Where is the Eastern Suburbs Railway?

RAIL SERVICES AUSTRALIA

Our Experience Adds Value

Graeme Gaggin, B. Surv

Mark Butler, B.Surv

Rail Services Australia

SUMMARY

Rail Services Australia has been engaged to deliver two projects involving the Eastern Suburbs Railway (ESR). Both projects required the data for the track design alignment to be available in co-ordinate form on the Integrated Survey Grid (ISG). This information was not available from any source so a methodology had to be developed to enable these projects to proceed.

This paper describes the methodology developed and implemented and the pitfalls encountered in its implementation.

The available public records were found to be inadequate and not up to date. Further research revealed the missing link which enabled the successful completion of both projects and the provision of what is considered to be a valuable base for future work.

INTRODUCTION

From NSW Government Railways to RSA, RAC, FC, SRA

Up until 1996 the NSW Government Railways was one organisation with, or separate to, buses and ferries. Due to the competition policy adopted by the NSW government it was decided to break up the railways into separate organisations and expose the different parts to appropriate competition. The result of this was the formation of RSA (formally Railway Services Authority, now Rail Services Australia, a government owned corporation) in June 1996. All survey activity was placed in this organisation from the previous business groups of the State Rail Authority.

RSA operates in all mainland states and territories in Australia and also has operations in a number of South East Asian countries.

RSA Survey

RSA Survey is a collection of regionalised survey offices that mostly work as autonomous offices and also combine to work on larger projects as required. RSA has survey offices in many parts of the state and is therefore well positioned to provide a wide range of survey functions.

What do we do?

RSA Survey carry out Cadastral, Control, Engineering and Hydrographic Surveys. RSA Survey also carries out large amounts of design work on the 11,000 km of railway track in NSW.

Who do we do it for?

Our major clients are the other NSW rail entities although we also work for other government and private organisations as the opportunities present themselves.

Purpose of the Paper

To share our experience in dealing with an interesting and challenging survey problem.
The purpose of this paper is to share our experiences in dealing with the Eastern Suburbs Railway (ESR) Line. The problems encountered on this job are not totally unusual for railway surveyors but parallel situations will come up in many areas as we move on to the GDA 1994 and surveyors are more and more faced with similar circumstances.

We will briefly explain the problems faced and possible solutions proposed as well as the solution adopted. We will speak in general terms about the results achieved and the work yet to be done.

Why is this a problem? Two current jobs and future jobs.

The ESR was designed on a co-ordinate system that has since been replaced. This means that there is little or no information as to how to relate the design with the rest of the world. This is a major limitation as far as the Geographic Information System (GIS) is concerned and is at least a major annoyance for regular survey activities.

We were faced with two current jobs, and a trickle of inquiries from builders, as to whether their work would infringe on the structural integrity of the underground system. The two major jobs were to load the alignment into the GIS and to re-survey each platform to reduce the gap between trains and the platform. There are no traverse stations to be found in the tunnels and so relating any fieldwork to the design presents interesting problems. The scope of the work did not allow the re-traverse of the tunnels and re-calculation of the design to the new control on this traverse.

COMPARISON of SURVEY OPTIONS AVAILABLE

GIS Applications.

Other methods available for the GIS applications included using the existing co-ordinated alignment to give the shape and "rubber banding" this to other information available. This would be at best approximate and possibly misleading to the users who don't understand the limited accuracies of the GIS data. We could also re-survey the whole line although this would be clearly well outside the budget for the data capture in the GIS.

Design of new platform copings.

We could have traversed down fire stairs to each platform from the remaining surface control. This could have involved significant surface traverses as well as many steep and short lines spiraling down the fire stairs. The resultant confidence in position and azimuth would have been fairly low and therefore this option was discounted.

Construct the new platform coping to fit the track as it currently sits. The problem is that when track maintenance activities are carried out, the track will be placed on its design alignment as evidenced by the track recovery marking thus potentially creating clearance problems.

BACKGROUND

This is not a history of the design or construction of the ESR. To this end we apologise for any inaccuracies that may appear in the following text. We simply wish to provide background information to assist in the understanding of the problems faced.

ESR design.

The Eastern Suburbs Railway was designed in the 1940's after a control traverse and detail survey over the entire route. There were a number of attempts to start construction and the line was finally constructed in the 1970's.

ESR Construction.

The Survey Control was re-traversed for the construction. The same co-ordinate system was used. The construction was carried out under a number of separate contracts. There were separate survey traverses for the tunneling for each contract.

Co-ordinate systems.

The co-ordinate system used by many government departments in Sydney at the time was based on Trig "E" using Cassini-Soldner projection. These co-ordinates were in feet and to aid in calculations the co-ordinates were expressed in southings and either eastings or westings to remove negative values.

Why we are doing something?

There are an increasing number of inquiries as to whether works proposed by third parties will interfere with the rail infrastructure. This can become a politically sensitive issue as most inquiries are in areas where land values both above and below ground are extremely high and also the safety and reliability of the rail system is in the public eye. We need to be sure that any works will not adversely affect the safety and reliability of the system. Meanwhile there are enormous economic pressures on other authorities and developers to use all that can be made available.

The public might think that the railways are well below ground and therefore all is fine. There are in fact places where the rail tunnel structure is quite close to the surface and must be considered before any digging is to occur or before large or heavy structures are built over the structures.

What are we doing?

As a result of the previous information it was decided that the best course of action would be to convert the existing information to reference frames that are in current use: ISG co-ordinates and AHD levels.

CONTROL METHODS

Original control, methods, accuracy and adjustments.

Information to hand indicates that the original control traverse was carried out with 20" theodolites available at the time. We also believe that steel wires were used in the original traverse.

Little information has come to light as to the accuracy and adjustments used in the original control traverse.

Re-traverse (Construction)

Methods

Prior to construction a re-survey of the control traverse was undertaken. We understand that the majority of angles were measured with 20" theodolites using angle-doubling techniques. The distances were measured with an invar wire. Great care was taken in an attempt to achieve results, which we would now consider unachievable with the equipment used.

Accuracy

The major traverse was a large loop roughly following the current rail line to Bondi Junction and then going round past Randwick Race Course and the University of NSW and coming back through Erskinville to Central Station. With such a large traverse it is hard to believe that the misclose was only 0.25 of a foot.

Adjustments

Least-Squares methods were not readily available at the time of the re-traverse. For reasons best known to those involved at the time it was decided not to adjust the re-traverse at all but rather to leave all the misclose in the shortest line. This line is the line immediately north of Central Station.

CONSTRUCTION

Tunnel Construction

The tunnels were constructed in a number of contracts. It is not clear what survey was carried out during the construction of the various tunnel and viaduct sections and it was not until the tunnel fit out stage that a closed underground control traverse was carried out.

Tunnel Control – Adjustment.

As construction and tunnel fitout progressed it appears that adjustments were made in an "ad hoc" manner rather than in any systematic way such as by least squares or Bowditch. What is known is that during the fitout phase a Wild T2 theodolite became available which apparently highlighted some deficiencies in previous surveys.

Tunnel Permanent Marking.

There were many stages of survey marking during the construction process. Survey position was transferred from one generation of marking to the next as construction moved and covered or destroyed the earlier generation.

Centre Line Set Out – Principle Points.

The final centerline marking was of the frame points. This marking was made in the base of the tunnel and is apparently about 1m below track level. The marks were large pins set into the tunnel floor. Although we can see no reason for the marks not to be there, attempts to find the marks have so far proved unsuccessful.

Principal Alignment Recovery Marks.

At each principal alignment point theodolites were set up and recovery marks placed. These were apparently placed with much care and precision. The recovery marks are bolts or pins in the wall of the tunnel. Each mark is labeled with the appropriate information required to position the adjacent track in three dimensions.

Other Alignment Recovery Marks.

Other alignment recovery marks were placed at approximately even distances along the line. These marks are of the same type as the principal alignment marks and are labeled in the same way.

Metrification.

During the construction period the railways, as with many other departments, adopted the metric system of measurements. This meant that although all design and construction was carried out using the imperial units of miles, chains and feet, final marking was made in kilometres and metres. No documentation of the conversion could be found in the plan room.

State of our records

The plan room currently holds over one hundred thousand plans. These plans cover subjects as wide as working plans showing alignment and grading of the proposed and constructed government railways to the design drawings for a special spanner or bolt used for locomotive maintenance.

Plans

Plans that were located for the ESR (see figure 1) showed the design alignment and the surface traverse together with all buildings on or near the route. These plans are held on microfilm and reading the information from these plans was sometimes akin to crystal ball gazing. On many occasions a section had to be recalculated for one or more reasons such as to confirm a particular digit in a co-ordinate or to fix an error in the documentation of the alignment.

It should be noted that the information on these plans is in imperial units in southings and eastings or westings, with mileages in miles, chains and feet.

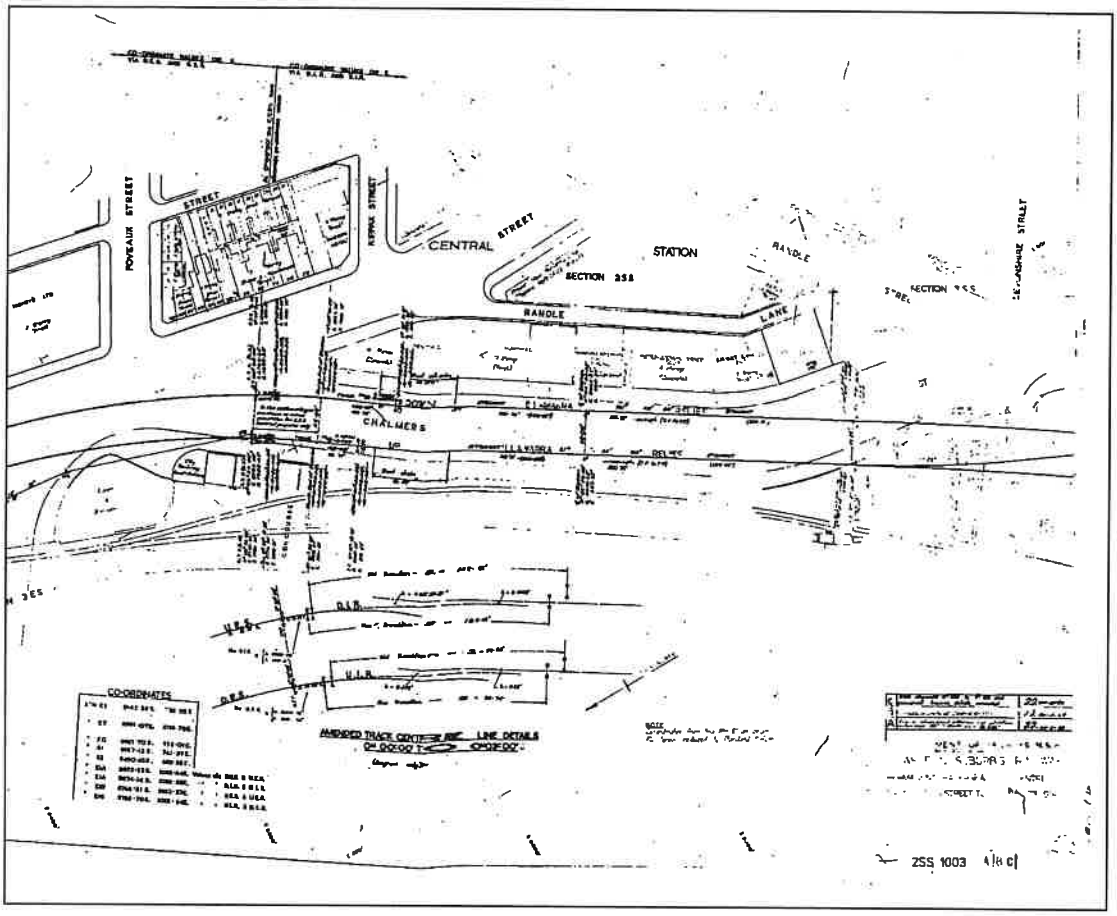

Figure 1: Sample Plan of ESR

Other

We also obtained a box of old papers which showed various bits of unidentified information to do with the survey work for the ESR. This information was not indexed and was therefore put aside on the basis that we were unable to extract anything relevant and meaningful.

PLANNED APPROACH

Our planned approach was as follows:

Identification of Common Survey Control

In order to achieve this it was necessary to carry out a two-phase process. The first phase was to carry out a transformation using survey marks for which we had co-ordinates, both in ESR datum and ISG. These marks numbered about six and were known to us from previous work we had carried out. The second phase was to use the transformation parameters produced in phase one to transform the remaining ESR control to ISG so that we could identify more common points.

Using the transformed co-ordinates of the ESR control it was possible to carry out a SCIMS radial search and identify, by comparison of co-ordinates, further survey marks common to both the ESR control and ISG.

This method proved effective if a little laborious and provided us with about 30 common marks spread fairly evenly over the length of the railway. It should be noted that no attempt was made to check the current viability of the survey marks. The fact that we had co-ordinates in both systems was enough for our purposes. In fact one of the reasons for doing this work was the rapidity of the disappearance of the ESR surface survey control.

Transformation

As mentioned above two survey control transformations were carried out. The first used six common control marks. These marks were not well distributed along the railway and provided only sufficient transformation accuracy to enable finding further marks. The final transformation consisted of approximately 30 final common survey marks that were adequately distributed over the length of the railway. Due to a known discontinuity in the original adjustment the final adjustment was actually carried out in two separate sections. The first section being Central to Bondi Junction (ESR) and the second section Central to Redfern (Illawarra Relief).

Our next task was to use our final transformation parameters to transform the design alignment to ISG. This process, like everything else on this job, proved to present quite a few challenges. Before the design alignment could be transformed it was considered to be more convenient to convert from Southings and Westings co-ordinates in feet to eastings and northings in metres. It was then necessary to re-calculate sections of the design alignment to remove anomalies and provide a continuous alignment suitable for transformation and further calculation.

The conversion from feet to metres was straightforward however the re-calculation of the design alignment presented a number of problems. The problems included difficult to read plans, plans with missing information, errors in the information shown on the plans and anomalies and discontinuities in the alignment. It must be remembered that the ESR design and plans were produced by hand using hand calculators and tables for calculations. Methods used were often a compromise between the accuracy of information and time of calculation. Indeed, survey methods reflected the difficulty and laborious nature of railway alignment calculations with logs and tables.

An example of the anomalies encountered is found approaching Central Station where the boundary of construction contracts falls at the location of a transition curve. At this location the plans show one set transition curve co-ordinates as you proceed towards Bondi Junction and a different transition curve co-ordinates as you proceed away from Bondi Junction. See figure 1.

Alignment Calculations:

Sections of the alignment were recalculated to enable us to deal with the various anomalies found. It has also allowed us to build a continuous alignment model which would make our future calculations much easier. Thus after our conversion of the alignment to metric eastings and northings and our subsequent recalculation, where required, we were in a position to begin transforming the alignment to ISG.

Alignment Transformation:

Using the transformation parameters derived from the transformation of the surface control we transformed the principal points of the track alignment. This process was trouble free as expected and gave us the basis of our ISG alignment model

ISG Alignment Model:

The transformed principal alignment points were now entered into RSA's alignment modeling software. This software also carries out an integrity check of the model which identified a few minor problems previously missed. We now had a continuous alignment model on which we could base our calculations. At this stage we had also satisfied our GIS requirements. For our platform gaps work we still required a connection between our alignment model and the real world.

The Real World:

Concurrently with the above work, field surveys were being carried out at each station on the ESR line. These surveys were based on newly installed control marks on each platform, which were assigned local plane co-ordinates. From this control the existing track centreline, the platform coping and the original track alignment recovery marks were located. This work, due to rigid Safeworking requirements, had to be carried out during nightly track possessions. This severely slowed progress on the project as it allowed only three and a half hours of productive work per shift. These surveys also recorded the information shown on the labels attached to each recovery mark. This information is not recorded on any documentation and is critical for our purpose. This survey also placed recovery marks at one metre intervals for future platform construction. At each platform around 400 dual faced radiations were observed and checked. Due to the volume of work and the restricted hours available to carry it out Leica TCRA 1101 Total Stations were used. Software was written to enable both faces to be observed with a single button press. Further enhancing the already impressive performance of these instruments.

Aligning the Model with the Real World:

Using our in house developed applications we derived ISG co-ordinates for the alignment recovery marks using the information recorded from the labels. Thus we now had co-ordinates for the track recovery marks in both ISG and our local plane system. We were now in position to transform our local plane system to ISG and complete our project. Sadly our transformations yielded residuals of up to 50 metres. Not a great result at this stage of the project!

Seeking a Solution:

After much checking, self-doubt about our approach and many hours of analysing the transformation results it became apparent that we had a problem with the kilometrage of the track recovery marks. Our analysis indicated that the kilometrage adjustments shown on the ESR plans were not correct. But what were they? In desperation we dived into that previously mentioned box of papers. We eventually found some documentation that appeared to solve our kilometrage dilemma. This documentation was undated, unsigned and with no clear status, however a pattern began to emerge which gave the confidence to accept the information. With this information were able to recalculate the ISG co-ordinates of the recovery marks and repeat the transformation of our local plane co-ordinates to ISG. This had the effect of reducing the residuals to around 150 millimetres. This was very encouraging but still far from the anticipated result. We took the normal surveyor's attitude and asked, "What are we doing wrong?"

Paradigm Shift:

Up to this point we had been operating on the assumption that a great deal of care and checking was employed in placing all the alignment recovery marks. We stepped back from this assumption and regenerated kilometrages of the track alignment recovery marks adopting where possible the principal point recovery marks. This indicated that the infill alignment recovery marks were precise for line but in kilometrage the precision was variable up to the 150-millimetre level. Thus, armed with what we now believed to be precise kilometrages, we were able to recalculate the ISG co-ordinates of the recovery marks and repeat the transformation of our local plane co-ordinates to ISG. This transformation now yielded the results we originally expected, that is, residuals in the order of millimetres. These transformation parameters were now used to transform all the field data collected. We were now working entirely within the Integrated Survey Grid. We were now able to complete our project by calculating and documenting our platform gap data.

Conclusion:

We were successful in completing our projects. We learnt the importance of good documentation. We are encouraged to be more diligent in the documentation of both these projects and future projects.