continue to remove the reliance on surveyors for ground control and site setout.

Improved communications will allow automatic (on the fly) updates to be sent from the office to the site, and fewer surveyors will be able to manage more projects simultaneously. This will be an important factor in addressing the current and projected skills shortage in surveying.

It is tempting to predict that, if the improvement in precise CORS networks continues for the next five years, as it has done for the last five, that take up for machine control will be virtually universal for projects of any significant size.

A.2.4 Summary

The table below shows the estimated productivity improvements from improved precise positioning for several aspects of the project. The improvements are limited to the surveying components.

Table 2 **Estimates of productivity impacts #**

Item	2012	2020
Route selection	20% improvement	10% improvement
Detail Control	40% improvement	20% improvement
Detail survey	40% improvement	10% improvement
Setout	20% improvement	10% improvement
As constructed	20% improvement	10% improvement

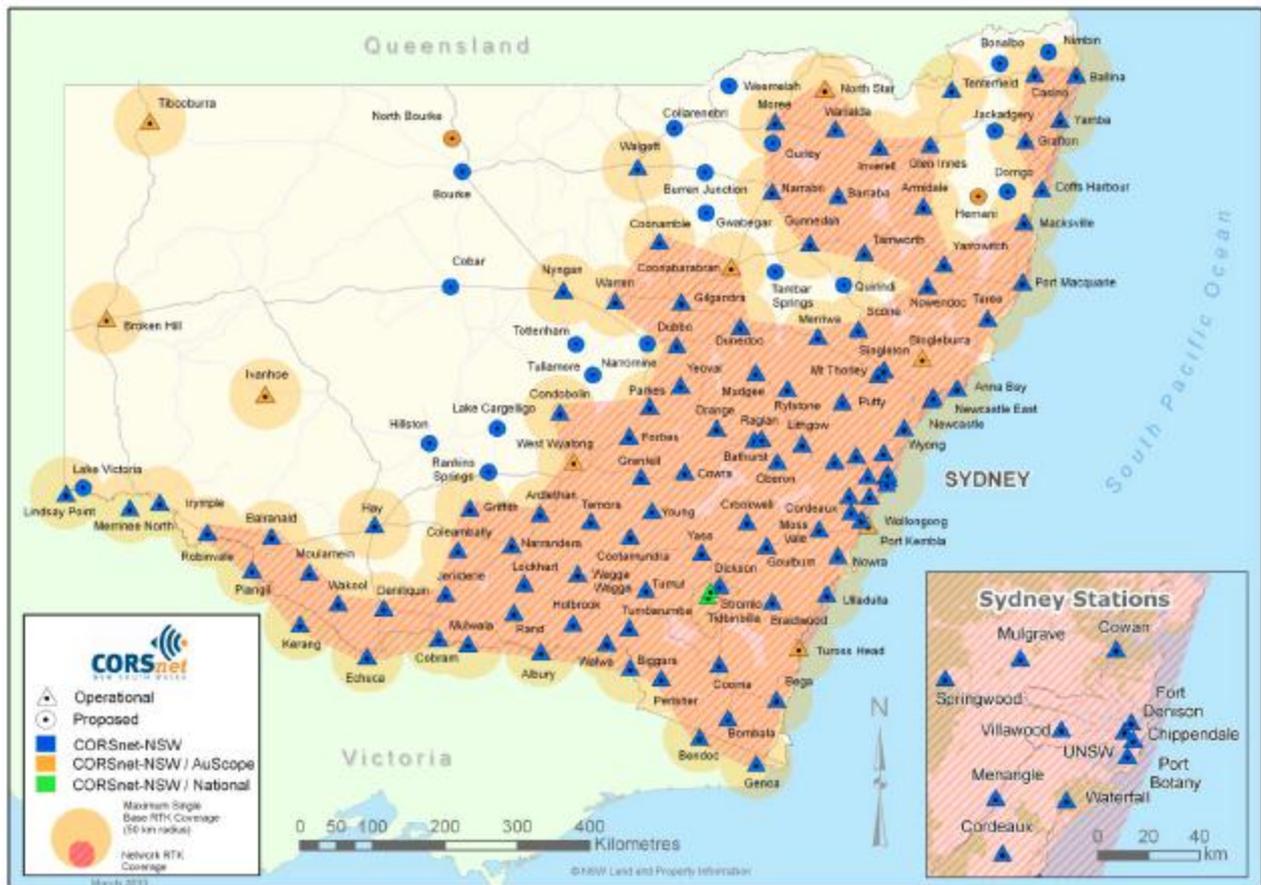
Data source: Lester Franks

A.3 Monitoring sea level rise

Land and Property Information New South Wales has been installing CORS reference stations at or near tide gauge locations at locations on the New South Wales coast to better monitor land movements at tide gauges. The locations currently installed are Newcastle Port, Fort Denison in Sydney Harbour and at Port Kembla. This is a component of the broader installation of a wider CORS network in the state. To date around 120 stations have been installed in the network (see Figure 2).

These stations are being used to provide data on land movement in the vicinity of tide gauges to allow for land movement adjustments in the records of tidal movements over time. Such information is of national and international significance in providing time series of sea levels as data relevant to research into sea level rise as a consequence of global warming.

Figure 2 NSW CORS network as at March 2013



Data source: (Janssen, 2013)

Measurement of sea level rise requires high levels of accuracy and stable reference points. Land movement at tide gauge stations must be measured accurately if useful movements in sea levels are to be recorded by tide gauges. An accurate time series of land movement is required for adjustments to be made to tide gauge observations of land movement at tide gauge locations.

Accuracies of less than 1 mm are required for this purpose. GNSS augmented by signals from a CORS network are ideal for providing accurate and continuous measurement of land movement at tide gauge stations. Recent studies have shown that CORS GNSS is able to provide vertical land motion monitoring with an accuracy of better than 1 mm per year (Janssen, 2013).

Tide gauge records have been augmented with GNSS CORS technology in New South Wales. Compared to traditional monitoring methods based on terrestrial surveying techniques the use of CORS GNSS technology is reported to offer significant improvements in the measurement of land movements at tide gauges. For example GNSS CORS monitoring offers continuous monitoring within a global reference frame. Precision and accuracy with a CORS GNSS is improving with time and homogenous across all sites. Finally labour costs are lower as the CORS GNSS reporting is automated whereas periodic terrestrial surveying requires at least two surveying staff per survey.

Furthermore monitoring is only periodic with terrestrial methods whereas the CORS GNSS provides continuous reporting.

Table 3 **Comparison of land movement monitoring using traditional terrestrial survey methods and GNSS CORS**

Issue	Terrestrial methods	GNSS CORS techniques
Monitoring	Episodic	Continuous
Reference Frame	Local	Global
Land motion	Relative	Absolute
Data	Validated in house	Shared, validated by others
Precision	Generally fixed	Improving with time/algorithms
Accuracy	Survey specific	Homogenous across all sites
Data archiving	Manual and centralised	Electronic and distributed
Labour	Intensive	Automated
Intent and outcome	Limited	Multi user infrastructure
Alarms	Not applicable	Near real time

Data source: (Janssen, 2013)

A.4 Infrastructure surveys – Structure from Motion

The purpose of this project was to evaluate a 90 kilometre section of road from Arthur's River in the north west of Tasmania through the Tarkine forest.

The road is to form part of a tourist loop road and will require upgrade and sealing from its current gravel only status.

As part of the project evaluation, the designers required data to analyse which corners and bridge approaches did not have sufficient sight distance, which would subsequently influence re-alignment and vegetation removal.

A conventional survey of this distance (90 kilometres) would potentially be prohibitively expensive, and due to the remoteness of the site, existing imagery and photography was patchy and of questionable accuracy for the required purpose.

The company was commissioned to develop an alternative methodology to collect the necessary data.

A.4.1 How was the project undertaken?

A method of 'Structure from Motion' was developed.

Structure from Motion software uses algorithms to determine traceable points in video frames. These points are then triangulated between frames to produce a model of the road in an arbitrary 'pixel space' coordinate system. The model is then fixed to real world locations via alignment with simultaneously collected GPS data.

For this project, a commercially available 'GoPro' camera was attached to a vehicle, and correlated with a mapping grade GPS receiver such that the

relationship between the two devices was known and could be incorporated into the solution.

The mapping grade (single frequency) GPS receiver was selected in this instance because it was likely to be less sensitive to obstructions such as canopy whilst still allowing analysis of collected data for precision. Static (motion free) observations were taken at selected intervals to increase accuracy.

RTK GPS, normally capable of achieving greater accuracy, could not be used as a control network did not exist, and the process of constantly moving the base station would have defeated the efficiencies hoped for.

In addition, CORS network solutions were not available due to remoteness and lack of mobile phone coverage.

After processing, it was found that positioning errors had propagated through the data due to the lower accuracy of the mapping grade GPS. Although the relative accuracy of sections of the road remained intact, the errors caused a misalignment with true absolute position that was significant.

Despite these deficiencies, the road designers were still able to use the data for analysis of sight distance, as the relative accuracy corner to corner was adequate.

So an innovative technique for a challenging project was completed in an environment where precise positioning techniques and augmentation could not presently be suitably employed.

A.4.2 How will the availability of higher resolution positioning affect the methodology in the future?

This project would have benefited from higher precision positioning technology.

If CORS was available, RTK solutions could have been employed and therefore significantly increased accuracy would be achievable. The propagation of errors from the GoPro camera could be properly accommodated by correlation to accurate positioning data.

The project team believes that the extension of high resolution positioning will facilitate increased innovation in data collection techniques. Some conventional techniques may be replaced by a combination of image capture and accurate positioning. This has correlations to mobile laser scanning however the intention of this project was to provide a very cost effective solution to a planning problem, rather than collect data sufficient for final design.

A.4.3 Summary of productivity impact

Table 4 Estimates of productivity impacts on motion surveys

Item	2020
Time Field	25%
Time office	50%
Accuracy	80%

Data source: Lester Franks

A.5 Augmented Reality

A.5.1 What is Augmented Reality?

Augmented reality (AR) can be considered as a live, direct or indirect, view of a physical, real-world environment whose elements are *augmented* by computer-generated sensory input such as sound, video, graphics or GPS data.

Augmentation is conventionally in real-time and in semantic context with environmental elements. (Wikipedia).

Essentially AR combines real and virtual information, in real time or near real time, in a 3D environment.

In the world of surveying, AR is really an emerging technology, and is the link to other professional areas such as town planning, mine planning, asset management, emergency management and urban renewal.

With the advent of GPS enabled mobile devices such as Smart Phones and Tablets, AR is on the cusp of becoming a standard tool for surveying and planning professionals. Interestingly, AR has uses both indoor and outdoor, so whilst augmented GPS signals such as Locata have limited use for conventional surveying, they will be critical to the take up of AR systems.

Uses of Augmented Reality

The uses of augmented reality include:

- viewing ore body structures in the field
- visualising concealed assets both underground and encased within building structures
- directing emergency personnel within congested or obscured sites, for example, fire fighting within buildings
- visualising proposed developments on site – showing proponents and stakeholders impacts of building placement, shading, access
- In machine use for augmenting machine control so that operators have instant updates of works completed.



Image source: TBA – seeking acknowledgement.

For real time use, AR relies on positioning techniques, principally at present from GPS enabled devices. Since autonomous GPS positions in hand held devices are generally of lower precision than those from devices capable of receiving corrected signals, the uses of AR are limited to imprecise, or indicative, applications only.

If, however, autonomous positioning improves, the usefulness of AR for precise applications will correspondingly increase. For example, if a developer wishes to show a local authority the likely impact of a proposed town house on a vacant parcel, the proposed building can be loaded into a tablet device, and used at the site to view the building from any location, to a precision consistent with GPS accuracy on the tablet. This is suitably accurate for this application.

However, if a local authority asset manager wishes to locate buried assets with AR enabled glasses, then the GPS positioning in the glasses needs to be of higher precision than currently available. Decimetre precision is required for the accurate location of buried services.

Improvements in autonomous GNSS signals are therefore more important for AR than CORS systems, and the driver is likely to be the mass market consumer rather than specialist users. CORS systems are a specialist user system whereas AR is likely to be taken up on a much wider scale by unsophisticated users.

For internal applications, AR is heading towards the integration of multiple sensors such as Locata, WiFi, scanners, magnetic field sensors, gyroscopes, accelerometers and photogrammetry. A process known as SLAM (Simultaneous Location and Mapping) uses image recognition in a known environment to constantly update a users' location. The use of SLAM is heavily dependent on computing power as image processing is computationally intensive.

Levels of adoption

The surveying industry is yet to adopt AR as a working tool. However, the industry links with the construction and development sector where uptake is considered to be more likely and widespread. As in the machine control examples, the role of the surveyor will be in data management, quality assurance and reporting.

AR has the capacity to replace paper plans, and when linked to a single server, can provide real time updates on works in progress by combining data received from, for example, laser scanners attached to the front of construction machinery. These techniques are already in use in the gaming sector (e.g. the new Xbox).

A.5.2 Summary

Table 5 **Estimates of adoption**

Item	2012	2020
Knowledge within surveying industry	10%	60%
Knowledge within allied professions	20%	80%
Take up by surveying industry	1%	20%
Take up by allied professions	5%	50%

Data source: Lester Franks

A.6 Land Management – Okehampton Case Study

In 2008 Lester Franks undertook a large rural boundary re-arrangement, or subdivision for boundary adjustment. Since the properties involved were largely clear of vegetation except in pockets, RTK GPS was employed to complete the majority of the survey.

The property "Okehampton" is situated adjacent to the town of Triabunna on the east coast of Tasmania. The combined area of the parcels to be treated was 1754 hectares. The property includes extensive frontage to the Tasman Sea.

Traditionally, such surveys were carried out with Electronic Theodolites, or Total Stations, and required a minimum two person field party. This is because line of sight surveying requires stations to be occupied and traverses to be constructed linking up the various sections of the survey. Line of sight surveying is necessarily constrained by topography and vegetation. The more undulating the terrain and the denser the vegetation, the slower the progress of the survey, and consequently the greater the cost involved.

GNSS surveying is to a large degree unconstrained by these limitations. Vegetation is only an issue when the canopy is sufficiently dense to interfere with satellite signals. Topography is only an issue when intervening hills disrupt repeating radio signals.

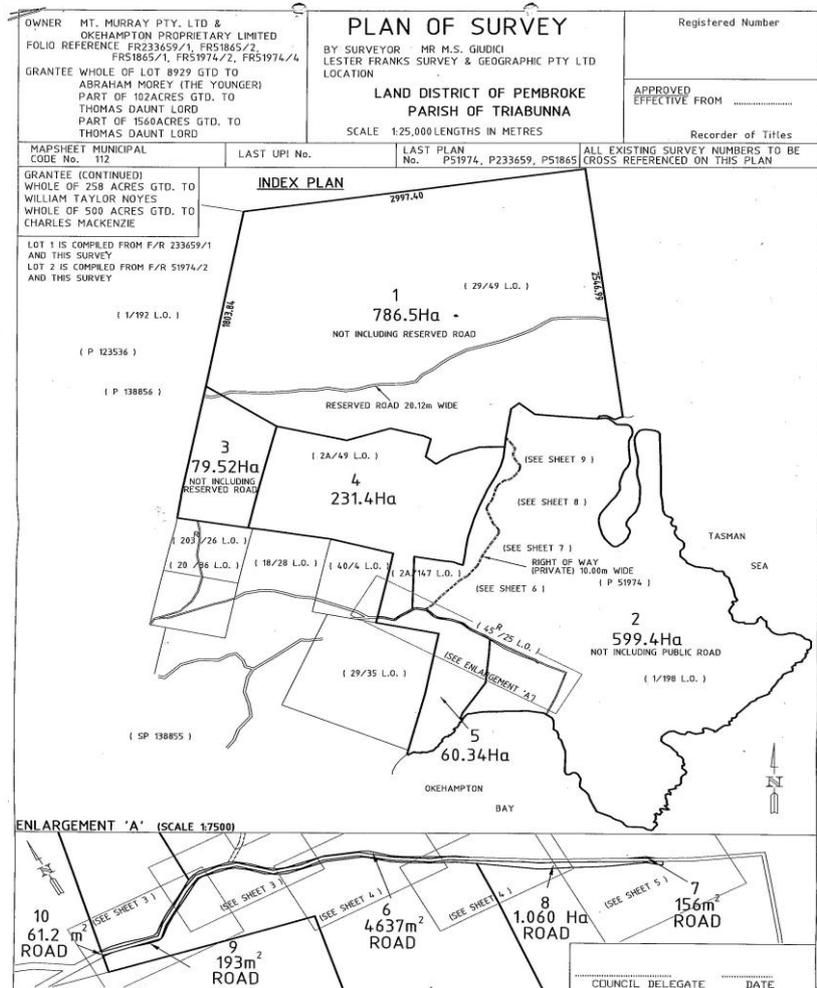
Total distances surveyed in the project were 22770 metres. This was achieved in five field days, averaging 4554 metres per day, inclusive of placing pegs.

Traditional traversing can achieve between 800 metres and 2000 metres per day depending on the constraints earlier described. For this project, it is estimated that an average of 1500 metres per day could have been achieved, due to the largely open nature of the terrain. This implies a survey time of just over 15

field days. Additionally, most of the survey could be completed by a one person field party.

Savings introduced by GNSS in this instance were therefore approximately 66%. This translates into a significant cost saving for the client.

Figure 3 Okehampton



Data source: Lester Franks (2008)

A.7 Geophysical surveys

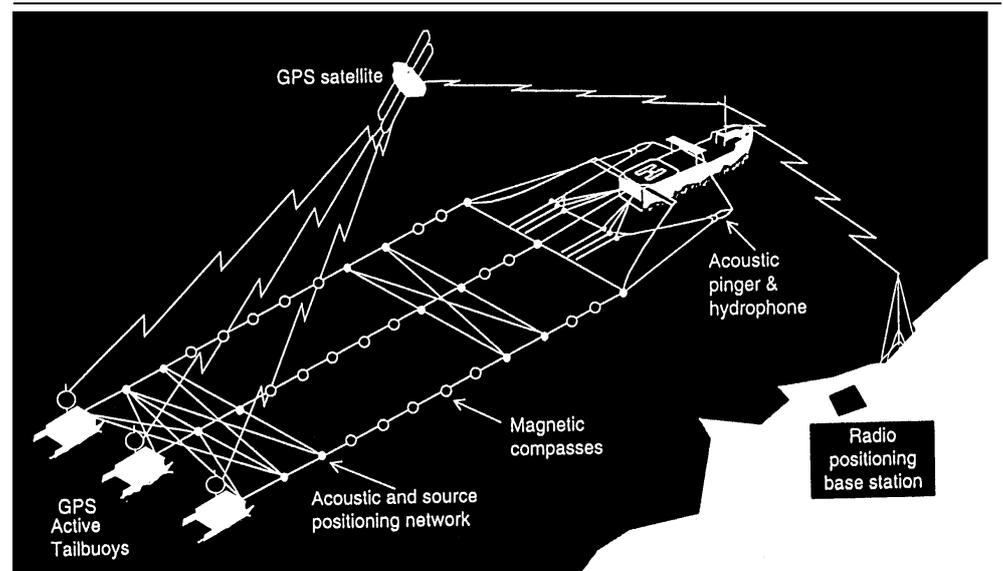
The oil and gas sector relies on geophysical surveys in the early stages of exploration requires Exploration activities that are predominantly supported by augmented GNSS are Seismic and Bathymetric surveys which both contribute to the overall geophysical assessment of potential and existing hydrocarbon deposits⁸.

⁸ Sources: Woodside

Woodside as an oil and gas company is essentially spatial in nature and completely reliant on correct spatial information for geophysical analysis of offshore exploration leases. Woodside itself typically operates at 90% involvement within commitment to offshore activities which includes both the exploration component and also the construction and maintenance of pipelines and plant connectivity to facilitate production stages.

Precise position is typically adopted at the decimetre level utilising Differential GPS (DGPS) corrections delivered by satellite communications as opposed to the cm level positioning associated with RTK. Such corrections are typically supplied via private operators via satellite communications to resolve positional integrity. Whilst DGPS is the primary service utilised under exploration activities, however there is a small reliance on RTK systems for important shore crossing / transition zones for pipeline connectivity. The reliance of independently operated RTK base stations for such activities is particularly important given the increased requirement for accuracies for construction and management of pipelines.

Figure 4 **Navigation survey setup for an offshore Survey Vessel (Seismic) utilising DGPS correction**



Data source: Woodside

Whilst Woodside itself is the project developer for Oil and Gas offshore fields, the precise position application is more often captured through the operation of service providing companies (such as CGGVeritas, Fugro or Western Geco). Such service providing companies, whom directly conduct the exploration surveys, utilise precise positioning to more efficiently operate and conduct the survey, integrate geophysical datasets spatially (allowing real-time quality control) and minimise the risk of downtime. Integrated positioning is further combined in an overall navigation network (above) which positions hydrophone streamers behind the vessel and allocates them to certain 'bins' within the survey area. The 'binned' area is an indication of completeness of

the survey and is used to evaluate the optimal survey routes and improve efficiency.

Woodside commissions approximately \$100 million worth of exploration surveys per year with costs of lost production (a typical survey vessel will be charged out in the vicinity of \$700,000 per day in production) totalling millions in lost revenue of operational cost. Therefore the integrity and reliability of the navigation and positioning surveys is paramount to the efficiency and productivity of operations and as such multiple systems are often integrated amongst an overall navigation system to ensure reliability.

A.7.1 Benefits

The benefits identified were:

- Reduced timeframes and improved efficiency for data acquisition
- Full integration of GNSS with nav/positioning systems
- Improvement in reliability and uncertainty of positional accuracy (improving efficiency of exploration process).
- Reduction in positional uncertainty for delivered data
- Reduced operational costs

A.7.2 Productivity Estimation

The measure of productivity is best quantified by the delivery of more reliable, accurate spatial data to improve the exploration process. The minimisation of downtime through exploration operations is essential in evaluating the productivity gains. Woodside's investment in exploration survey equates to approximately \$100 million per year and current downtime estimates predict that of this \$100 million, 10% is lost to downtime, with a proportion of this being attributable to poor navigation data and/or inefficiencies relating to the accurate steering of survey coverage.

Productivity is also realised through the evaluation of datasets in real-time via the assessment of positional information and its quality which is aided via correctional information sent to the vessel via satellite communications.

Appendix B Glossary of terms

Term	Definition
RTK	Real Time Kinematics
GPS	Global positioning system – the US Navstar system
CORS	Continuously Operating Reference Stations
GNSS	Global Navigational Satellite System
DGPS	Differential GPS – a form of augmented GNSS
DGNSS	Differential GNSS – this applies where greater accuracy and reliability is provided to the GNSS signal usually by transmitting a correction to the GNSS receiver. The correction is typically calculated using ground based reference stations such as in a CORS network