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

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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)
### What is PNG94?

**Papua New Guinea Geodetic Datum 1994**

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

<table>
<thead>
<tr>
<th>Reference Ellipsoid:</th>
<th>GRS80</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map Projection:</td>
<td>Papua New Guinea Map Grid 1994 (PNGMG94) Zones 54, 55 and 56</td>
</tr>
<tr>
<td>Projection type:</td>
<td>Universal Transverse Mercator (UTM) Southern Hemisphere</td>
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PNG94 Fiducial (zero order) Network

<table>
<thead>
<tr>
<th>Site ID</th>
<th>Site Name</th>
<th>Monument number</th>
<th>PNG94 Latitude</th>
<th>PNG94 Longitude</th>
<th>PNG94 Ellipsoidal Height</th>
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<tbody>
<tr>
<td>MORE</td>
<td>NMB TOWER GPS</td>
<td>PSM 15832</td>
<td>9°26'02.76968&quot;</td>
<td>147°11'12.20017&quot;</td>
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<td>AIAM</td>
<td>AIAMBAK</td>
<td>PSM 9550</td>
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<td>141°16'01.44648&quot;</td>
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<tr>
<td>MIS1</td>
<td>BWAGAIA AIR</td>
<td>PSM 9195</td>
<td>-10°41'19.90490&quot;</td>
<td>152°49'58.93878&quot;</td>
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<td>GOKA</td>
<td>GOROKA</td>
<td>PSM 9833</td>
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<td>145°23'30.44618&quot;</td>
<td>1864.580</td>
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<tr>
<td>ALT2</td>
<td>GURNEY</td>
<td>PSM 9538</td>
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<td>150°20'18.09080&quot;</td>
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<td>KAVI</td>
<td>KAVIENG AIR</td>
<td>PSM 9513</td>
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<td>150°48'22.53578&quot;</td>
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<td>KIKO</td>
<td>KIKORI AIRPORT</td>
<td>PSM 5583</td>
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<td>144°14'55.76611&quot;</td>
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<td>MAD1</td>
<td>MADANG</td>
<td>GS 15495</td>
<td>5°12'41.28824&quot;</td>
<td>145°46'56.19305&quot;</td>
<td>73.293</td>
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<tr>
<td>MANU</td>
<td>MANUS SECOR</td>
<td>PSM 9522</td>
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<td>MENDE</td>
<td>MENDI</td>
<td>PSM 9507</td>
<td>6°06'36.73422&quot;</td>
<td>143°39'22.16540&quot;</td>
<td>1615.154</td>
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<td>9799</td>
<td>UNITECH SPORTS</td>
<td>PSM 9799</td>
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<td>146°59'52.37457&quot;</td>
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<td>YANI</td>
<td>VANIMO DOPPLER</td>
<td>PM 03/1</td>
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<td>141°18'15.65064&quot;</td>
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<tr>
<td>NM34</td>
<td>WANKKUN</td>
<td>PSM 15029</td>
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<td>142°50'10.07846&quot;</td>
<td>79.056</td>
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GPS Campaigns 1992 and 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

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) (1993-2001)
UniTECH and RVO (1996-2008)
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

- Postseismic decay
- Earthquake (coseismic offset)

Diagram showing position over time with reference epoch and interseismic deformation.
Semi-kinematic (dynamic) datum concept

- Postseismic decay
- Interseismic deformation (site velocity model)
- Earthquake (coseismic offset)

- Reference Epoch (1994.0)
- Event Epoch (2000.895)

- 1994
  - (2000, 895)
  - (1994

- 2000.895 patch model

- Time (epoch)
- Position
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

Coordinate list will be updated after completion of Airports Survey

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

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

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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.