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THE STATEFIX WEST AUSTRALIAN GPS NETWORK

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ABSTRACT

The STATEFIX project, commissioned and managed by the West Australian Department of Land Administration, represents the densification of the Australian National Network in West Australia to an average spacing of approximately 200km. Some 230 dual frequency baselines (mean baseline length 202km) were observed between March 1996 and November 1996. Data processing and network adjustment were undertaken at Curtin University of Technology. Final results indicate the network is accurate (relative to the ANN) to better than 2cm in the horizontal component (95% confidence), and 6cm in the vertical component (95% confidence). The STATEFIX project has been particularly challenging in terms of the vast area surveyed (over 2,500,000km^2) and the isolated nature of many control points, located in uninhabited desert areas. This paper will outline STATEFIX observation, processing and network adjustment strategies, and describe the precision and accuracy analysis performed for the network.

INTRODUCTION

West Australia is one of the largest yet most sparsely populated states in the world and the establishment a state geodetic control network has been an enormous challenge to surveyors since settlement by Europeans in the early nineteenth century. The STATEFIX project was conceived by the West Australian Department of Land Administration (DOLA) ten years ago as part of an Australia-wide policy to improve geodetic control using satellite-based positioning technology and aid the transition from the existing Australian Geodetic Datum (AGD84) to a geocentric datum, the Geocentric Datum of Australia 1994 ($GDA_{1994.0}$).

STATEFIX uses existing points of the Australian National Network (ANN) as a control framework. The ANN itself represents a densification of the Australian Fiducial Network (AFN) which consists of eight permanent, continuously operating, Rogue GPS receivers on the Australian mainland and Tasmania (Manning and Harvey, 1992). The network was initially observed during the International GPS Service for Geodynamics (IGS) Epoch '92 campaign, July to August, 1992. The AFN, in conjunction with six additional sites beyond the Australian mainland, forms the Australian Regional GPS Network (ARGN). AFN station co-ordinates are based on the ITRF92 at epoch 1994.0, and are estimated to have a precision of a few centimetres (2-4 parts in 10^8).

The Australian National Network (ANN) consists of 78 GPS campaign points spaced at approximately 500 km intervals across Australia. This network was observed between 1992 and 1994; the first GPS observation campaign being conducted during the IGS Epoch '92 campaign and followed by a further nine days of observations during August-September, 1993. It is estimated that the horizontal and vertical precisions of the co-ordinates at the 95 percent confidence level are better than three centimetres and five centimetres respectively (Morgan *et al*, 1996). Figure 1 highlights the location of AFN and within Australia.

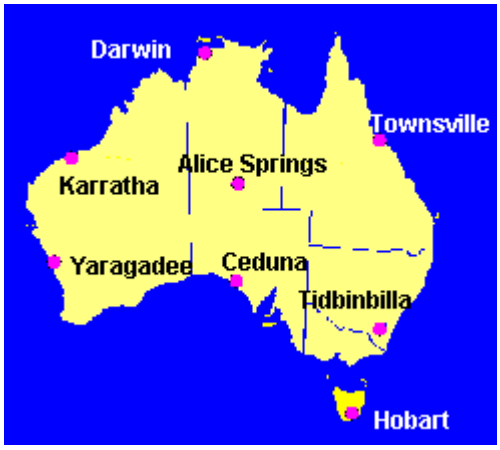

Figure 1 Australian Fiducial Network (AFN)
(from http://anzlic.org.au/geodesy/argn/)

The STATEFIX project was conceived ten years ago but only executed in 1996. Several reasons were used explain this delay. By 1996 technological advances in GPSreceiver hardware and software, and greater availability of equipment and expertise, were anticipated to ensure the objectives of the project could be easily achieved. The specification set by DOLA (DOLA, 1996) is an absolute accuracy of 5cm (95% confidence) in X, Y, Z and latitude, longitude and height. Furthermore, minimum ionospheric disturbance due to the low in 1996 of the eleven year sunspot cycle was deemed important to ensure success when processing the long baselines required by necessity for this project.

This paper outlines STATEFIX observation, processing and network adjustment strategies, discusses precision and accuracy analysis performed for the network, and offers recommendations for the future densification of regional networks

STATEFIX NETWORK DEFINITION AND DATA COLLECTION

The full STATEFIX network is illustrated in figure 2a. Baseline lengths range from 45km to distances longer than 450km. In total, 228 baselines have been observed to 119 stations. The mean baseline length is 200km.

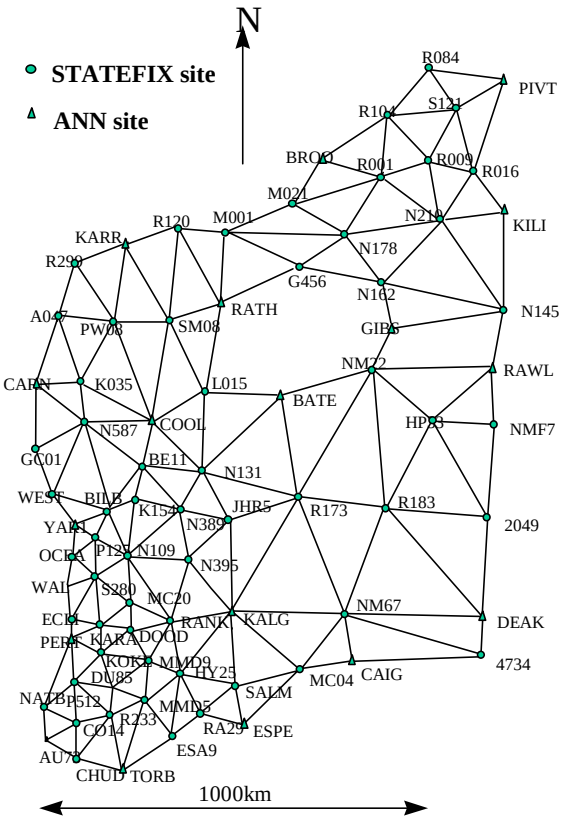

Figure 2a The STATEFIX Network

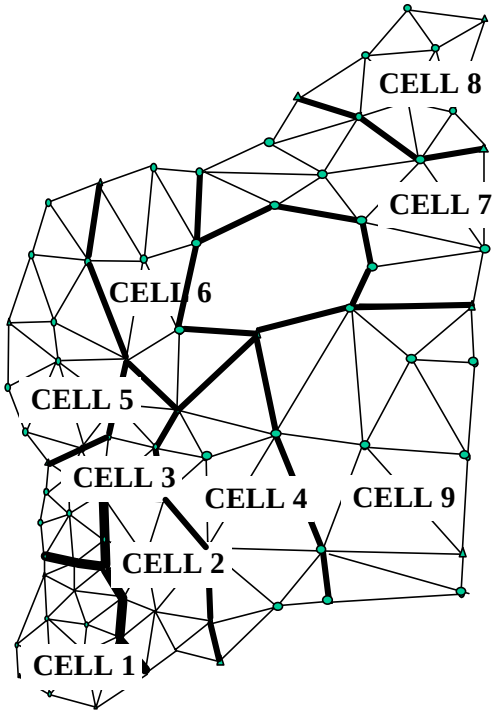

Figure 2b Diagram showing division of STATEFIX Network into 9 cells

For the purposes of observation and processing, the STATEFIX network was divided into 9 individual cells (figure 2b). Because of the size of the STATEFIX network, cells were observed by different private contractors over different time periods in 1996. Baselines of less than 250km in length were observed for a minimum of 12 hours, baselines longer than 250km in length were observed for a minimum of 16 hours. The observation interval was 30 seconds for all baselines. A minimum of three receivers were in use for each cell simultaneously. In total, 198 baselines were observed, with 30 of these being measured twice as they constituted cell boundaries. Several other repeat baselines were observed within individual cells.

All cells, with the exception of cell 3, were observed using Trimble 4000 SSI dual frequency GPS receivers. Cell 3 was observed with Ashtech Z-12 dual frequency GPS receivers. Cells 3 and 5 also incorporated data from the IGS permanent Rogue SNR-8 receiver at Yaragadee (YAR1), whilst cells 5 and 6 incorporated data from a similar receiver (though different antenna) at Karratha (KARR), which is part of the Australian Fiducial Network (AFN).

DATA PROCESSING AND ADJUSTMENT

Baselines from each cell were processed at Curtin University using the in-house SWAG (South West Australian GPS software) GPS processing software suite. The following data processing procedures/models were applied :

a) IGS Precise Orbits:
   IGS precise orbits were held fixed in the processing of all cells.
b) Earth Body Tide Modelling:
   The Wahr two-step Earth body tide model was applied, as per IERS standards (McCarthy 1992) in the processing of all cells.
c) Antenna phase centre modelling:
   The IGS PCV_01 antenna phase centre models (Rothacher and Mader 1996), referenced to the Dorne Margolin T chamber test values of Schupler (1994), were applied.
d) Atmospheric Modelling:
   Processing was undertaken using the ionosphere free linear combination (Φ_{IF} = $2.546\Phi_{L1}$ - $1.984\Phi_{L2}$). Corrections to the zenithal delay tropospheric model parameters in the form of scaling and second order rate of change parameters were estimated as part of the baseline solutions.
e) Ambiguity Resolution:
   Ambiguity resolution was attempted on all baselines using a combination of the wide lane observable and the ionospheric free observable. Ambiguities were successfully resolved on all STATEFIX baselines with the exception of one baseline in cell 8.
f) Length of Data Span:
   The smaller cells, 1, 2 and 3, were processed by dividing the observation time spans into two independent sessions and computing two solutions for each baseline. Cells 4 - 9 were processed using the full 16 hour session.
g) Rigorous Adjustment of Simultaneously Observed Baselines:
   All simultaneously observed baselines were rigorously adjusted taking baseline correlations into account. The resultant baseline vectors and full multi-baseline covariance matrix for each day were then adjusted into the single cell solutions or full STATEFIX network solution.
h) Individual Cell Adjustment
   One ANN point was held fixed in each cell and coordinates of other ANN stations within the cell were computed and compared with their ANN coordinates as an accuracy estimation. Internal cell precision was also studied. Full results and analysis from the individual cell adjustments can be found Stewart *et al* (1997).

i) Full Network Adjustment Strategy:

The full STATEFIX network was adjusted using GEOLAB version 2.4, constraining all ANN station coordinates to 5cm in height and 3cm in plan (95% confidence).

4. RESULTS

i) Relative Errors

Figures 3a and 3b illustrate the relative errors from the STATEFIX network solution at a 95% confidence level. Both the relative horizontal and height errors exhibit a baseline length dependency with error of 0.01 - 0.04 ppm in the horizontal and approximately 0.2ppm in height. Relative horizontal errors are all better than 1cm. Relative height errors are better than 6cm with the exception of baselines connected to site R084 in cell 8, which demonstrate uncertainties of between 7 and 8 cm.

ii) ANN coordinate recovery

In addition to the full solution, a series of further adjustments were conducted which were identical to the full solution except that one ANN point was left free, allowing a direct comparison of STATEFIX coordinates with ANN 'ground truth' coordinates. The results from the coordinate recovery tests are presented in table 1 overleaf. The ANN site coordinates from the additional network adjustments are recovered to better than 2.5cm (±1-2cm) in all components. The largest error is 5.5cm, in the X component at CARN and the overall recovery of DEAK.

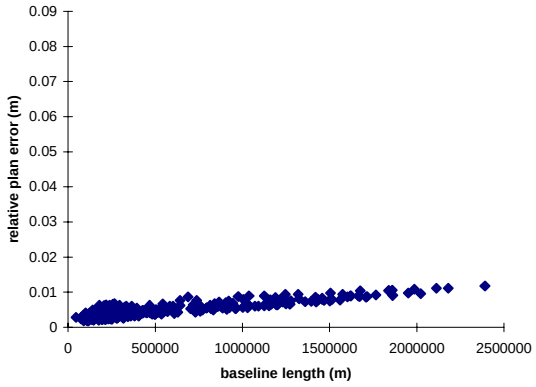

Figure 3a Relative Plan Error for STATEFIX Network Solution

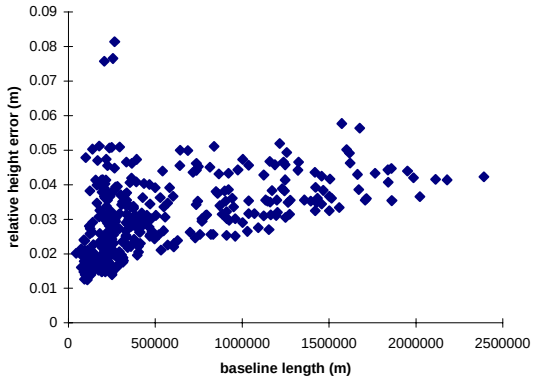

Figure 3b Relative Height Error for STATEFIX Network Solution

SUMMARY

The precision of the adjusted STATEFIX station coordinates within the ANN is better than 1cm in the horizontal and 6cm in height (95% confidence). ANN station recovery tests retrieved ANN coordinates with an accuracy of better than 2.5cm ± 1-2cm. The relative precision of the STATEFIX network is better than 0.04ppm in the horizontal and 0.2ppm in height. Given that the published formal error on the ANN, the reference

framework for STATEFIX, is 3cm in the horizontal and 5cm in height (95% confidence), the accuracy of the STATEFIX network can be said to be of a similar order of magnitude to the ANN.

The STATEFIX network has illustrated that given adequate planning, high precision GPS control networks can be established over large, remote regions. The success of the project can be mainly attributed to the existing geodetic control infrastructure offered by the Australian National Network and the long observation spans which ensured adequate data were available to resolve ambiguities, even on long baselines.

Table 1 Recovery of ANN Coordinates from STATEFIX Network Solutions

ANN station	*recovery X (m)*	*recovery Y (m)*	*recovery Z (m)*
BATE	0.005	0.015	0.019
CAIG	0.007	0.037	0.002
CARN	0.055	0.031	0.013
COOL	0.010	0.026	0.007
DEAK	0.056	0.040	0.060
ESPE	0.002	0.020	0.020
KILI	0.010	0.023	0.025
PER2	0.001	0.007	0.013
PIVT	0.012	0.010	0.034
RATH	0.020	0.023	0.005
YAR1	0.025	0.038	0.015
mean	0.018	0.020	0.019
standard deviation	0.019	0.011	0.016

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