

A regional geodetic network to monitor ground surface response to resource extraction in the northern Surat Basin, Queensland

M. C. Garthwaite, M. Hazelwood, S. Nancarrow, A. Hislop and J. H. Dawson

Community Safety and Earth Monitoring Division, Geoscience Australia, Symonston, ACT 2601, Australia

Corresponding author: Matt Garthwaite matt.garthwaite@ga.gov.au

SUPPLEMENTARY PAPERS

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SUPPLEMENTARY PAPERS

Supplementary Table Positions, corner reflector alignments and other associated information for the 65 geodetic sites installed in the northern Surat Basin.

INTRODUCTION

This supplementary paper, published in November 2016, includes updates to the positions originally published in Garthwaite *et al.* (2015). Several of the original corner reflector positions were found to be in error. We have done a thorough re-processing of all the original survey data to arrive at the positions reported here. Reported information is current as of November 2016 and should be used instead of the previously reported information. Contact the corresponding author or geodesy@ga.gov.au for further updates to the positions.

SURVEY METHODOLOGY

In Supplementary Table 1 we report the GDA94 positions of each survey mark and corner reflector with heights referenced to the GRS80 ellipsoid. These positions were deduced using different methods described below. Survey marks that are co-located with corner reflectors (sites 1–42 but excluding 7 and 33; marked as ‘geodetic’ quality) were occupied using a GNSS antenna whilst being used as an RTK base station for a period between 73 and 260 minutes. A setup similar to that pictured in Figure 3b was used. Raw data from this observation period was converted to RINEX format and post-processed using Geoscience Australia’s online GNSS processing service, AUSPOS (Jia *et al.* 2014), which gives a position relative to the GDA94 and ITRF2008 reference frames. The average AUSPOS-reported 2-sigma uncertainty for these 40 positions is 0.017 m in the horizontal and 0.040 m in the vertical (maximum values are 0.032 m in horizontal and 0.103 m in vertical).

The positions of the remaining survey mark sites (sites 33, and 43–67; marked as ‘rough’ quality) have been measured using a handheld GPS device and therefore have horizontal and height accuracies of several metres. Geodetic-quality positions for all survey mark sites will be derived from campaign occupation surveys of at least 1 week duration conducted on an annual basis. To date, these campaign surveys have been conducted in September 2015 and October 2016.

All corner reflector positions were measured using a roving RTK instrument on a point that acts as the azimuth rotation centre of the reflector-mounting stand (marked on Figure 4a). Modelled XYZ offsets between the measured point and the corner reflector apex applicable for the current alignments are available from the corresponding author. An average of three 180 second RTK observations were

taken and block shifted to GDA94 using the difference between the RTK position for the nearby survey mark (within 50 m) and the AUSPOS-derived position for that mark. The block shift method is appropriate given that the distances between survey marks and corner reflectors are less than 50 m, which gives results within the uncertainties of the survey method. Positional uncertainties for the corner reflectors are estimated according to the guidelines laid out by the ICSM (2014), considering the positional uncertainty of the RTK base station set up on the survey mark and the manufacturer specified survey uncertainty of the RTK equipment. The average estimated 2-sigma uncertainty for the 40 corner reflector positions is 0.022 m in the horizontal and 0.044 m in the vertical (maximum values are 0.035 m in horizontal and 0.105 m in vertical).

ITRF POSITIONS

The positions reported here are with respect to the static GDA94 reference frame at an epoch of 1994. Dawson and Woods (2010) give transformation parameters for converting GDA94 positions to ITRF2008. To perform the transformation, readers can use the free software provided on the ICSM website at <http://www.icsm.gov.au/gda/software.html> to obtain ITRF coordinates for a preferred epoch.

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| Site ID | Land | Type | Quality | Survey Mark | | | | | | | Corner Reflector | | | | | | | | | | |
|---------|--------------|---------|----------|----------------------------|---------------------------|----------------------------|-------------------------------|------------------------------------|----------------------------------|-------------------------------|-----------------------------|----------|-------------|---------------------------|----------------------------|-------------------------------|------------------------------------|----------------------------------|----------------------------|------------------------------|-------------------------------|
| | | | | Survey mark hole depth (m) | Latitude (GDA94; degrees) | Longitude (GDA94; degrees) | Ellipsoidal Height (GRS80; m) | Horizontal 2-sigma uncertainty (m) | Vertical 2-sigma uncertainty (m) | GNSS observation time (hr:mm) | Average CR pillar depth (m) | CR Fence | CR size (m) | Latitude (GDA94; degrees) | Longitude (GDA94; degrees) | Ellipsoidal Height (GRS80; m) | Horizontal 2-sigma uncertainty (m) | Vertical 2-sigma uncertainty (m) | CR Boresight Azimuth (deg) | CR Boresight Elevation (deg) | SM-CR horizontal baseline (m) |
| 1 | Private Land | Soil | Geodetic | 1.35 | -26.83496186 | 151.16559471 | 408.676 | 0.018 | 0.044 | 1:13 | 1.31 | Yes | 1.5 | -26.83472283 | 151.16559639 | 409.297 | 0.023 | 0.048 | 255.418 | 52.920 | 26.486 |
| 2 | Private Land | Soil | Geodetic | 2.50 | -26.95192158 | 151.23759790 | 431.919 | 0.016 | 0.039 | 1:50 | 1.14 | Yes | 1.5 | -26.95164603 | 151.23760507 | 432.520 | 0.021 | 0.043 | 255.383 | 52.699 | 30.539 |
| 3 | Private Land | Soil | Geodetic | 6.20 | -27.10102633 | 151.25900346 | 390.884 | 0.014 | 0.032 | 2:51 | 2.85 | No | 2.5 | -27.10074500 | 151.25880041 | 391.531 | 0.020 | 0.037 | 257.640 | 54.000 | 37.110 |
| 4 | Road Reserve | Soil | Geodetic | 6.20 | -27.30917750 | 151.27194023 | 384.307 | 0.013 | 0.027 | 4:20 | 2.90 | No | 2.0 | -27.30888445 | 151.27194926 | 384.654 | 0.019 | 0.033 | 257.630 | 54.310 | 32.483 |
| 5 | Private Land | Soil | Geodetic | 5.90 | -27.45727237 | 151.19081156 | 402.463 | 0.013 | 0.032 | 2:59 | 2.86 | Yes | 2.5 | -27.45694333 | 151.19081888 | 402.595 | 0.019 | 0.037 | 257.620 | 55.150 | 36.468 |
| 6 | Private Land | Soil | Geodetic | 6.20 | -27.37494742 | 151.08590906 | 386.916 | 0.021 | 0.049 | 1:37 | 2.90 | Yes | 1.5 | -27.37475158 | 151.08591526 | 387.569 | 0.025 | 0.053 | 255.467 | 54.363 | 21.709 |
| 7 | Not used | | | | | | | | | | | | | | | | | | | | |
| 8 | Road Reserve | Soil | Geodetic | 6.30 | -27.23313012 | 151.01669931 | 372.058 | 0.029 | 0.103 | 1:49 | 2.90 | No | 2.0 | -27.23280294 | 151.01675825 | 372.810 | 0.032 | 0.105 | 256.220 | 56.126 | 36.723 |
| 9 | Road Reserve | Soil | Geodetic | 6.20 | -27.12624046 | 151.10919091 | 369.682 | 0.016 | 0.037 | 2:39 | 2.85 | No | 2.0 | -27.12600856 | 151.10919506 | 370.386 | 0.021 | 0.042 | 257.640 | 55.070 | 25.699 |
| 10 | Road Reserve | Soil | Geodetic | 6.20 | -26.94652123 | 151.14356454 | 389.780 | 0.024 | 0.077 | 1:23 | 2.85 | No | 1.5 | -26.94652447 | 151.14387018 | 390.375 | 0.028 | 0.079 | 255.431 | 53.247 | 30.353 |
| 11 | Road Reserve | Soil | Geodetic | 6.20 | -26.82300731 | 150.93949324 | 367.713 | 0.016 | 0.033 | 2:19 | 2.90 | No | 1.5 | -26.82269794 | 150.93949994 | 368.291 | 0.021 | 0.038 | 255.535 | 54.260 | 34.289 |
| 12 | Road Reserve | Soil | Geodetic | 6.10 | -26.92598813 | 150.91618351 | 358.061 | 0.015 | 0.033 | 3:18 | 2.90 | Yes | 1.5 | -26.92613617 | 150.91636945 | 358.628 | 0.020 | 0.038 | 255.548 | 54.589 | 24.703 |
| 13 | Private Land | Soil | Geodetic | 2.10 | -27.09571321 | 150.92359989 | 394.008 | 0.014 | 0.028 | 3:38 | 2.85 | Yes | 1.5 | -27.09531977 | 150.92361228 | 395.325 | 0.020 | 0.034 | 255.548 | 54.850 | 43.616 |
| 14 | Private Land | Soil | Geodetic | 6.20 | -27.40007203 | 150.94480464 | 386.975 | 0.013 | 0.025 | 3:54 | 2.85 | Yes | 2.5 | -27.39984897 | 150.94481388 | 387.687 | 0.019 | 0.031 | 257.620 | 56.750 | 24.736 |
| 15 | Private Land | Soil | Geodetic | 5.20 | -27.29924978 | 150.82020400 | 425.884 | 0.018 | 0.035 | 2:24 | 2.45 | Yes | 1.5 | -27.29909113 | 150.82018603 | 426.600 | 0.023 | 0.040 | 255.606 | 55.865 | 17.673 |
| 16 | Private Land | Soil | Geodetic | 6.30 | -27.07834656 | 150.75640276 | 380.928 | 0.013 | 0.024 | 3:41 | 2.90 | Yes | 1.5 | -27.07815855 | 150.75640740 | 381.273 | 0.019 | 0.031 | 255.634 | 55.859 | 20.842 |
| 17 | Private Land | Soil | Geodetic | 6.10 | -26.91790104 | 150.78470759 | 353.176 | 0.014 | 0.033 | 2:39 | 2.90 | Yes | 1.5 | -26.91765870 | 150.78471246 | 353.741 | 0.020 | 0.038 | 255.617 | 55.388 | 26.862 |
| 18 | Private Land | Soil | Geodetic | 6.10 | -26.67398582 | 150.77302574 | 360.428 | 0.013 | 0.024 | 3:28 | 2.90 | Yes | 1.5 | -26.67374003 | 150.77301293 | 361.042 | 0.019 | 0.031 | 255.618 | 55.015 | 27.269 |
| 19 | Private Land | Soil | Geodetic | 6.20 | -26.91511503 | 150.67041996 | 358.997 | 0.016 | 0.042 | 1:54 | 2.90 | Yes | 1.5 | -26.91488367 | 150.67042874 | 359.649 | 0.021 | 0.046 | 255.676 | 56.101 | 25.657 |
| 20 | Road Reserve | Soil | Geodetic | 6.40 | -27.02414282 | 150.57680583 | 357.022 | 0.019 | 0.041 | 1:13 | 2.80 | Yes | 1.5 | -27.02392492 | 150.57682628 | 357.590 | 0.024 | 0.045 | 255.727 | 56.899 | 24.236 |
| 21 | Private Land | Soil | Geodetic | 3.40 | -27.23812759 | 150.67001763 | 388.070 | 0.013 | 0.031 | 2:37 | 2.80 | Yes | 1.5 | -27.23782295 | 150.67002476 | 388.599 | 0.019 | 0.036 | 255.682 | 56.702 | 33.773 |
| 22 | Private Land | Soil | Geodetic | 5.30 | -27.42431618 | 150.74601998 | 412.257 | 0.029 | 0.042 | 2:20 | 2.75 | Yes | 1.5 | -27.42436132 | 150.74628323 | 412.870 | 0.032 | 0.046 | 255.647 | 56.565 | 26.512 |
| 23 | Private Land | Soil | Geodetic | 5.30 | -27.60322713 | 150.85931824 | 380.642 | 0.017 | 0.041 | 2:06 | 2.60 | No | 1.5 | -27.60336873 | 150.85952555 | 381.454 | 0.022 | 0.045 | 255.591 | 56.185 | 25.793 |
| 24 | Road Reserve | Soil | Geodetic | 6.00 | -27.50993946 | 150.44319649 | 336.546 | 0.016 | 0.032 | 2:30 | 2.83 | Yes | 1.5 | -27.50970157 | 150.44320674 | 337.151 | 0.021 | 0.037 | 255.629 | 56.738 | 26.391 |
| 25 | Road Reserve | Soil | Geodetic | 6.20 | -27.61155279 | 150.29681514 | 315.782 | 0.016 | 0.033 | 2:27 | 2.80 | Yes | 1.5 | -27.61131113 | 150.29681988 | 316.148 | 0.021 | 0.038 | 255.711 | 57.874 | 26.796 |
| 26 | Private Land | Soil | Geodetic | 6.10 | -27.25891225 | 150.48481033 | 354.458 | 0.021 | 0.051 | 2:14 | 2.85 | Yes | 1.5 | -27.25884416 | 150.48511192 | 355.130 | 0.025 | 0.054 | 255.600 | 56.003 | 30.816 |
| 27 | Private Land | Soil | Geodetic | 6.10 | -26.76703484 | 150.62158790 | 352.477 | 0.016 | 0.046 | 2:46 | 2.80 | Yes | 1.5 | -26.76677804 | 150.62175985 | 353.058 | 0.021 | 0.050 | 255.697 | 56.135 | 33.207 |
| 28 | Private Land | Soil | Geodetic | 2.20 | -26.56015028 | 150.65924566 | 370.378 | 0.015 | 0.031 | 2:36 | 1.33 | Yes | 1.5 | -26.55990915 | 150.65924219 | 370.761 | 0.020 | 0.036 | 255.673 | 55.518 | 26.725 |
| 29 | Private Land | Soil | Geodetic | 3.10 | -26.67075759 | 150.49699122 | 381.681 | 0.014 | 0.031 | 2:40 | 1.80 | Yes | 1.5 | -26.67054050 | 150.49700836 | 382.233 | 0.020 | 0.036 | 255.759 | 56.751 | 24.121 |
| 30 | Private Land | Bedrock | Geodetic | N/A | -26.90021171 | 150.38828711 | 338.036 | 0.015 | 0.034 | 2:28 | N/A | Yes | 1.5 | -26.90014360 | 150.38847114 | 338.696 | 0.020 | 0.039 | 255.644 | 55.950 | 19.788 |
| 31 | Private Land | Soil | Geodetic | 6.10 | -27.20758413 | 150.33158596 | 332.613 | 0.020 | 0.052 | 2:26 | 2.80 | Yes | 1.5 | -27.20731375 | 150.33154798 | 333.198 | 0.024 | 0.055 | 255.682 | 56.885 | 30.209 |
| 32 | Private Land | Soil | Geodetic | 6.00 | -27.37006074 | 150.19469886 | 321.394 | 0.019 | 0.044 | 2:27 | 2.80 | Yes | 1.5 | -27.36983162 | 150.19465531 | 322.050 | 0.024 | 0.048 | 255.760 | 58.081 | 25.766 |
| 33 | Private Land | Bedrock | Rough | N/A | -27.46924400 | 149.91657800 | 350.724 | | | | | | | | | | | | | | |
| 34 | Private Land | Soil | Geodetic | 6.00 | -27.19455084 | 150.11085499 | 316.038 | 0.017 | 0.042 | 2:02 | 2.80 | Yes | 1.5 | -27.19428269 | 150.11085935 | 316.812 | 0.022 | 0.046 | 255.801 | 58.296 | 29.733 |
| 35 | Private Land | Soil | Geodetic | 6.10 | -27.08604926 | 150.25951128 | 370.246 | 0.014 | 0.026 | 2:30 | 2.90 | Yes | 1.5 | -27.08564874 | 150.25962529 | 370.983 | 0.020 | 0.032 | 255.717 | 57.118 | 45.821 |
| 36 | Road Reserve | Soil | Geodetic | 5.50 | -26.86583532 | 150.21787600 | 336.940 | 0.016 | 0.031 | 3:12 | 2.90 | Yes | 1.5 | -26.86582006 | 150.21761134 | 337.003 | 0.022 | 0.036 | 255.733 | 56.978 | 26.369 |
| 37 | Road Reserve | Soil | Geodetic | 6.00 | -26.81351649 | 150.15892975 | 342.562 | 0.032 | 0.075 | 1:18 | 2.83 | Yes | 1.5 | -26.81326956 | 150.15892491 | 343.143 | 0.035 | 0.077 | 255.764 | 57.259 | 27.381 |
| 38 | Private Land | Soil | Geodetic | 4.00 | -26.64736170 | 150.31033596 | 387.474 | 0.015 | 0.034 | 2:38 | 2.53 | Yes | 1.5 | -26.64703413 | 150.31031469 | 388.248 | 0.020 | 0.039 | 255.680 | 55.976 | 36.373 |
| 39 | Private Land | Soil | Geodetic | 6.20 | -26.46235232 | 150.38447314 | 373.356 | 0.014 | 0.033 | 2:39 | 2.80 | Yes | 1.5 | -26.46209768 | 150.38447944 | 374.123 | 0.020 | 0.038 | 255.814 | 57.088 | 28.233 |
| 40 | Private Land | Soil | Geodetic | 3.50 | -26.56617292 | 150.13479705 | 350.040 | 0.018 | 0.044 | 2:14 | 2.80 | Yes | 1.5 | -26.56594872 | 150.13479710 | 350.656 | 0.023 | 0.048 | 255.780 | 56.952 | 24.855 |
| 41 | Private Land | Soil | Geodetic | 0.85 | -26.77111436 | 149.95251353 | 386.089 | 0.019 | 0.041 | 2:48 | 1.25 | Yes | 1.5 | -26.77087451 | 149.95251710 | 387.403 | 0.023 | 0.045 | 255.849 | 58.548 | 26.596 |
| 42 | Private Land | Soil | Geodetic | 6.10 | -26.96703534 | 150.00706453 | 317.476 | 0.019 | 0.040 | 1:58 | 2.80 | Yes | 1.5 | -26.96680264 | 150.00706707 | 318.275 | 0.024 | 0.044 | 255.857 | 58.550 | 25.804 |
| 43 | Road Reserve | Soil | Rough | 6.10 | -27.17390400 | 149.90564500 | 304.584 | | | | | | | | | | | | | | |
| 44 | Road Reserve | Soil | Rough | 6.00 | -27.58992300 | 149.13877000 | 308.664 | | | | | | | | | | | | | | |
| 45 | Road Reserve | Soil | Rough | 6.00 | -27.34391200 | 149.40456800 | 340.394 | | | | | | | | | | | | | | |
| 46 | Private Land | Soil | Rough | 2.90 | -27.07974600 | 149.57586800 | 324.044 | | | | | | | | | | | | | | |
| 47 | Road Reserve | Soil | Rough | 6.00 | -26.64200900 | 149.73541200 | 339.674 | | | | | | | | | | | | | | |
| 48 | Not used | | | | | | | | | | | | | | | | | | | | |
| 49 | Road Reserve | Soil | Rough | 6.00 | -26.08224000 | 149.80504700 | 325.254 | | | | | | | | | | | | | | |
| 50 | Road Reserve | Soil | Rough | 6.00 | -26.06954700 | 149.53964800 | 334.624 | | | | | | | | | | | | | | |
| 51 | Private Land | Soil | Rough | 6.20 | -26.51155500 | 149.40478000 | 359.134 | | | | | | | | | | | | | | |
| 52 | Private Land | Soil | Rough | 3.40 | -26.86695700 | 149.25460400 | 344.474 | | | | | | | | | | | | | | |
| 53 | Road Reserve | Soil | Rough | 0.90 | -27.15923500 | 149.07241600 | 289.684 | | | | | | | | | | | | | | |
| 54 | Road Reserve | Soil | Rough | 6.00 | -27.46941600 | 148.69537100 | 266.854 | | | | | | | | | | | | | | |
| 55 | Private Land | Soil | Rough | 4.80 | -27.02159800 | 148.82102100 | 338.944 | | | | | | | | | | | | | | |
| 56 | Private Land | Soil | Rough | 6.20 | -26.38042700 | 149.11485700 | 393.744 | | | | | | | | | | | | | | |
| 57 | Road Reserve | Soil | Rough | 3.60 | -26.07596500 | 149.13286100 | 363.704 | | | | | | | | | | | | | | |
| 58 | Road Reserve | Soil | Rough | 6.10 | -26.49108100 | 148.81625000 | 358.414 | | | </ | | | | | | | | | | | |