Deformation Modelling to support the Papua New Guinea Geodetic Datum 1994 (PNG94)

Richard Stanaway

Quickclose Pty Ltd and

University of New South Wales

Also acknowledging:

Robert Rosa (Unitech,Lae)

John Kwasi and John Oa (PNG OSG – Geodetic Section)

and support from Luther Sipison (DLPP) and Charles Ouba (OSG)

48th Association of Surveyors of Papua New Guinea Congress, Port Moresby, 24-26 July 2014

What is PNG94?

Papua New Guinea Geodetic Datum 1994

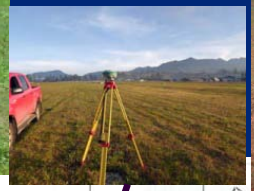
Geocentric Datum – ITRF92 realised by 14 fiducial stations computed at epoch 1994.0 (1st January 1994) – same realisation as GDA94 in Australia

Reference Ellipsoid:	GRS80
Map Projection:	Papua New Guinea Map Grid 1994 (PNGMG94)
	Zones 54, 55 and 56
Projection type:	Universal Transverse Mercator (UTM)
	Southern Hemisphere

PNG94 Fiducial (zero order) Network

Site ID	Site Name	Monument number	PNG94 Latitude	PNG94 Longitude	PNG94 Ellipsoidal Height
MORE	NMB TOWER GPS	PSM 15832	-9°26'02.76968"	147°11'12.20017"	116.610
AIAM	AIAMBAK	PSM 9550	-7°20'51.81934"	141°16'01.44646"	95.465
MIS1	BWAGAOIA AIR	PSM 9195	-10°41'19.90490"	152°49'58.93878"	87.456
GOKA	GOROKA	PSM 9833	-6°04'53.07151"	145°23'30.44618"	1664.580
ALT2	GURNEY	PSM 9538	-10°18'37.50877"	150°20'18.09080"	94.871
KAVI	KAVIENG AIR	PSM 9513	-2°34'53.06528"	150°48'22.53578"	78.828
KIKO	KIKORI AIRPORT	PSM 5583	-7°25'24.65305"	144°14'55.76611"	88.965
MAD1	MADANG	GS 15495	-5°12'41.28824"	145°46'56.19305"	73.293
MANU	MANUS SECOR	PSM 9522	-2°03'02.29337"	147°21'37.63577"	129.751
MEND	MENDI	PSM 3507	-6°08'36.73422"	143°39'22.16540"	1815.154
9799	UNITECH SPORTS	PSM 9799	-6°40'16.96985"	146°59'52.37457"	130.389
VANI	VANIMO DOPPLER	PM 63/1	-2°41'05.28039"	141°18'15.65564"	80.516
NM34	WANKKUN	PSM 15029	-6°08'52.07208"	146°04'52.44226"	510.015
WUVU	WUVULU ISLAND	PSM 15456	-1°44'07.59465"	142°50'10.07846"	79.056











GPS Campaigns 1992 and 1993

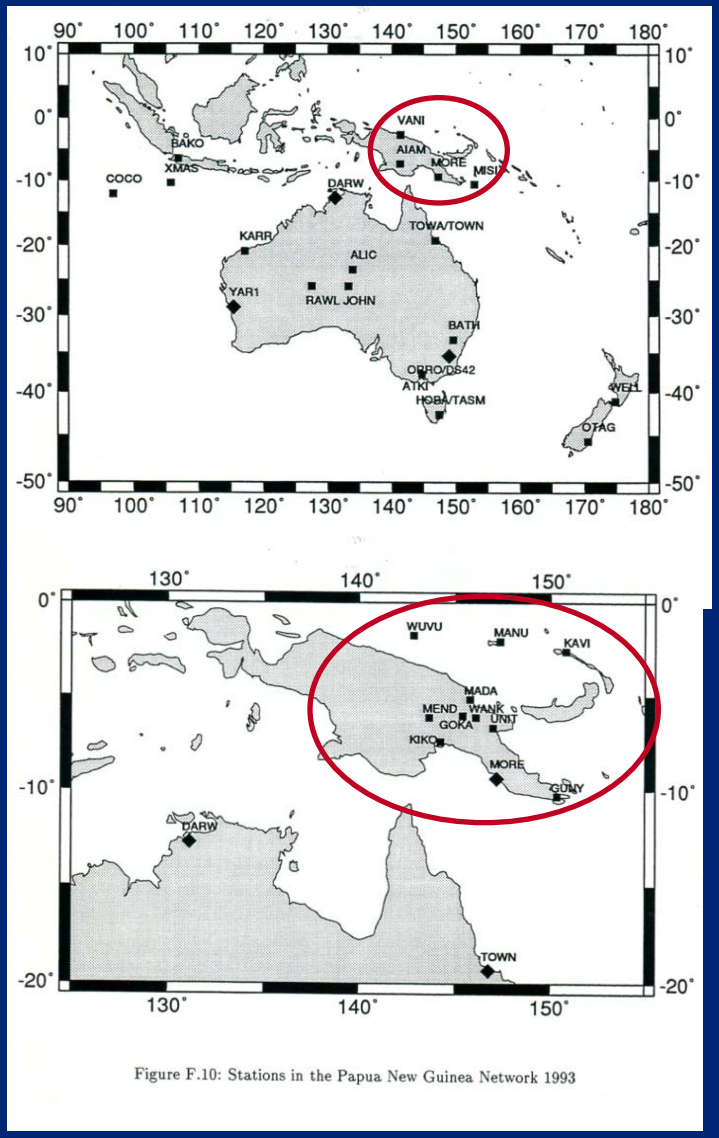
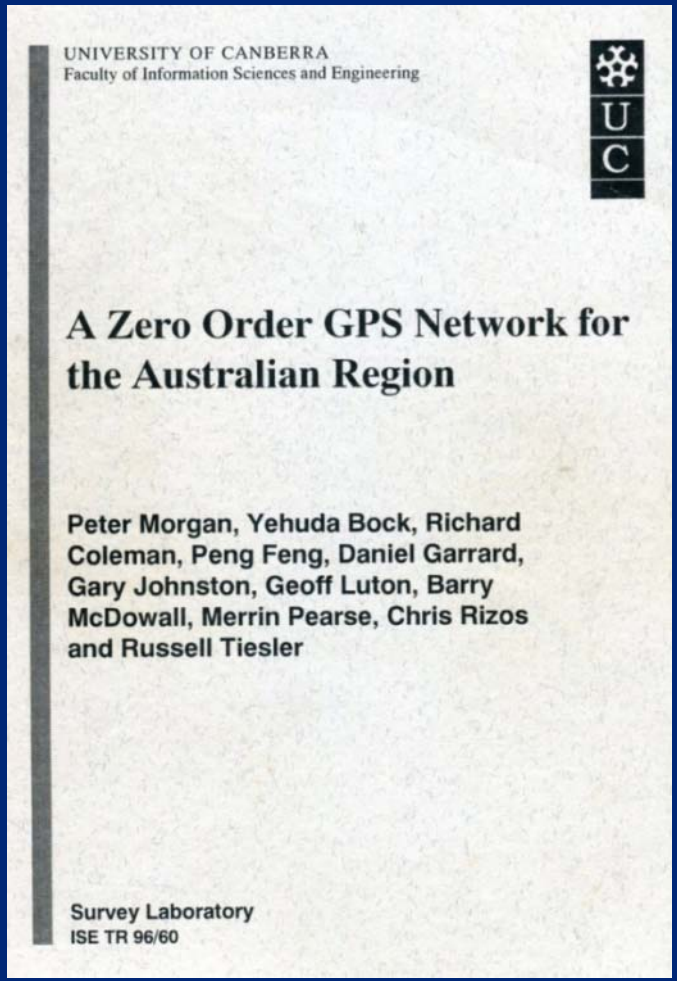


Figure F.10: Stations in the Papua New Guinea Network 1993



PNG94 Fiducial Network Computation

GAMIT/GLOBK software
→ ITRF92 coordinates at epoch of measurement
(Peter Morgan at Uni of Canberra)

ITRF92 coordinates of global IGS network used to compute orbits

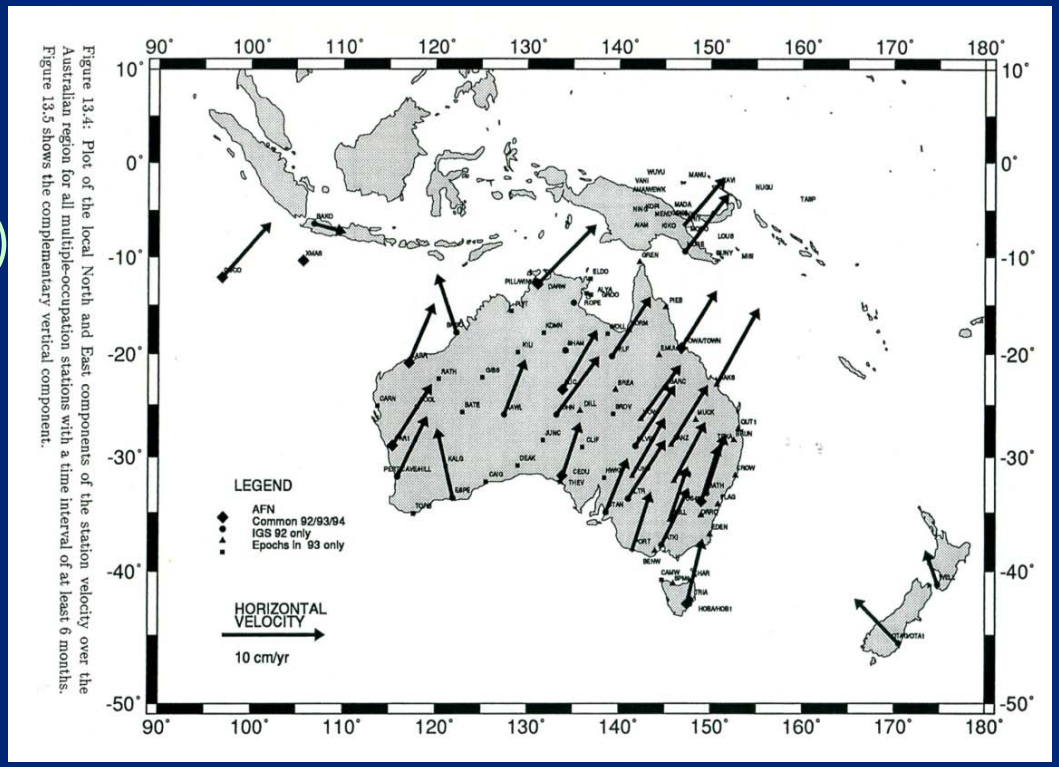


Figure 13.4: Plot of the local North and East components of the station velocity over the Australian region for all multiple-occupation stations with a time interval of at least 6 months. Figure 13.5 shows the complementary vertical component.

Coarse site velocity model
(derived from two year time-series)
used to compute coordinates
at epoch 1994.0 (PNG94 in PNG and GDA94 in Australia)

Formal Uncertainty of coordinates 5 cm at 1σ

PNG94 Secondary and Tertiary Networks

1999 adjustment:

Prof. John Allman, Jan van der Kevie and Robert Rosa

Doppler, terrestrial observations and additional GPS measurements were combined in a block adjustment over PNG constrained by coordinates of the PNG94 fiducial network

NEWGAN used for network least-squares adjustment

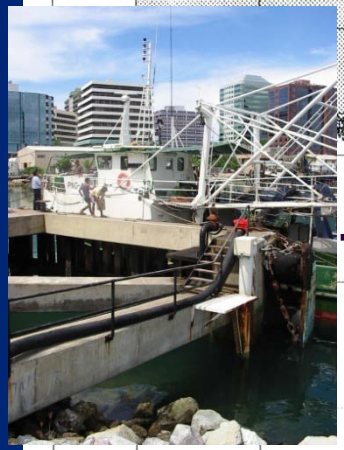
Ashtech PRISM software used for post-processing of static GPS baselines

Primary Network of 968 stations

~ 400 with positional uncertainties (PU) of < 0.25 m

Remainder with PU up to 10 metres!

Tide Gauge GPS Connections



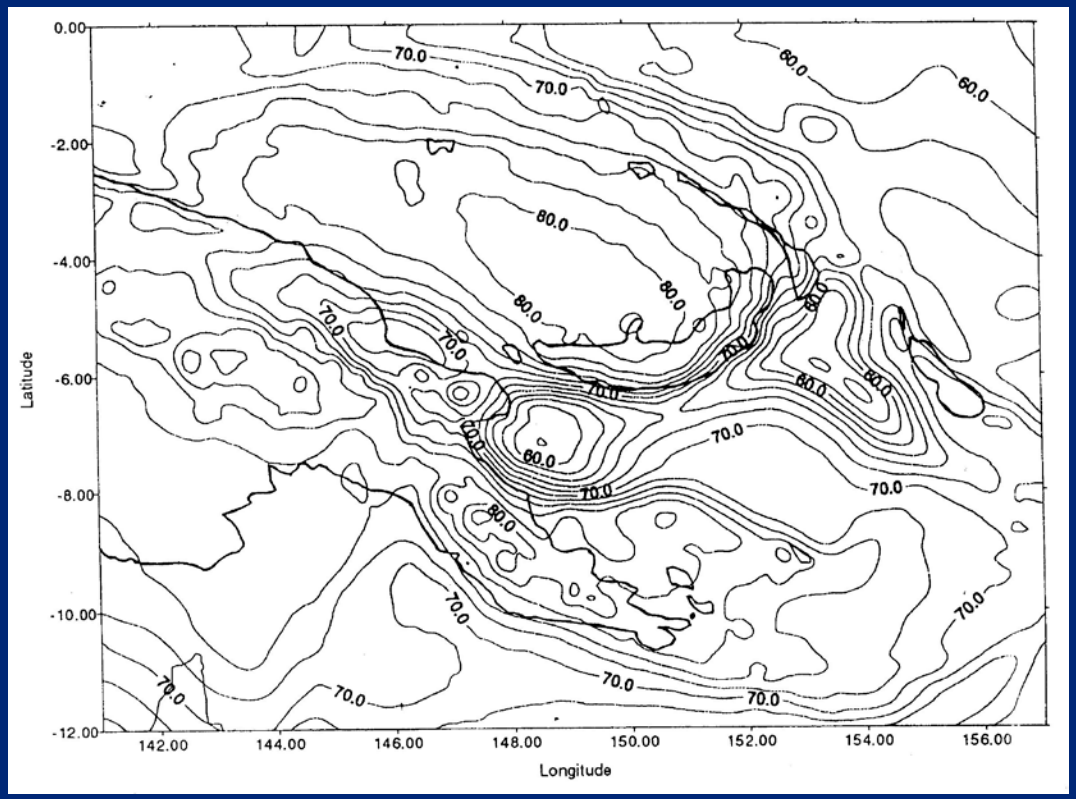
PNG Geoid Model 1994

Gravimetric geoid model developed by Prof. Bill Kearsley (UNSW) using limited gravity data and tide gauge connections.

Zero order term of 0.94 m applied to align gravimetric geoid with MSL.

Uncertainties of 2 m in some areas (e.g. Lae) but usually < 0.5 m

MS-DOS executable program to extract N values – not useable on Windows XP, Vista, 7 or 8 OS

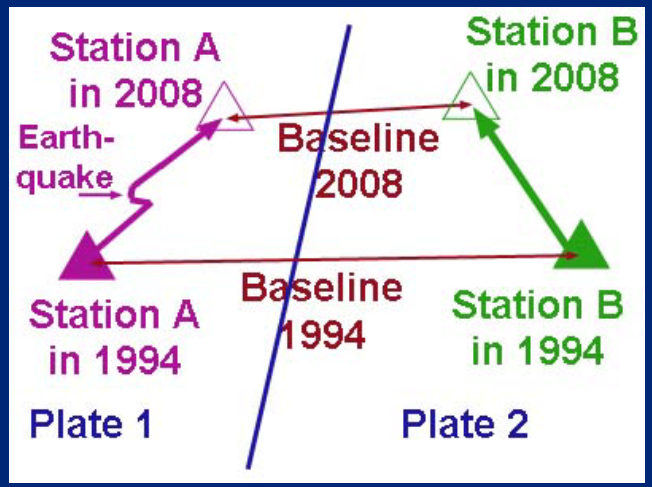


Problems with PNG94

Originally realised as a static datum in a very complex tectonic environment – regular large earthquakes

(cannot measure baselines across plate boundaries)

Cannot transform current ITRF and WGS84 to PNG94 with any precision without a suitable velocity and deformation model (conformal transformations cannot be applied)



Geodynamics studies in PNG

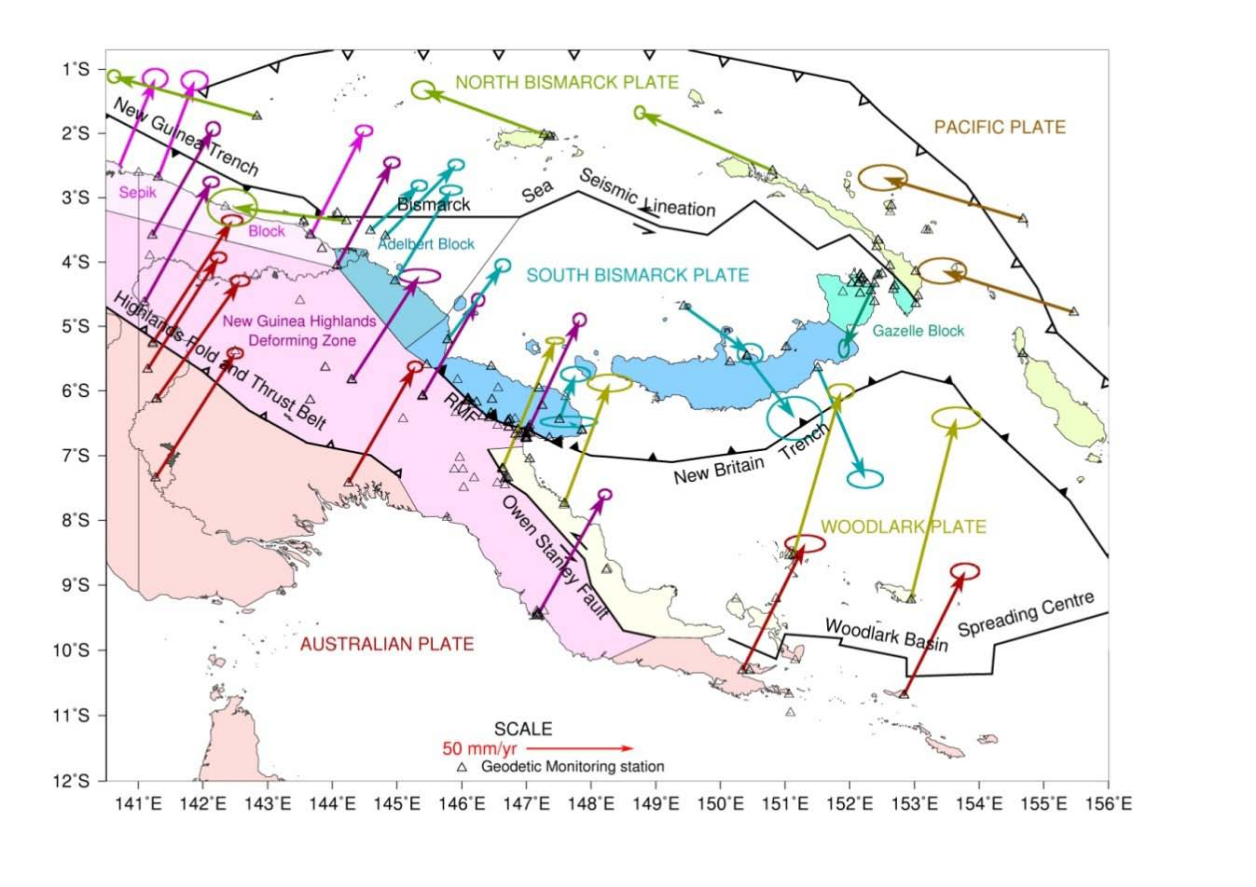
GPS campaigns to monitor plate tectonics in PNG:

UNSW and NMB (1990-1994)
RPI and UCSC (USA)
UniTECH and RVO (1993-2001)

ANU (RSES Geodynamics) (1996-2008)

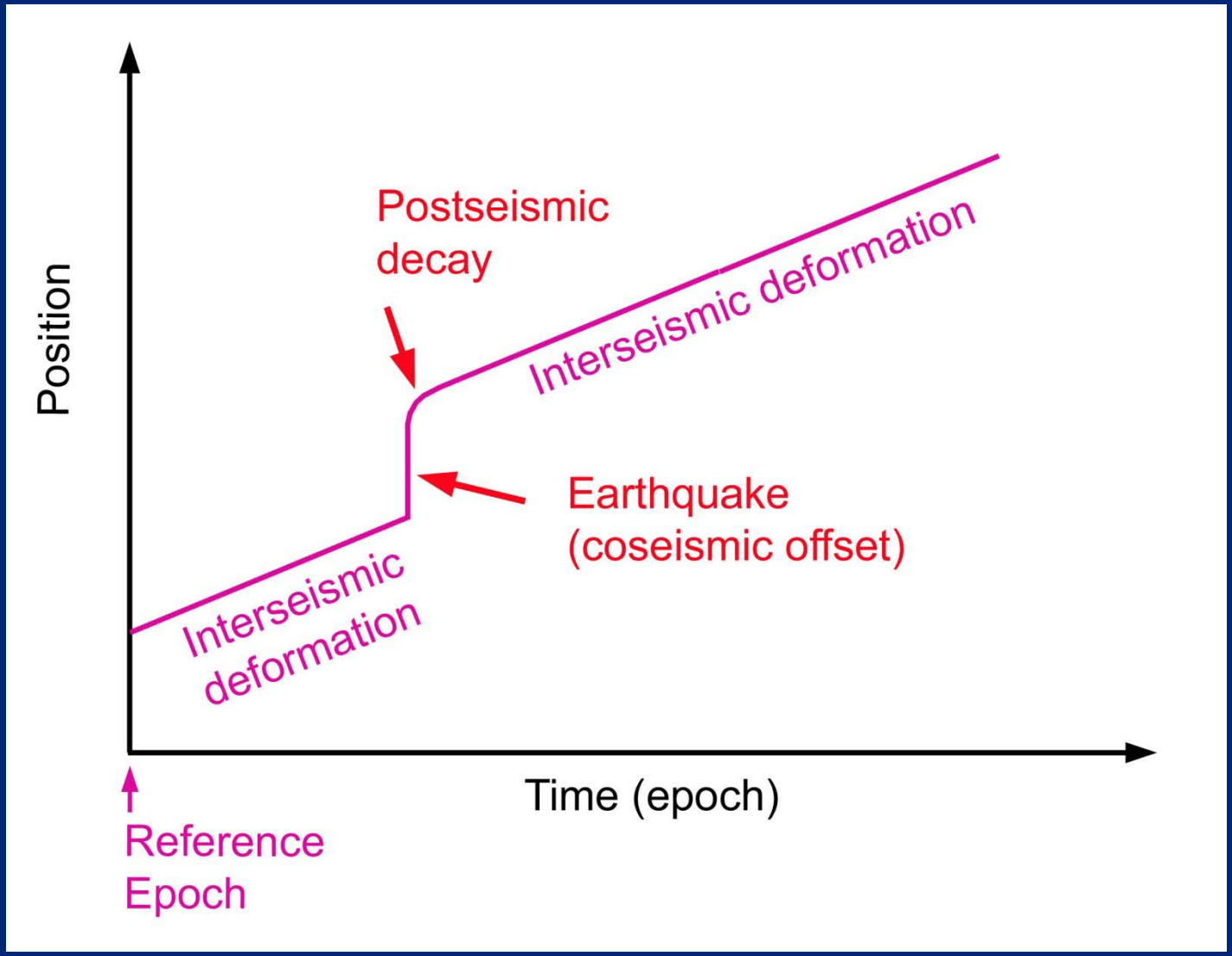
GNS-New Zealand (2009-2013)

Airport Geodetic Survey (PNGASL – AAM- ALS) (2013-)

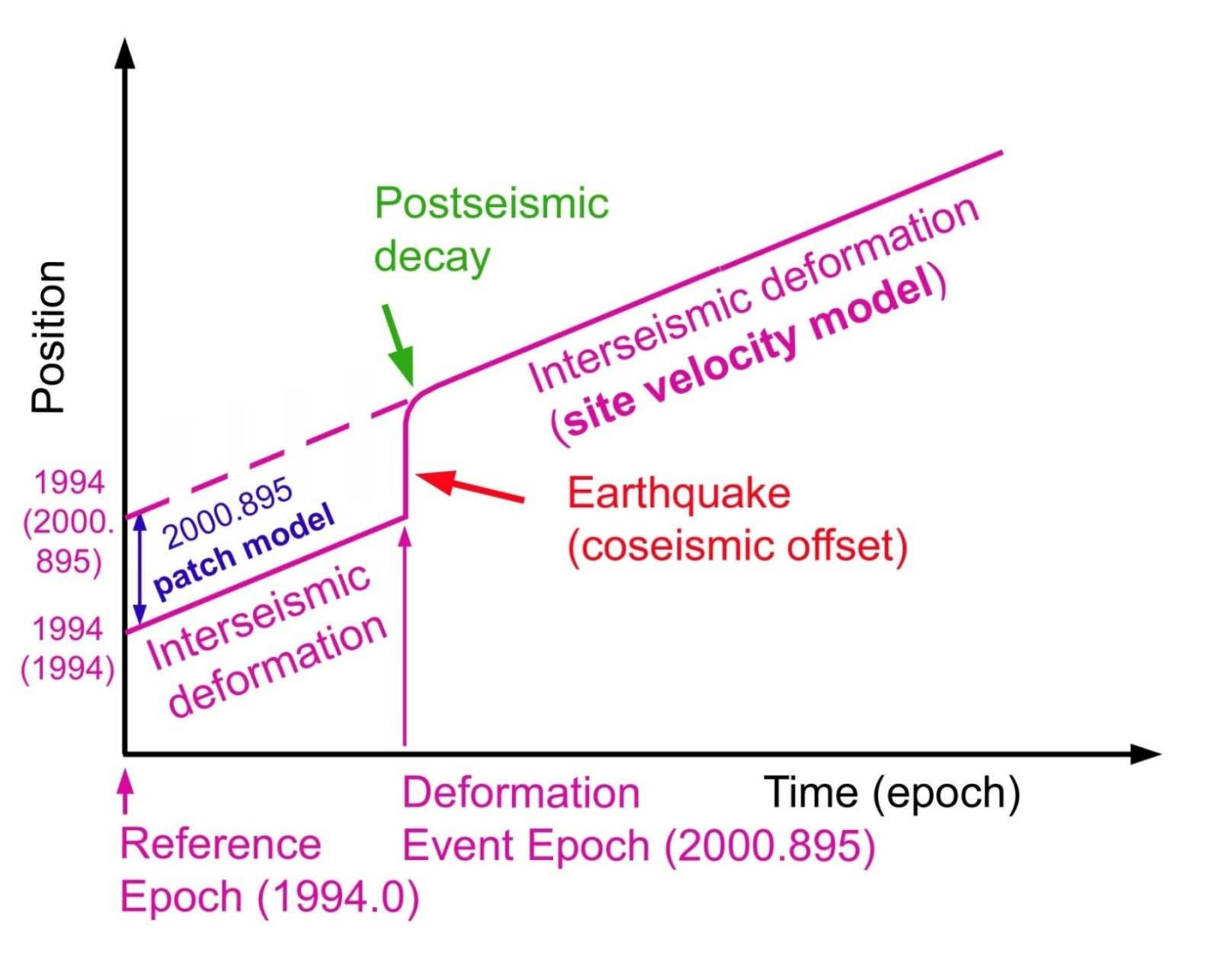


Resulting in improved plate and site velocity model for PNG
Uncertainty of coordinates now 15 mm at 1σ

Deformation characterisation



Semi-kinematic (dynamic) datum concept



Redefinition of PNG94 as a semi-kinematic datum

Quickclose in conjunction with PNG OSG geodetic section have re-computed and densified the PNG94 network to improve formal uncertainties

Implemented a semi-dynamic datum

(deformation model using estimated site velocities from microplate Euler pole, fault locking models and known coseismic offsets) to enable ITRF and WGS84 coordinates to be propagated to epoch 1994.0

PNG94 (ITRF92 at epoch 1994.0) - 1st order control - Adjustment 7th June 2008 - Updated 1st December 2011

Station location			PNG94 Ellipsoidal Coordinates							PNGMG94 Grid Coordinates			MSL RL	ITRF Site Velocity		PNG94	
Location	GPS ID	NMB Number	Latitude			Longitude			Ellipsoid Height	Zone	Easting	Northing	(PNG08)	E m/yr	N m/yr	Latitude Decimal	Longitude Decimal
Aiambak	AIAM	PSM 9550	-7	20	51.8206	141	16	1.4470	95.52	54	529475.73	9187801.94	21.20	0.037	0.058	-7.34772794	141.26706861
Alotau - Gurney Airport	ALT2	PSM 9538	-10	18	37.5094	150	20	18.0912	94.87	56	208478.37	8859053.57	16.37	0.031	0.058	-10.31041928	150.33835867
Bulolo - Unitech Weather	BULO	PSM 32629	-7	12	25.0357	146	37	32.2264	802.11	55	458667.37	9203356.01	722.94	0.027	0.058	-7.20695436	146.62561844
Buka Airport	BUK1	PSM 4871	-5	25	34.3712	154	40	8.4373	73.25	56	684918.22	9399967.57	2.87	-0.059	0.031	-5.42621422	154.66901036
Daru - Airport	DARU	AA 440/A	-9	5	15.5229	143	12	27.1952	80.28	54	742639.83	8994719.42	5.28	0.035	0.055	-9.08764525	143.20755422
Finschhafen	FINS	PSM 19471	-6	36	55.4209	147	51	17.6868	74.24	55	594504.66	9268686.35	7.42	-0.006	0.004	-6.61539469	147.85491300
Gobe - Airport	GOBE	PSM 15262	-6	52	45.5700	143	43	21.3500	129.24	54	800901.00	9238734.50	50.98	0.034	0.054	-6.87932500	143.72259722
Goroka - Airport	GOKA	PSM 9833	-6	4	53.0717	145	23	30.4470	1664.47	55	322023.98	9327531.64	1584.83	0.023	0.046	-6.08140881	145.39179083
Hoskins - Airport	HOSK	PSM 9795	-5	28	0.4073	150	24	31.6614	101.35	56	212869.72	9395119.32	18.42	0.022	-0.027	-5.46677981	150.40879483
Kavieng - Airport	KAVI	PSM 9513	-2	34	53.0660	150	48	22.5361	78.81	56	256077.96	9714464.61	2.85	-0.067	0.027	-2.58140722	150.80626003
Kenabot - Lands Base	KENB	PSM 23342	-4	20	45.1168	152	16	7.9951	136.69	56	418875.65	9519602.79	63.12	-0.002	-0.041	-4.34586578	152.26888753
Kerema - Catholic Mission	KERE	PSM 31703	-7	57	28.0191	145	46	19.0726	97.57	55	364647.58	9120168.45	21.32	0.030	0.052	-7.95778308	145.77196461
Kikori - Airport	KIKO	PSM 5583	-7	25	24.6531	144	14	55.7677	88.93	55	196298.45	9178490.00	12.38	0.035	0.054	-7.42351475	144.24882436
Kiunga - Airport	KIU3	PSM 32685	-6	7	28.3824	141	17	12.2347	112.45	54	531725.31	9323018.83	37.48	0.038	0.056	-6.12455067	141.28673186
Kumul - Oil Export Platform	KU34	Kumul 34	-8	3	51.3916	144	33	38.3558	103.3	54	892563.96	9106883.55	28.22	0.035	0.054	-8.06427544	144.56065439
Lae - Unitech DSLS Base	LAE1	PSM 31107	-6	40	25.3661	146	59	35.4668	140.37	55	499246.79	9262320.80	67.45	0.026	0.052	-6.67371281	146.99318522
Lae - Unitech Sports	9799	PSM 9799	-6	40	16.9707	146	59	52.3754	130.31	55	499765.91	9262578.60	57.40	0.026	0.052	-6.67138075	146.99788206
Lake Kopiago - Airport	KOPI	PSM 17001	-5	23	9.0852	142	29	42.1907	1412.79	54	665650.98	9404480.51	1329.45	0.031	0.055	-5.38585700	142.49505297
Losuia	LOSU	AA 583	-8	32	7.2596	151	7	30.8181	85.16	56	293644.60	9056016.40	5.61	0.021	0.071	-8.53534989	151.12522725
Madang - Airport	MAD1	GS 15495	-5	12	41.2891	145	46	56.1940	73.27	55	365044.17	9423829.87	4.95	0.023	0.039	-5.21146919	145.78227611
Manus - Lombrum Secor	MANU	PSM 9522	-2	3	2.2944	147	21	37.6363	129.77	55	540084.32	9773337.48	50.77	-0.065	0.027	-2.05063733	147.36045453
Mendi - Airport	MEND	PSM 3507	-6	8	36.7344	143	39	22.1658	1815.08	54	793981.21	9320198.80	1732.11	0.029	0.047	-6.14353733	143.65615717
Misima - Airport	MIS1	PSM 9195	-10	41	19.9049	152	49	58.9388	87.46	56	481741.61	8818417.91	12.70	0.030	0.055	-10.68886247	152.83303856
Moro - Airport	MORA	PSM 17442	-6	21	44.9072	143	13	46.0940	917.86	54	746627.49	9296194.53	837.64	0.033	0.054	-6.36247422	143.22947056
Mount Hagen - Airport	HGEN	PSM 3419	-5	49	55.7591	144	18	23.7948	1710.15	55	201725.79	9354636.51	1626.57	0.030	0.048	-5.83215531	144.30660967
Nadzab - Airport	NADZ	ST 31024	-6	33	47.9879	146	43	39.6541	148.83	55	469894.96	9274514.88	76.13	0.024	0.056	-6.56332997	146.72768169
Namatanai - Airport	NAMA	GS 19461	-3	39	58.5422	152	26	6.1582	114.96	56	437261.32	9594742.59	42.81	-0.061	0.001	-3.66626172	152.43504394
Nogoli Hides - Helipad	NOGO	PSM 30041	-5	56	2.4348	142	47	16.7455	1340.2	54	697930.59	9343770.78	1258.04	0.032	0.054	-5.93400967	142.78798486
Pomio	JACQ	PSM 9515	-5	38	42.9782	151	30	19.6067	151.55	56	334476.29	9375795.22	77.26	0.020	-0.053	-5.64527172	151.50544631
Popondetta	POPN	PSM 9371	-8	46	9.6499	148	14	0.3966	187.53	55	635667.54	9030425.34	105.82	0.024	0.054	-8.76934719	148.23344350
Port Moresby - NMB Base	NMB2	PSM 31927	-9	26	2.7697	147	11	12.2000	123.02	55	520498.37	8957148.59	47.17	0.028	0.053	-9.43410269	147.18672222
Rabaul - RVO Base	RVO_	RVO	-4	11	27.1915	152	9	49.5108	266.24	56	407190.52	9536723.33	191.46	0.007	-0.052	-4.19088653	152.16375300
Tabubil - Airport	TAB2	PSM 32695	-5	16	45.0122	141	13	38.9016	559.82	54	525205.42	9416471.93	478.52	0.036	0.055	-5.27917006	141.22747267
Tari - Airport	TARI	T630	-5	50	37.7496	142	56	45.8643	1755.79	54	715472.19	9353687.25	1672.91	0.031	0.053	-5.84381933	142.94607342
Tokua - Airport	TOKU	GS 9822	-4	20	27.7832	152	22	45.8215	82.05	56	431137.64	9520146.01	10.11	-0.010	-0.036	-4.34105089	152.37939486
Tufi - Hospital	TUFI	PSM 7518	-9	4	46.4549	149	19	22.2495	99.44	55	755324.26	8995533.60	20.14	0.027	0.056	-9.07957081	149.32284708
Vanimo - Doppler	VANI	PM 63/1	-2	41	5.2819	141	18	15.6562	80.59	54	533829.65	9703242.49	2.20	0.013	0.045	-2.68480053	141.30434894
Wankkun - Pillar	NM34	NM/J/34	-6	8	52.0739	146	4	52.4422	509.98	55	398344.12	9320370.15	435.85	0.026	0.047	-6.14779831	146.08123394
Wafi - Helipad	WAF1	PSM 32631	-6	51	54.6238	146	26	58.8693	501.56	55	439199.05	9241120.81	425.57	0.032	0.054	-6.86517328	146.44968592
Wau - Airport	WAUA	GS 9840	-7	20	48.5674	146	43	2.8288	1193.56	55	468815.82	9187900.80	1112.92	0.025	0.056	-7.34682428	146.71745244
Wewak - Airport	WEWK	PSM 15497	-3	35	2.5848	143	40	0.1481	83.91	54	796268.18	9603418.22	4.85	0.017	0.053	-3.58405133	143.66670781
Woodlark - Guasopa	GUA1	PSM 9519	-9	13	30.0049	152	56	37.3585	78.64	56	493816.89	8980271.66	1.61	0.020	0.078	-9.22500136	152.94371069
Wuvulu	WUVU	PSM 15456	-1	44	7.5951	142	50	10.0781	79.03	54	704257.66	9808081.66	1.34	-0.068	0.019	-1.73544308	142.83613281

Coordinate list will be updated after completion of Airports Survey

Current PNG94 zero and first order network

New PNG08 “MSLoid”model

EGM2008 model

fitted to observed MSL at limited TG around PNG

2.5’ grid of N values

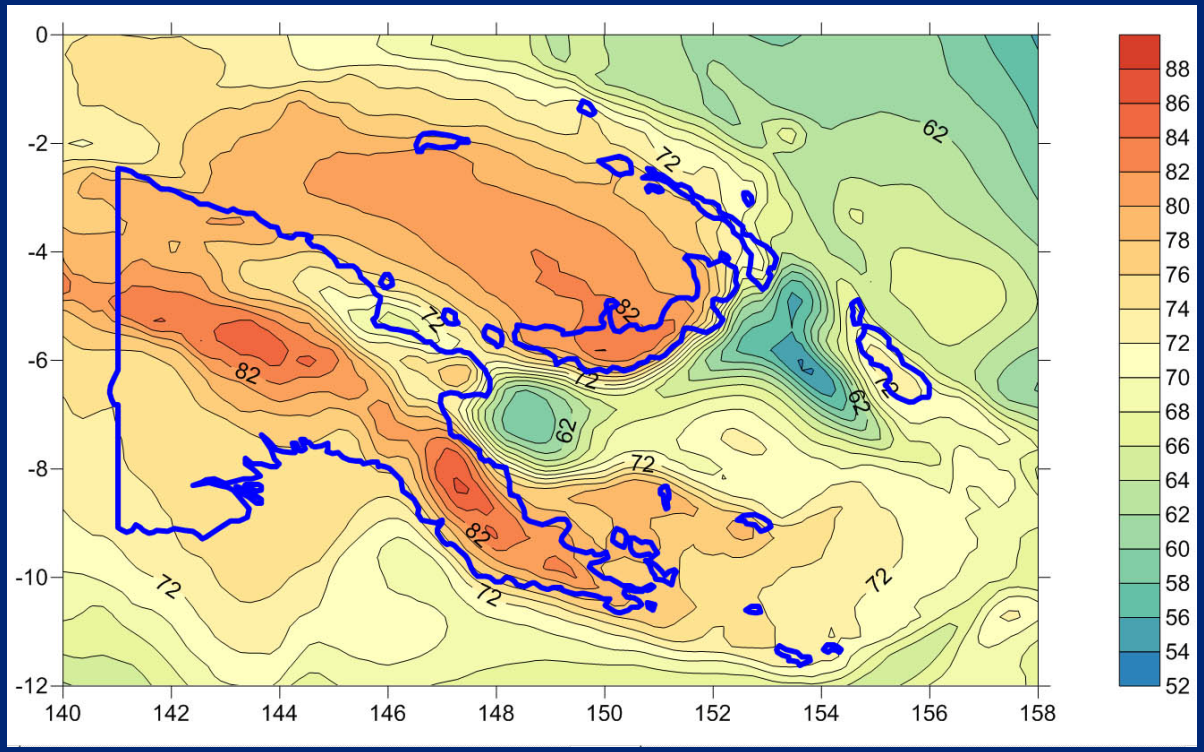
Precision 0.2 m 1σ

ASCII, Leica, Topcon and Trimble formats for use in GNSS and GIS

Future improvements:

Dynamic height model

MDT updates & denser TG



Improved AGD66(PNG) to PNG94 transformation Model

GNSS observations on legacy datum AGD66 primary survey control will enable better transformation parameters to be estimated – e.g. Bevan Rapids origin as required by the PNG *Oil and Gas Act*.

Unfortunately many primary control stations are on remote mountain peaks and are very costly to access / limited utility – so reliance on second and third order control in towns to estimate parameters.

Complicated by overlapping and inconsistent realisations of AGD66 as well as tectonic deformation between 1970 and 1994

PNG94 access on internet

ASPNG web-site

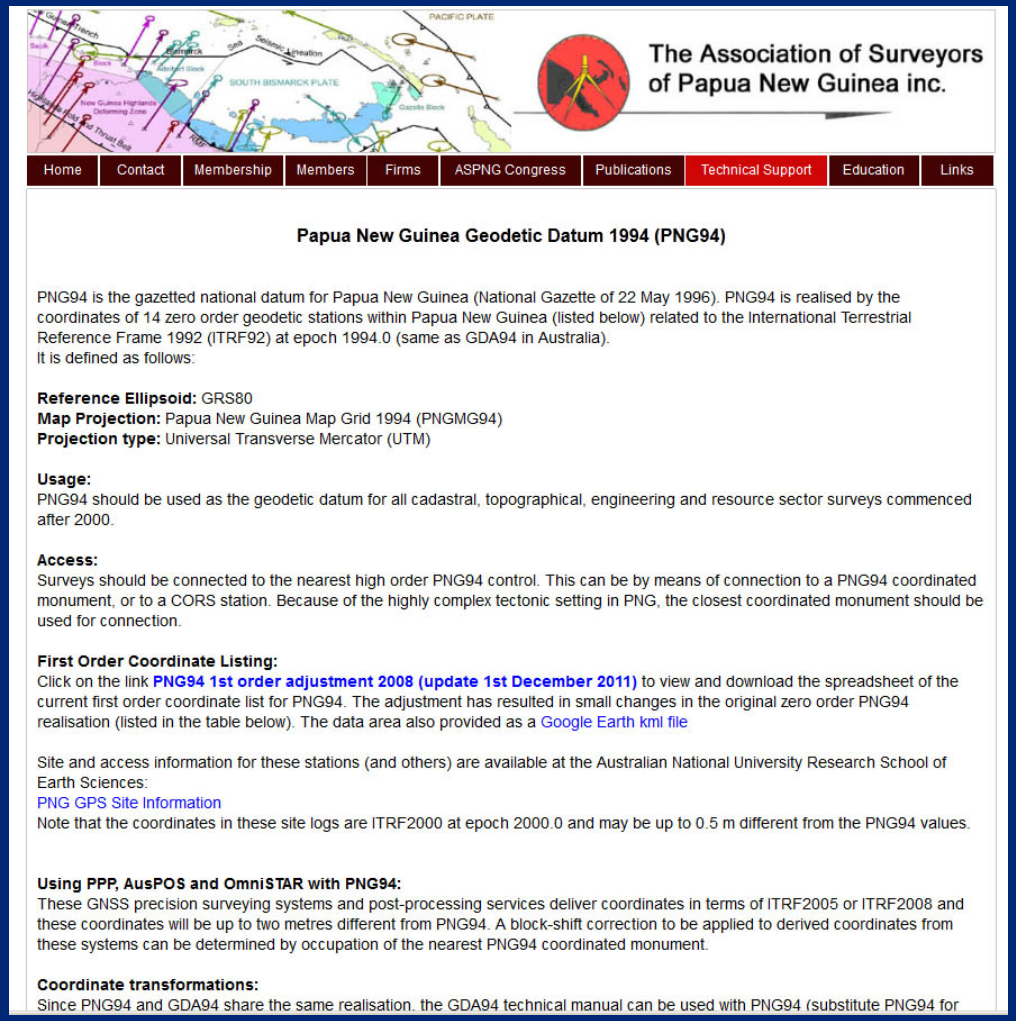
http://www.aspng.org

Coordinate lists

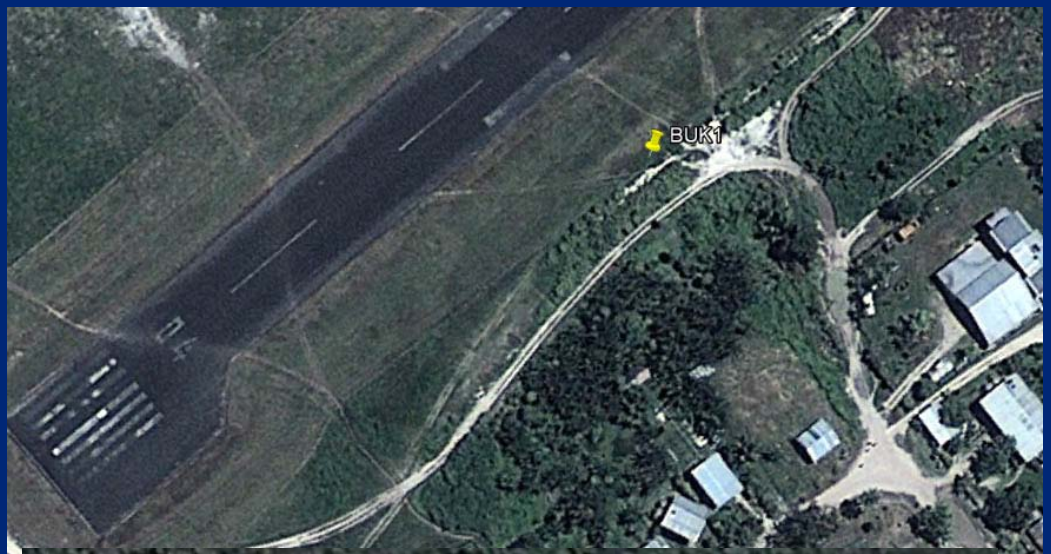
Technical Data

Station diagrams coming soon but many available at

http://rses.anu.edu.au/geodynamics/gps/png/site_info/sitelogs.html



PNG94 1st order control on Google Earth



International - IGS Contributions – LAE1 CORS

LAE1 in operation since 1998 and on IGS network since 2001 – Run by Surveying Dept at PNG Uni of Technology (Unitech)

An important IGS Reference Frame station and used for ITRF

Problems in recent years with software incompatibility with new Windows software and with internet and power outages as well as lack of funding.

Regional Contributions – APREF - NMB2 and WAIG GNSS CORS

PNG Government funded CORS station at NMB **NMB2** in Port Moresby – October 2011

On APREF network and collocated with DORIS beacon

MOSB on IDS network

NMB2 replaced by WAIG in January 2014

Contributions to SPSLCMP

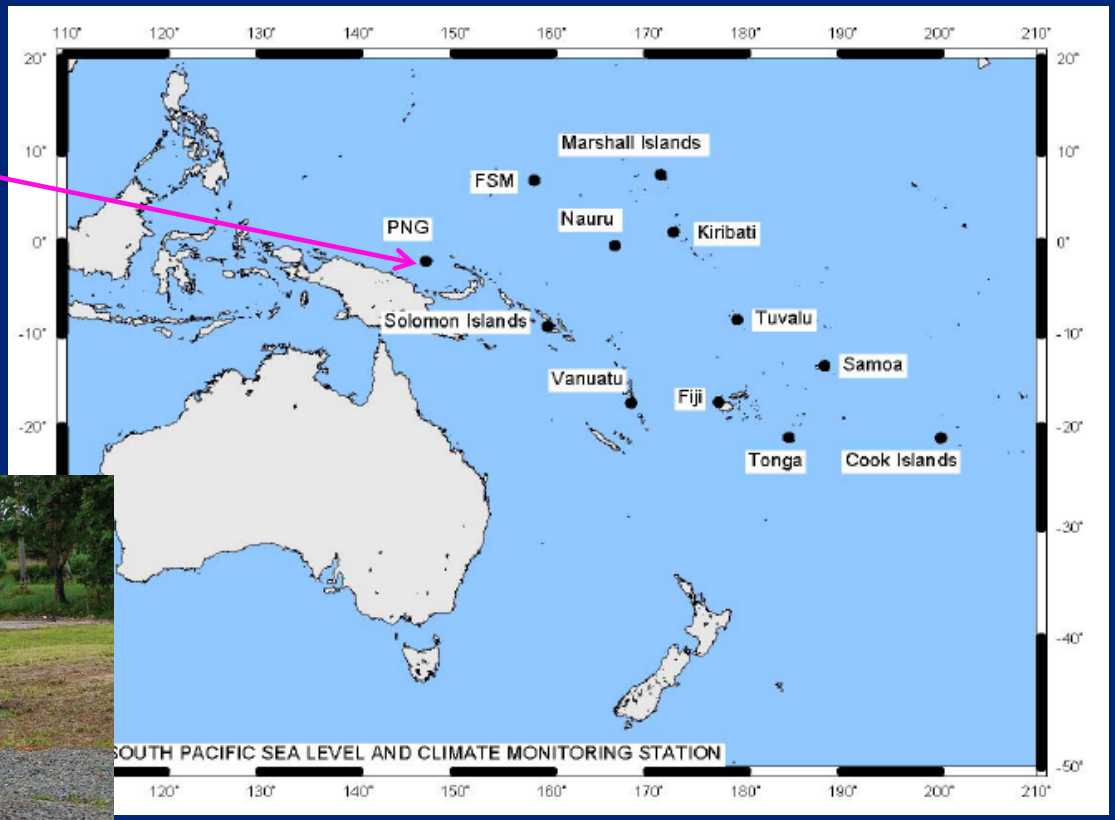
SEAFRAME

Tide Gauge and

CORS at Manus Island

Managed by

Geoscience Australia



Impediments to geodetic surveying in PNG

Insufficient funding from national government to fund geodetic infrastructure. Situation has improved however as there was no funding between 2001 and 2011.

International contractors and consultants not connecting their surveys to PNG94 and established height datum.

adhoc realisation of ITRF and WGS84 leading to inconsistent spatial data and DEM on major projects (by not connecting to PNG94). Increase in "private" and overlapping geodetic networks.

Vandalism of geodetic infrastructure by raskols and landowners

Inadvertent destruction of geodetic control by construction

Unreliable power supply and internet for active CORS operation

Lack of robust transformation parameters between AGD66 and PNG94 leading to 8 metre errors in GIS data (default parameters are often used)

Planned improvements to PNG's datum

Airports survey for PNGASL currently underway (AAM and Arman Larmer Surveys). High precision GNSS survey of 29 major airports in PNG

(Acknowledgements to Carl Nangi and Michael Sury for their work)

Repeat GNSS observations on all geodynamics stations concurrent with airports survey will provide sufficient data for precise site velocity model in PNG (Direct input from scientific studies into the datum)

Gridded velocity and seismic patch model for PNG, to enable PPP and Auspos solutions to be propagated to epoch 1994.0 and to facilitate GNSS post-processing within ITRF using input PNG94 coordinates

Construction of CORS at each major provincial capital to support local GNSS surveys and DCDB updates. This aspect could be run by the private sector as a subscription service to surveyors. RTK corrections by radio link or GSM.

Tide Gauge observations and connections to improve geoid model and develop offset models for Chart Datum, LAT and CDW height datums

What can the geodetic section do for surveyors?

- Provide PNG94 control connection to your survey

  (in some instances this may be free of charge, otherwise charges will be minimal)

- WAIG base station data for surveys in POM, Oro and Central Province

- Process static GNSS data to obtain PNG94 and MSL

  (free or minimal charge on the proviso that a PSM is established and sketch provided)

- Geodetic surveys for resource sector projects

  (charged according to ASPNG scale of fees)

- Provide guidance and PSM numbers (John Oa)

Key personnel: John Kwasi, John Oa (oajgeodesy@gmail.com),
Richard Stanaway (richard.stanaway@quickclose.com.au)

What PNG surveyors can do for PNG Geodesy!

- Connect all your surveys to PNG94 1st order control
- Submit PSM sketches!!! **Many hundreds not provided.**
- Provide GNSS static data on existing 1st order stations (8 hrs + data for these will be processed for free !)

  (email this data to Richard Stanaway at richard.stanaway@quickclose.com.au for free PNG94 derivation until free online processing facility becomes active)
- Maintain survey control and witness posts in your area

  (replace witness posts and do a sketch showing new connections)
- Get PSM numbers for good quality stations

Geodetic PSMs are the fundamental physical infrastructure of PNG!

Options for a new PNG datum - neighbours

2012 option – aligned with Indonesian datum and extensive land border along 141 degrees E (1.2 m offset from 1994)

2020 option? Australian alignment (epoch 2020?) – maritime border – Torres Strait (1.8 m offset from 1994 and 0.6 m offset between 2012 and 2020)

Updated epoch will reduce uncertainties with site velocity and earthquake patch models.

10Q