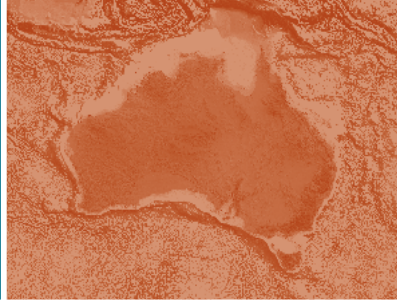




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EDM Height Traversing Levelling Survey Report

Manus Island, Papua New Guinea, September 2012

S. J. K. Yates, A. Lal

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Manus Island, Papua New Guinea, September 2012

GEOSCIENCE AUSTRALIA
RECORD 2014/19

S. J. K. Yates¹, A. Lal²



Australian Government
Geoscience Australia

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1. National Geospatial Reference Systems, Geospatial and Earth Monitoring Division, Geoscience Australia GPO Box 378 Canberra ACT 2601
 2. Secretariat of the Pacific Community (SPC)

Department of Industry

Minister for Industry: The Hon Ian Macfarlane MP

Parliamentary Secretary: The Hon Bob Baldwin MP

Secretary: Ms Glenys Beauchamp PSM

Geoscience Australia

Chief Executive Officer: Dr Chris Pigram

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1 Introduction

This report outlines the high precision levelling survey completed between the Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) tide gauge and Continuous Global Navigation Satellite System (CGNSS) station in Manus Island, Papua New Guinea from 9th to 12th September 2012.

Personnel involved in the survey were Stephen Yates, Project Officer, Geoscience Australia and Andrick Lal, Surveyor, Secretariat of the Pacific Community (SPC).

The Electronic Distance Measuring (EDM) height traversing levelling technique was employed to observe differences in height between the deep benchmark arrays in Manus Island, which runs approximately 1.5 km from the SEAFRAME tide gauge sensor to the continuous operating reference station CGNSS antenna. Previous levelling surveys using this technique have been conducted along the route in 2006, 2007, 2009 and 2010.

In addition, precise differential levelling surveys were performed along the deep benchmark (BM) array from 1994 to 2006 by the National Tidal Centre Australia (NTCA). This report contains a comparison between the 2010 and 2009 EDM height traversing results as well as a combined comparison since the first differential levelling survey in 1994.

2 The Survey

The EDM height traversing levelling survey was carried out between the SEAFRAME tide gauge sensor, continuous CGNSS station and the deep driven bench marks:

PNGMBM	– GNSS Benchmark
PNG14	– SEAFRAME sensor benchmark
PNG1	– Deep Driven Benchmark
PNG2	– Deep Driven Benchmark
PNG29	– Deep Driven Benchmark
PNG30	– Deep Driven Benchmark
PNG3	– Deep Driven Benchmark
PNG31	– Deep Driven Benchmark

All the deep bench marks were located and found in good order and undisturbed. Also included in the survey were temporary holding marks PNG26, PNG28, PNG34 and PNG100. The benchmark, PNG20 (Iron bolt adjacent to the Tide Gauge Hut) was found disturbed therefore it was replaced with PNG101 (stainless steel bolt in concrete – radar sensor bolt)

The EDM height traversing levelling technique was performed to the Class L2A specifications (ICSM, Standards and Practices for Control Surveys). After reduction an internal precision of $1\text{mm}\sqrt{K}$ or better was achieved (zero order); well within the specifications of the project which is $2\sqrt{K}$ where K is the distance in kilometres. A table of results and comparisons and the 2012 reduced levels are detailed later in this report.

2.1 Bench Mark Locality Diagram



2.2 The Manus Island Datum

The Datum for the survey is Tide Staff Zero (TSZ). Reduction of the data has been computed holding PNG1 fixed at 2.2987675 metres. This value was determined by the NTCA by adopting the Tide Staff Zero (TGZ) from the 1994 survey.

2.3 Equipment

- Leica total station model TM30 (Serial No: 361441)
- Leica precision prisms GPH1P (2).
- Leica rigid tripod.
- Stainless steel target poles supported by Leica telescopic bi-poles (2).
- Shortened stainless steel target pole for the SEAFRAME sensor BM connection.
- Leica cast iron change plates (2).
- Kestral 4000 pocket weather tracker

2.4 Method

The “Leap-Frog” EDM height traversing technique was employed for the Manus Island tide gauge levelling survey. This technique involves setting up a total station (TCA1800L) midway between two target/reflectors (on reflector rods with struts). The targets remain at a particular change point for the

back-sight and fore-sight observations. The instrument measures slope distances ($\pm 1\text{mm}$) and vertical angle ($1''$) to derive height differences (between the instrument's trunnion axis and the reflectors). In support of the slope distance observations, the ambient temperature, pressure and humidity are recorded (Kestral 4000 pocket weather tracker) and input into the instrument to apply the first velocity correction to the observed distances (Rüeger & Brunner, 1982). Four rounds of observations are taken to the back-sight and fore-sight targets from each instrument setup. All levelling runs started and finished with the same reflector and reflector rod, i.e. an even number of setups when the two reflector rod configuration was used. This eliminates any reflector rod zero error. This technique can also be performed using a single set-up / single rod configuration which is particularly useful when levelling between bench marks which are close together e.g. between the CGNSS RMs.

Reduction of the digital data was computed by the Geoscience Australia levelling program "leveling1.exe". This program computes the height difference between the two reflectors.

2.5 Manus Island 2012 Reduced Levels

Table 2.1 Manus Island, Papua New Guinea – Reduced levels 2012 survey

Date: 9th – 12th September 2012

Datum: Tide Staff Zero (TSZ) (1994)

Point ID	Reduced Level	Type
PNG1	2.2988	Stainless Steel Rod in Ground
PNG29	4.4804	Stainless Steel Rod in Ground
PNG34	8.5051	Stainless Steel Pin in Concrete
PNG26	26.2898	Stainless Steel Pin in Concrete
PNG3	34.1474	Stainless Steel Rod in Ground
PNG28	31.1332	Stainless Steel Pin in Concrete
PNG31	33.1101	Stainless Steel Rod in Ground
PNGMBM	37.6893	Stainless Steel Pillar Pin
*PNGM	38.6505	Pillar Plate (ARP)
PNG100	3.3066	Stainless Steel Pin in Concrete
PNG2	2.4957	Stainless Steel Rod in Ground
PNG101	3.2889	Threaded Stainless Steel Bolt
PNG14	4.5790	Stainless Steel Pin
PNG30	3.2879	Stainless Steel Rod in Ground
RM1	35.8871	Stainless Steel Rod in Ground
RM2	37.3137	Stainless Steel Rod in Ground
RM3	37.6004	Stainless Steel Rod in Ground
PNGM_MET	37.1943	Top of Met Station

**The RL of the Reference Point PNGM (ARP) is derived from adding the static height difference of 0.9612 m (PNGMBM to PNGM) to the levelled RL of PNGMBM.*

2.6 Survey Support

The survey team very much appreciated the assistance from staff of Lombrum Naval base, Manus Provincial Administration and the Manus Island Weather Service Office.

Personnel consulted during the visit were:-

- Mr. Kanawi Sindol –Assistant Administrator, Manus Provincial Administration
- Mr. Piten Nama –Manus Provincial Surveyor
- Mr. Hymson Waffi – Officer In Charge, Manus Island Weather Service, Momote Aiprort
- Mr Alois Tinglei – Survey Assistant, Manus Provincial Survey Office
- Mr Mark Mohe – Electronics Technician, Papua New Guinea Defence Force, Lombrum, Manus Island. Phone (675) 71958058 Fax (675) 9701002

All personnel consulted had a keen interest in the project and were always supportive with any project associated matters.

2.7 Issues and Correspondence

All project personnel must ensure that prior approval is required for entry into Lombrum Naval Base (PNG Defence Force) from the Commander; the local focal point have to be notified upon every visit to arrange for clearance into the Naval Base.

All correspondence and clearance to the Site was arranged via Mr. Kanawi Sindol.

The survey equipment was freighted via DHL to Mr Hymson Waffi of Manus Island Weather Service Office.

The vehicle used in the survey for commuting from Lorengau to Lombrum was hired from Travel Car Ltd.

3 Comparisons

3.1 Comparisons between 2012 and 2010 EDM Surveys

Table 3.1 Manus Island, PNG 2012 EDM Height Traversing Levelling & Comparison 2012 - 2010. PNG1 - adopted fixed height OF 2.29877m

From	To	Levelled Ht. Diff.	RL 2012	Misclose (mm)	Dist. (km)	1mm√k	RL 2010	Difference (mm) 2012 - 2010
PNG1			2.29877				2.2988	
PNG29	PNG29	2.18160	4.48037	0.338	0.178	0.422	4.4799	0.47
PNG34	PNG34	4.02472	8.50509	0.324	0.115	0.340	8.5011	3.99
PNG26	PNG26	17.78475	26.28984	0.050	0.205	0.453	26.2869	2.94
PNG3	PNG3	7.85759	34.14743	0.425	0.183	0.427	34.1459	1.53
PNG28	PNG28	-3.01424	31.13318	-0.063	0.105	0.324	31.128	5.18
PNG31	PNG31	1.97687	33.11005	-0.038	0.073	0.271	33.1032	6.85
	PNGMBM	4.57929	37.68934	0.150	0.070	0.265	37.6851	4.24
PNG1			2.29877				2.2988	
PNG100	PNG100	1.00784	3.30661	-0.093	0.103	0.321	3.3073	-0.69
	PNG2	-0.81095	2.49566	0.325	0.162	0.402	2.4963	-0.64
PNG1			2.29877				2.2988	
PNG101	PNG101	0.99009	3.28886	-0.138	0.147	0.383	NEW MARK	NEW MARK
	PNG14	1.29015	4.57901	-0.150	0.016	0.128	4.5801	-1.09
PNG34			8.50509				8.5011	
	PNG30	-5.21715	3.28794	-0.190	0.050	0.223	3.2866	1.34
			Misclosure for all bays levelled =	0.942	1.407	1.186		
PNGMBM			37.68934				37.6851	4.21
	RM1	-1.80224	35.88710	0.060	0.025	0.158	35.8825	4.63
PNGMBM			37.68934				37.6851	4.21
	RM2	-0.37561	37.31373	-0.018	0.023	0.153	37.3096	4.10
PNGMBM			37.68934				37.6851	4.21
	RM3	-0.08892	37.60043	-0.170	0.024	0.155	37.5958	4.64
PNGMBM			37.68934					
	PNGM_MET	-0.4950	37.19429	-0.050	0.064	0.253	NEW MARK	NEW MARK

All levelling was performed within the project specifications of 2√k

3.2 Combined Comparisons 1994 to 2012

Table 3.2: Manus Island, PNG - Comparison of the RL's for Precise Differential Levelling (1994 - 2006) and EDM Height Traversing (2006 - 2012). Units are in millimetres (mm)

Year	PNG1	PNG2	PNG3	PNG14	PNG29	PNG30	PNG31	PNGMBM
1994	0.0000	0.0000	0.0000	0.0000				
1995	0.0000	-0.0300	-1.0300	-0.8800				
1997	0.0000	-0.4800	-1.7500	-2.6800				
1998	0.0000	0.1900	-0.9900	-1.4100				
2000	0.0000	-0.0200	-0.5300	-1.9000				
2002.4	0.0000	-0.1900	-0.5200	-1.8600	0.0000	0.0000	0.0000	0.0000
2003.7	0.0000	-4.9500	-0.3900	-2.7900	0.0800	0.5200	3.3500	2.5400
2006.1	0.0000		0.5100	-0.9400	0.5900		1.8300	1.3900

Year	PNG1	PNG2	PNG3	PNG14	PNG29	PNG30	PNG31	PNGMBM
2006.1	0.0000		1.7900	-1.6300	0.8800		3.3800	3.3000
2007.7	0.0000	-5.0500	1.4200	-2.0600	0.3100	0.3800	3.0100	2.2300
2009.5	0.0000	-5.0500	0.3200	-1.2000	0.5100	0.4800	1.2100	0.6300
2010.9	0.0000	-4.7040	-0.1820	-1.1605	0.6800	0.5250	-1.6985	-1.0415
2012.6	0.0000	-5.3885	1.3480	-2.2915	1.1815	1.8180	5.1625	3.1705

Note 1 - PNG2 was not levelled in 2006

Note 2 - Unable to locate PNG30 in 2006

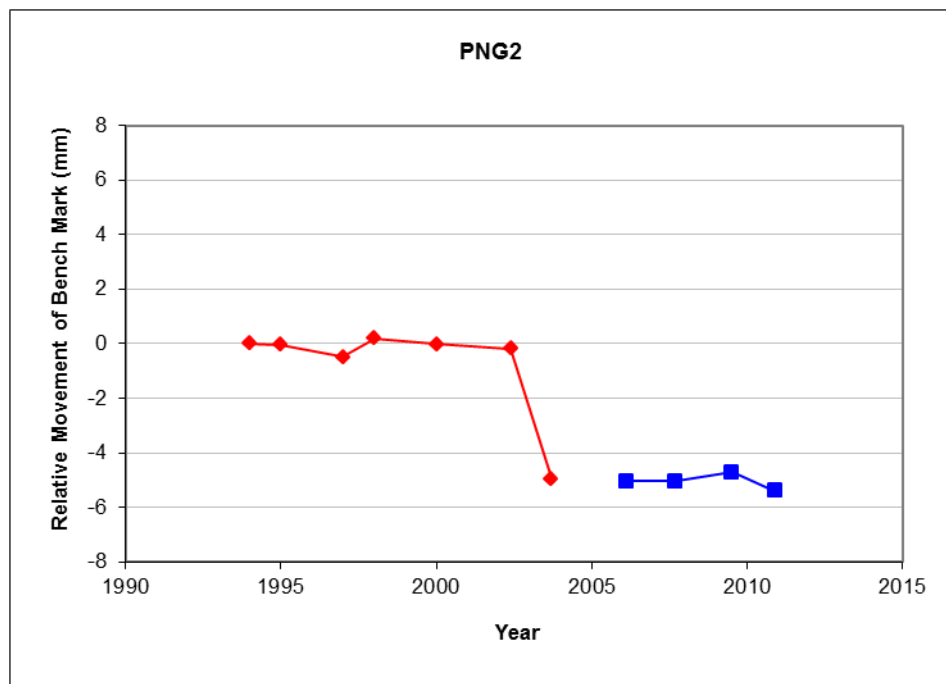
*The RL of the Reference Point PNGM (ARP) is derived from adding the static height difference of 0.9612 m (PNGMBM to PNGM) to the levelled RL of PNGMBM

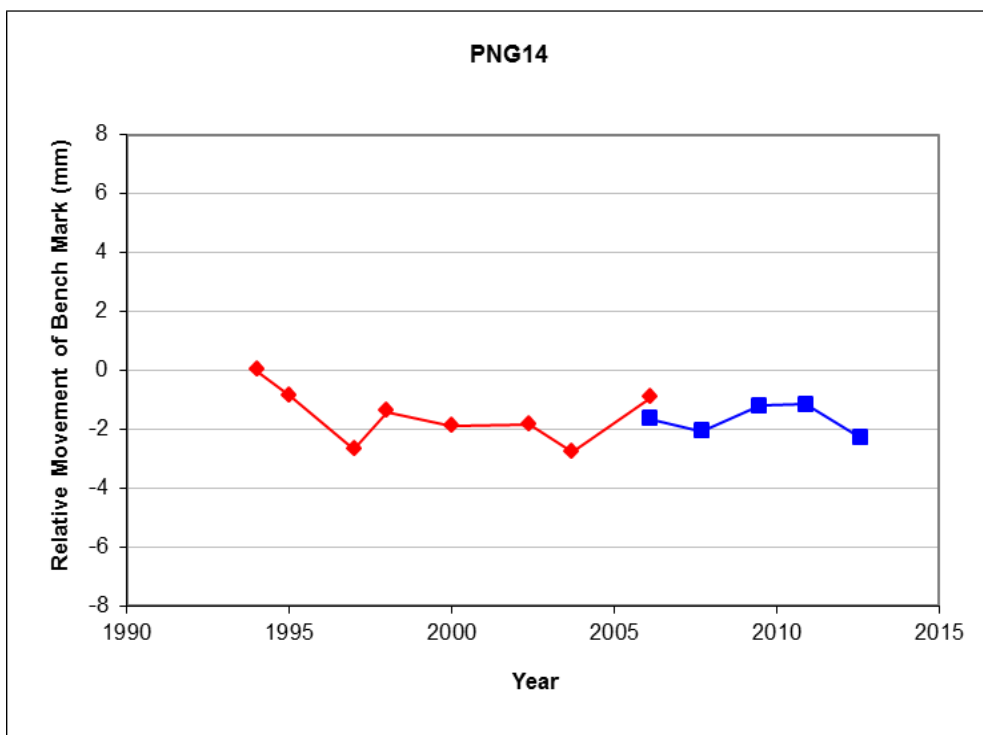
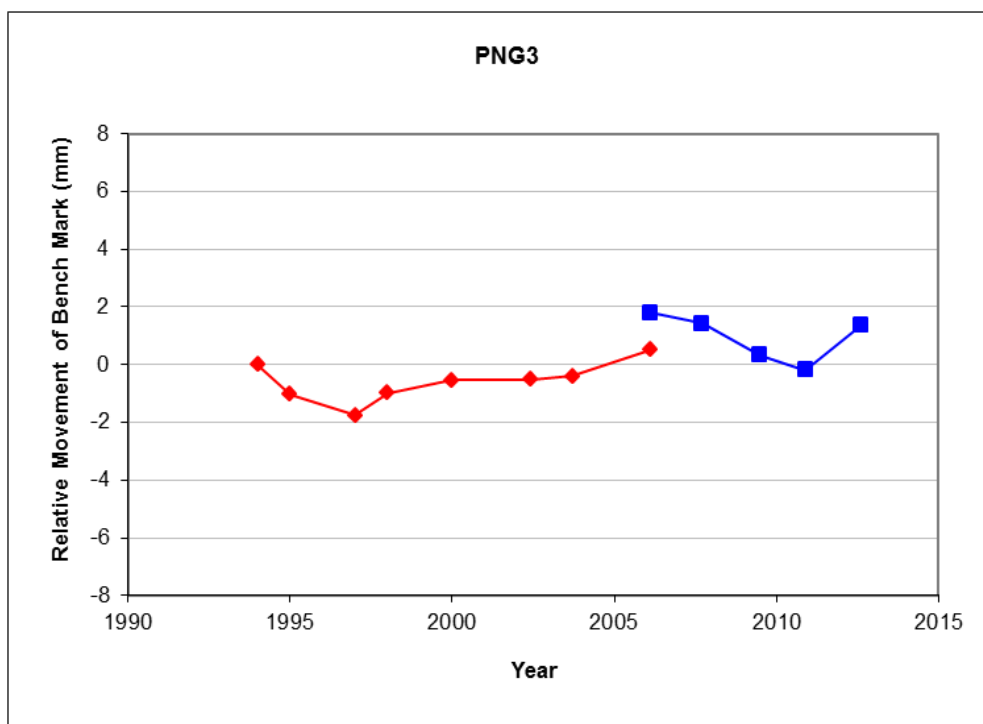
3.3 Time Series of Bench Mark Movement relative to Fixed Deep Bench Mark PNG1

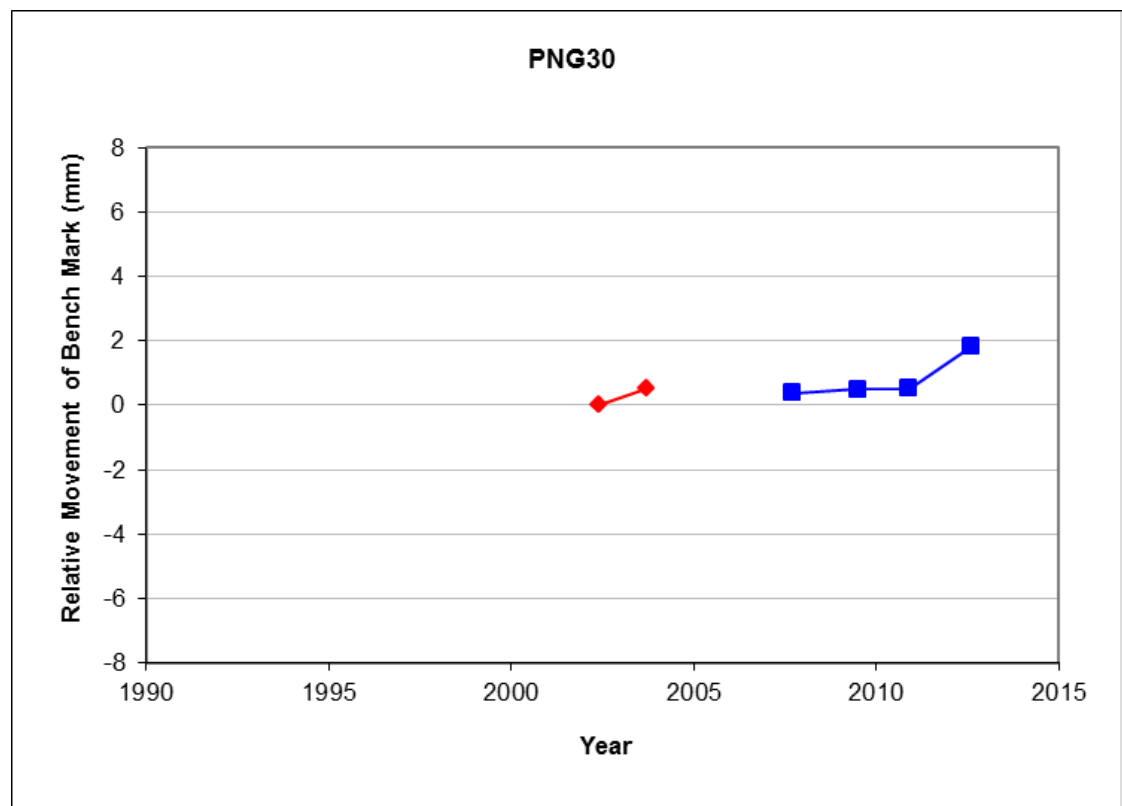
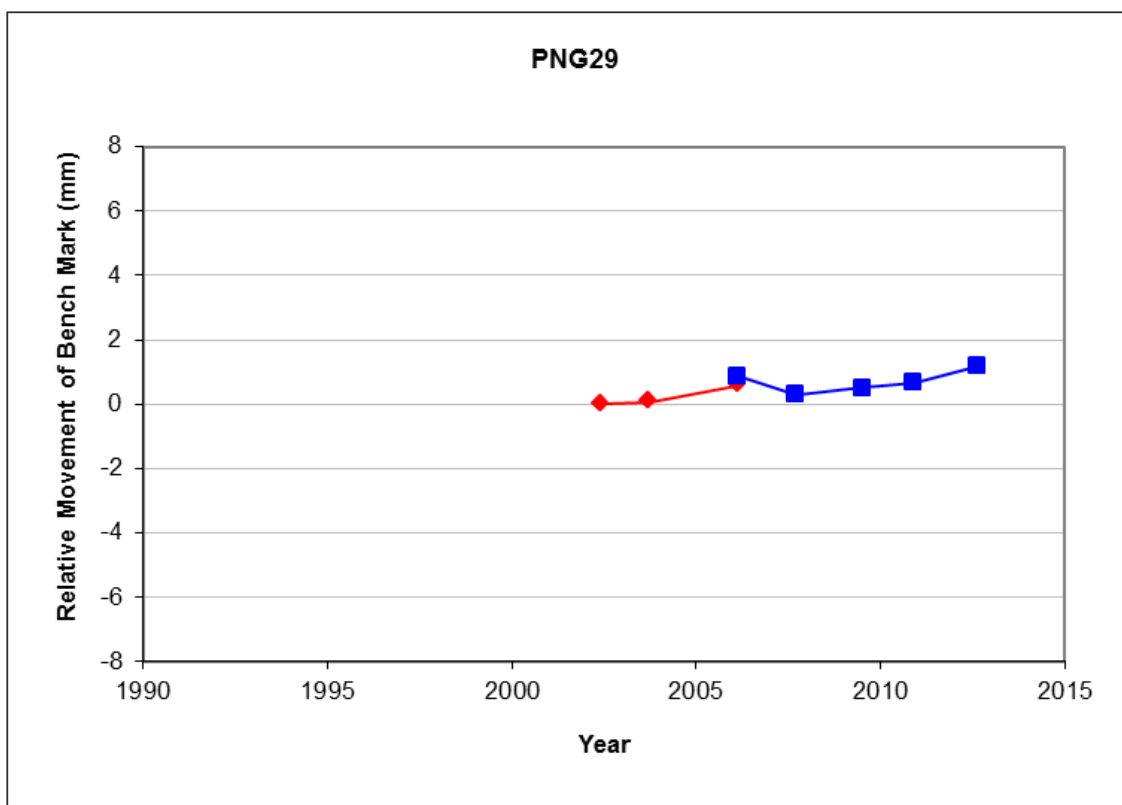
The purpose of this survey is twofold: firstly, to provide accurate changes in land height to be used in computations of absolute sea level rise and secondly to provide accurate assessments of relative sea level changes due to localised deformation.

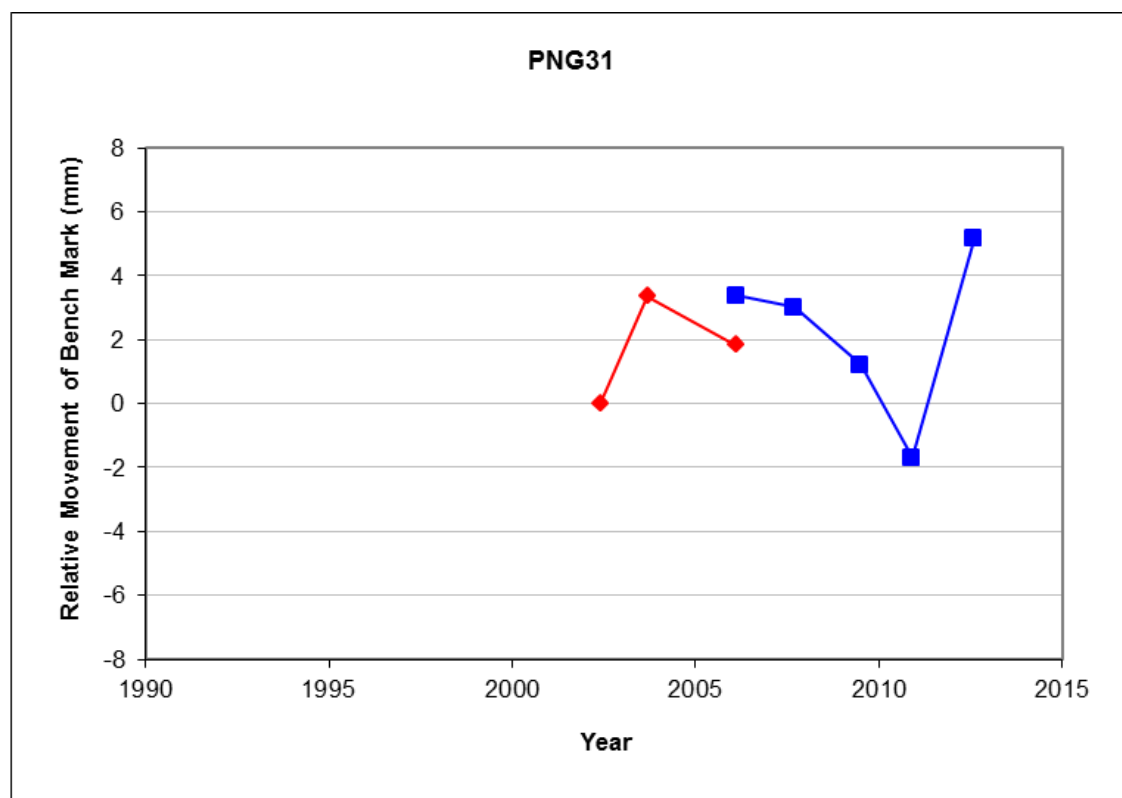
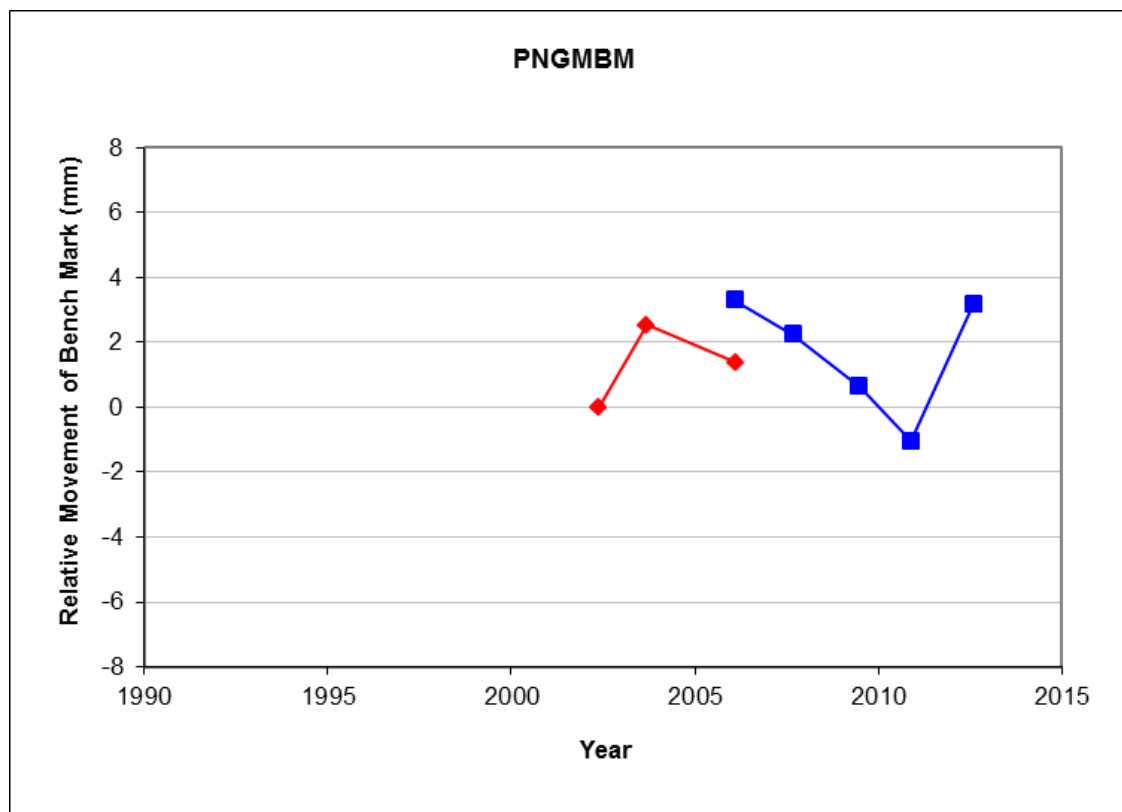
Note: PNG31, PNGMBM, RM1, RM2 and RM3 – All these sites are within close proximity of each other near the CGNSS Site. Results showed a ~5mm drop since 2006, but 2012 survey have showed that these marks have rebounded to ~ 4.5mm uplift in the time series of PNG2, PNG3, PNG14, PNG29 and PNG30.

Precise Differential Levelling: 1993 - 2004 ◆ —◆
EDM Height Traversing: 2004 onwards ◆ —◆









4 Deep Driven Bench Mark Locality Diagrams

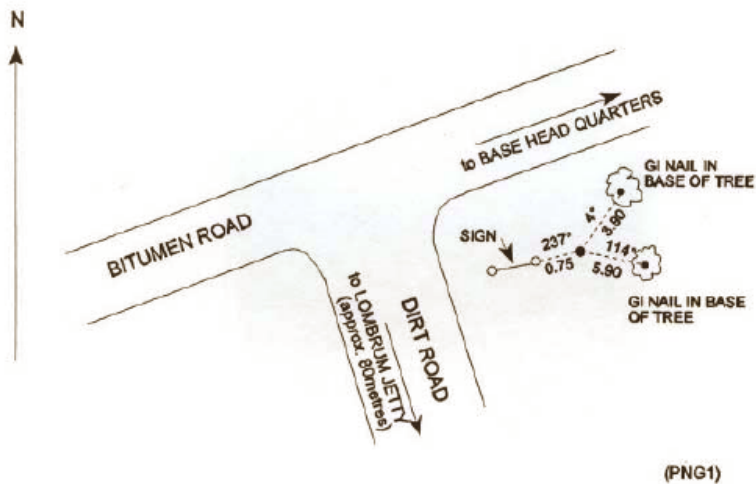


SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT



Survey Bench Mark Record

Bench Mark Number: PNG1

Original Bench Mark Established by: National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.		Date: 26-09-94
Existing Bench Mark Established by:		Date:
Notes / References: Deep Survey Benchmark This survey mark is not in a good locality GPS occupation.		
Country: Papua New Guinea Island: Manus Island		City: Lombrum
<u>Marking and locality sketch</u> Bench Mark: 4.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level. Locality sketch: Mark approximately 150m from the tide gauge station.  (PNG1)		
Not to scale	Distances in Metres	Magnetic bearings
Approved by: Geoscience Australia / SOPAC		Date: April 2006



**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: PNG2

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 26-09-94
<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.	
<i>Country:</i> Papua New Guinea <i>Island:</i> Manus Island	<i>City:</i> Lombrum
<u>Marking and locality sketch</u> Bench Mark: 2.0m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.1m below ground level. Locality sketch: Mark approximately 500m from the tide gauge station. (PNG2)	
Not to scale	Distances in Metres
Magnetic bearings	
Approved by: Geoscience Australia / SOPAC	
Date: April 2006	



**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: PNG3

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 27-09-94
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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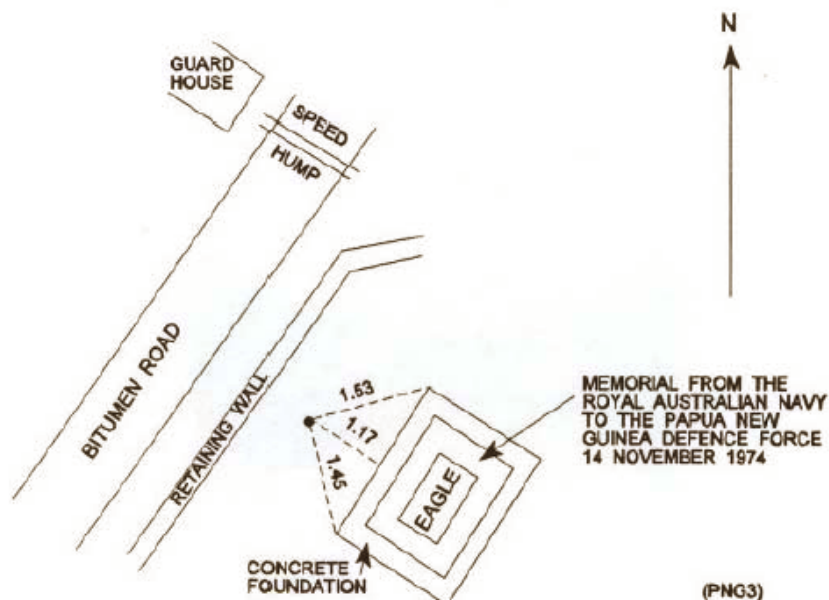
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Papua New Guinea <i>Island:</i> Manus Island	<i>City:</i> Lombrum
---	----------------------

Marking and locality sketch

Bench Mark: 3.0m of 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 800m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
Approved by: Geoscience Australia / SOPAC		Date: April 2006



**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: PNG29

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 09-05-02
<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.	
<i>Country:</i> Papua New Guinea <i>Island:</i> Manus Island	<i>City:</i> Lombrum
<u>Marking and locality sketch</u> Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level. Locality sketch: Mark approximately 320m from the tide gauge station. The diagram is a schematic map. A vertical line on the left is labeled 'ROAD'. To its right is a 'STORAGE AREA FOR FROZEN FOOD'. Further right is a 'NISSAN HUT'. Below the storage area, a horizontal line represents a 'CONCRETE DRAIN'. A point labeled 'PNG29' is marked on this drain, with a vertical line segment labeled '1.20' indicating its depth. Another horizontal line below the first drain is also labeled 'CONCRETE DRAIN'. At the bottom, a horizontal line is labeled 'MAIN ROAD'. An arrow on the left points 'FROM CGPS STN' and an arrow on the right points 'TO TIDE GAUGE'. A horizontal distance of '1.10' is marked between the storage area and the Nissan hut.	
Not to scale Distances in Metres Magnetic bearings	
Approved by: Geoscience Australia / SOPAC Date: September 2006	



**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: PNG30

<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 09-05-02
<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.	
<i>Country:</i> Papua New Guinea <i>Island:</i> Manus Island	<i>City:</i> Lombrum
<u>Marking and locality sketch</u> Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level. Locality sketch: Mark approximately 500m from the tide gauge station.	
Not to scale Distances in Metres Magnetic bearings	
Approved by: Geoscience Australia / SOPAC Date: September 2006	



**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: PNG31

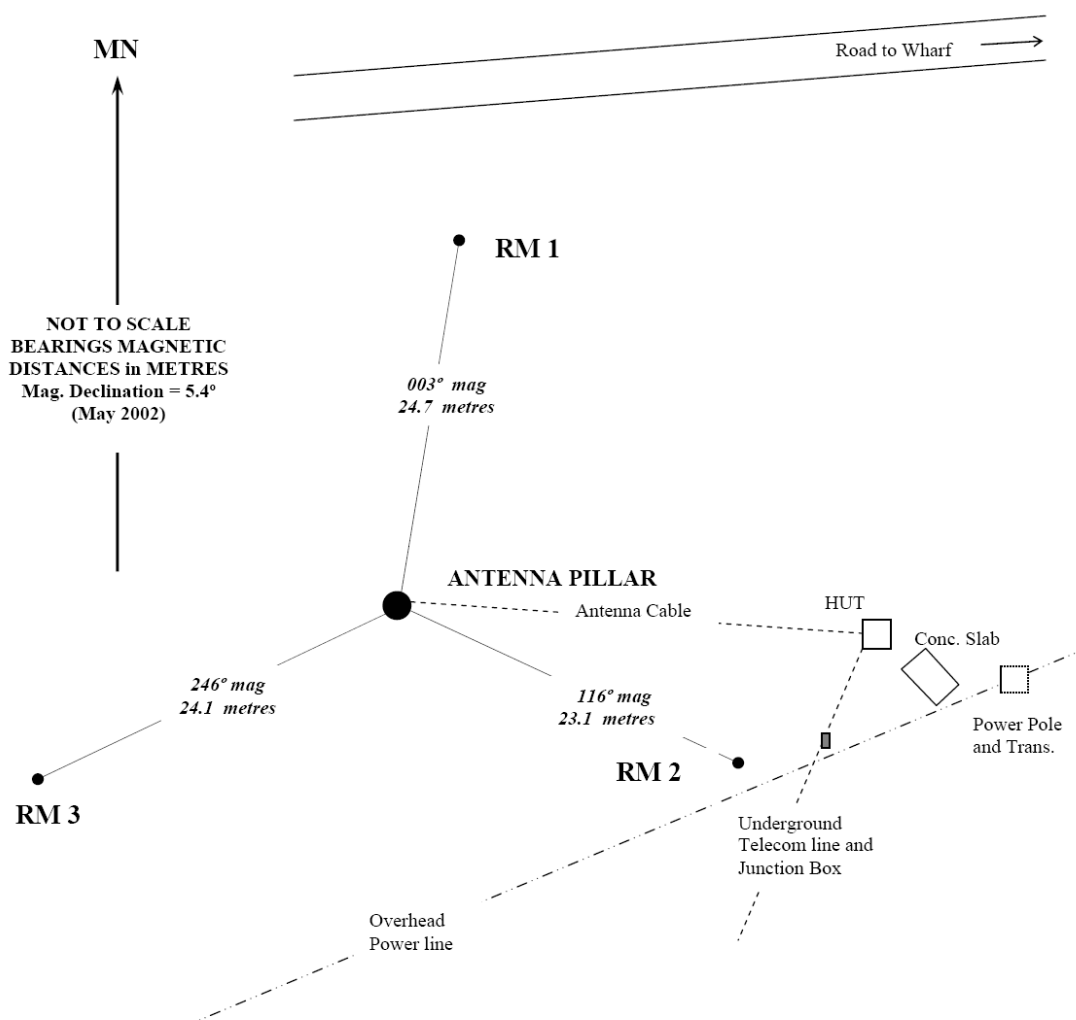
<i>Original Bench Mark Established by:</i> National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA.	<i>Date:</i> 09-05-02
<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.	
<i>Country:</i> Papua New Guinea <i>Island:</i> Manus Island	
<i>City:</i> Lombrum	
<u>Marking and locality sketch</u> Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.4m. Top of mark 0.2m below ground level. Locality sketch: Mark approximately 1000m from the tide gauge station. CHAPEL OF SAINT NICHOLAS CHURCH STEPS DOWN RETAINING WALL CONCRETE SLAB RETAINING WALL 0.63 1.21 ● PNG31 TO CGPS STATION MAIN ROAD TO TIDE GAUGE CGPS COMPOUND	
Not to scale Distances in Metres Magnetic bearings	
Approved by: Geoscience Australia / SOPAC	
Date: September 2006	

5 PNGMBM and PNGM Reference Mark Locality Diagrams

PNG CGPS Station, Lombrum, Manus Is. – Reference Marks

REFERENCE MARKS

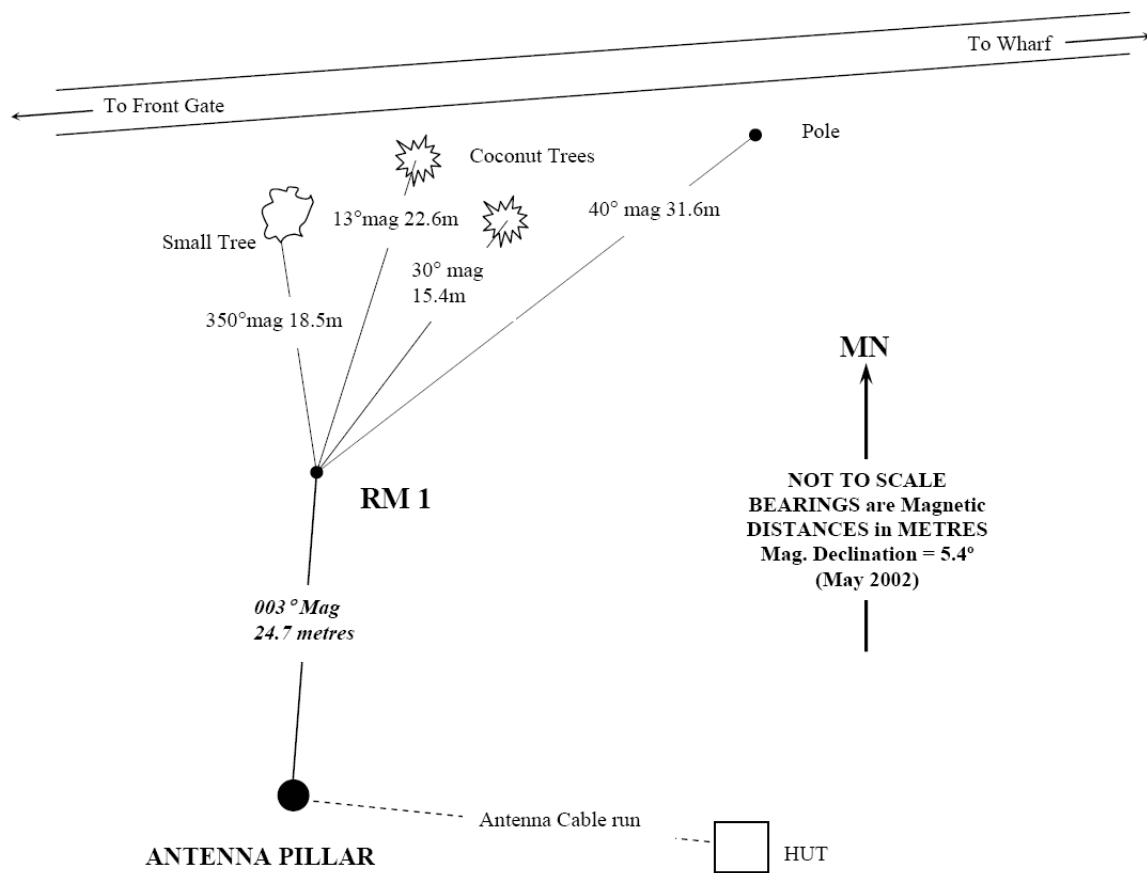
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



PNG CGPS Station, Lombrum, Manus Is. – RM 1

REFERENCE MARKS

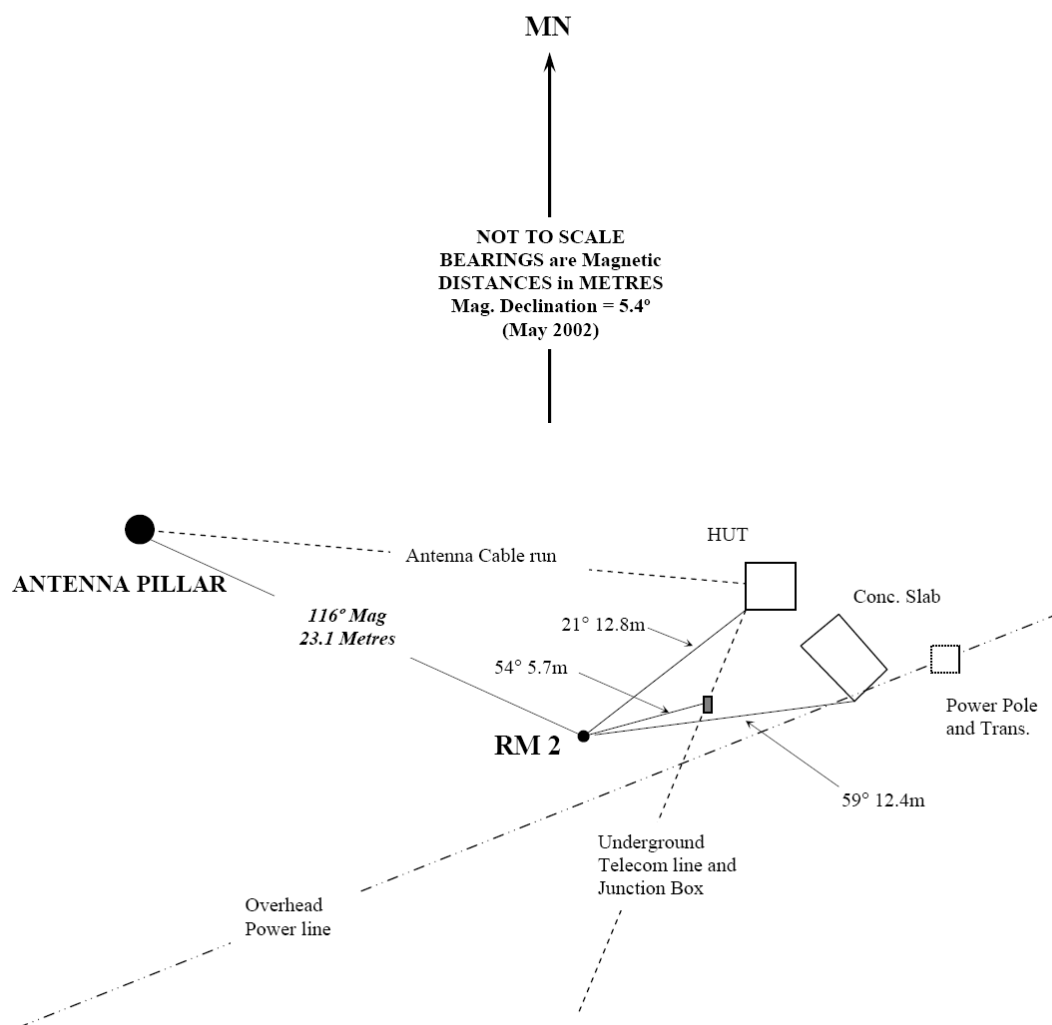
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



PNG CGPS Station, Lombrum, Manus Is. – RM 2

REFERENCE MARKS

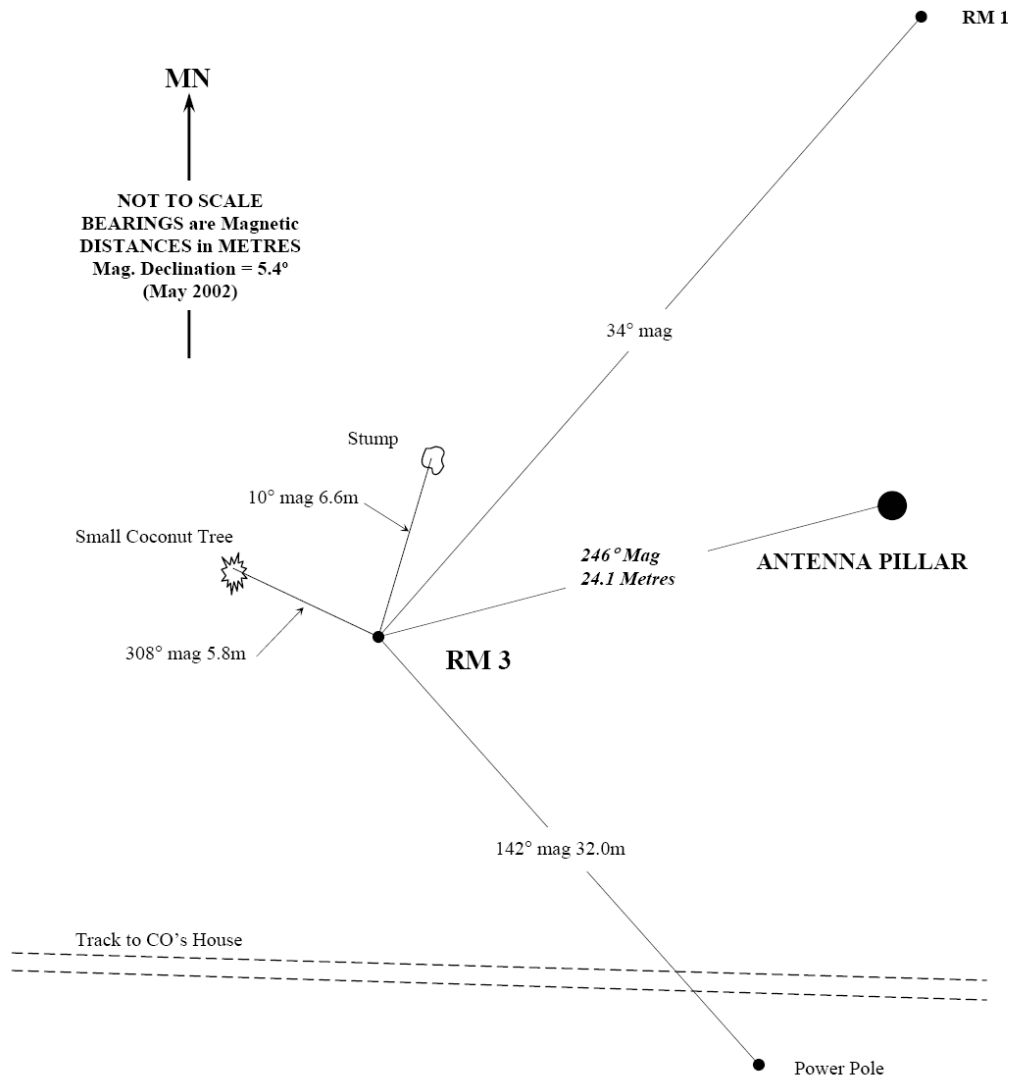
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



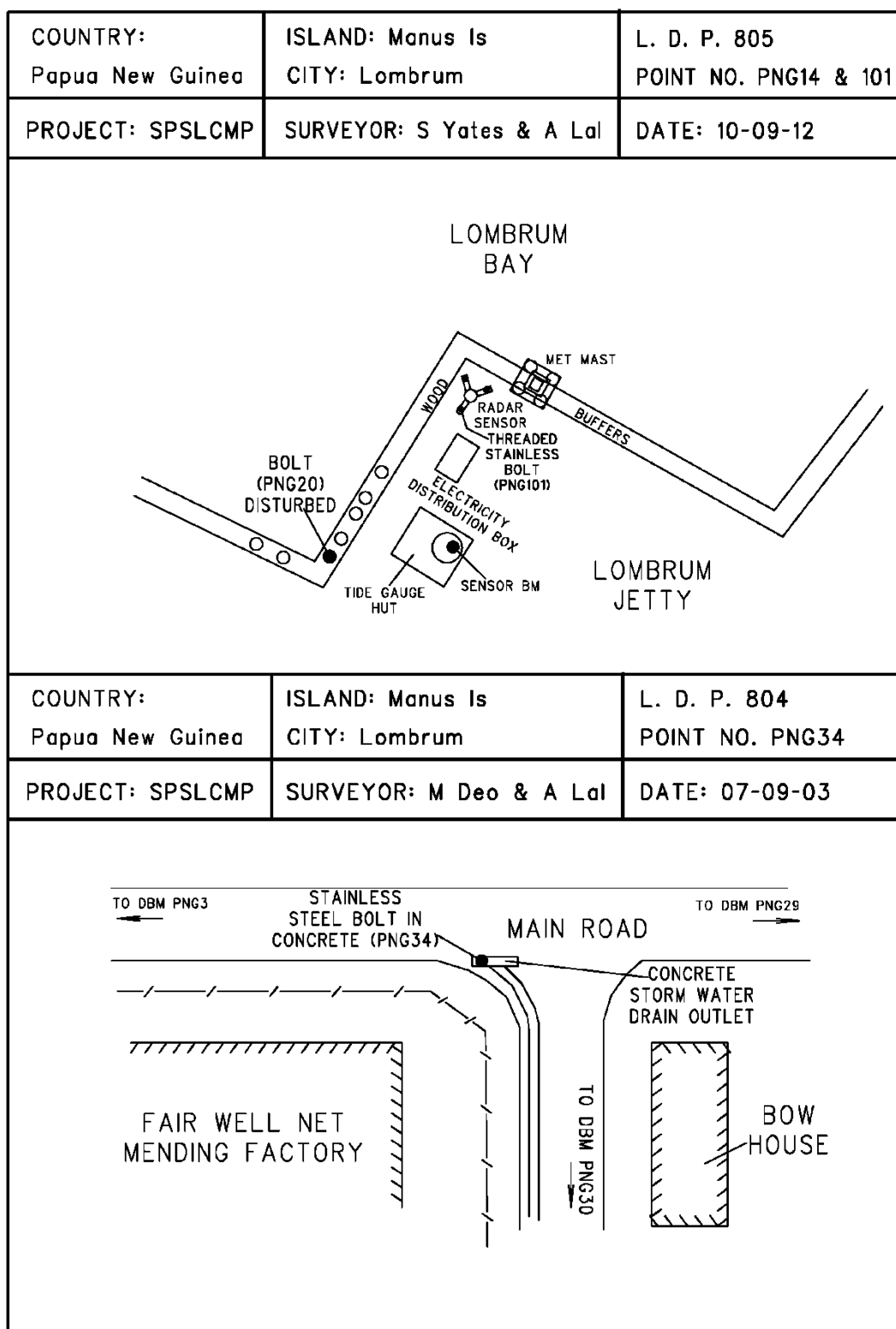
PNG CGPS Station, Lombrum, Manus Is. – RM 3

REFERENCE MARKS

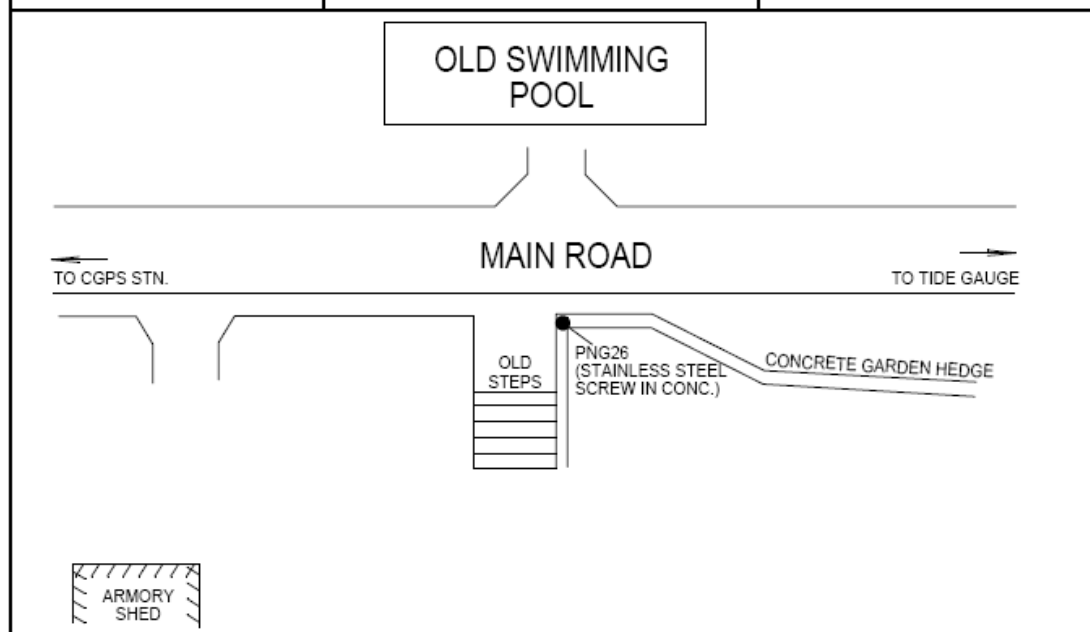
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



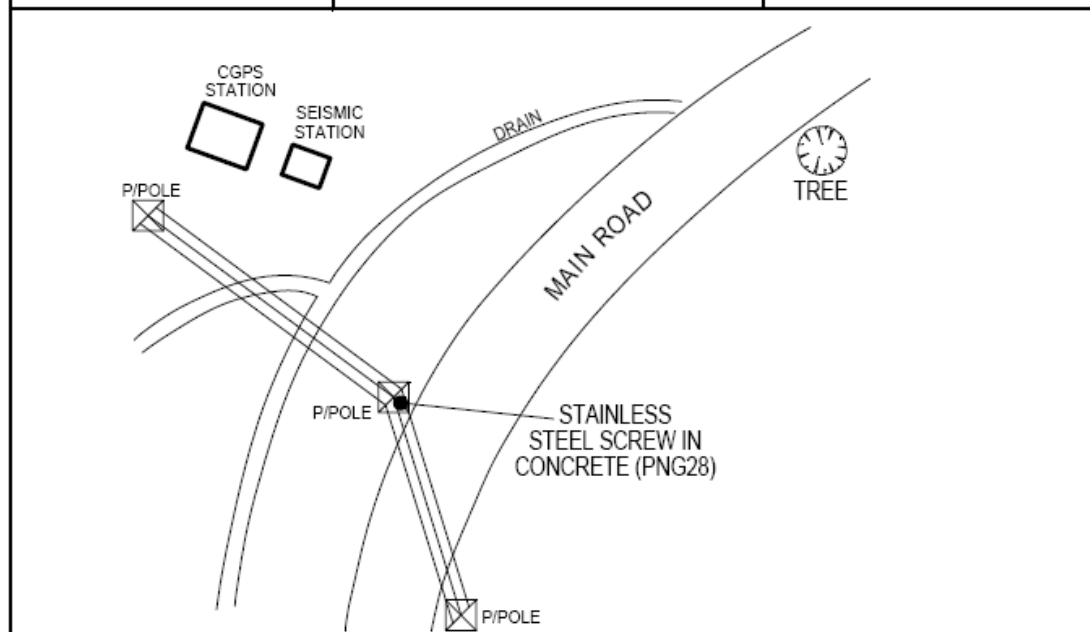
6 Temporary Holding Mark Locality Diagrams

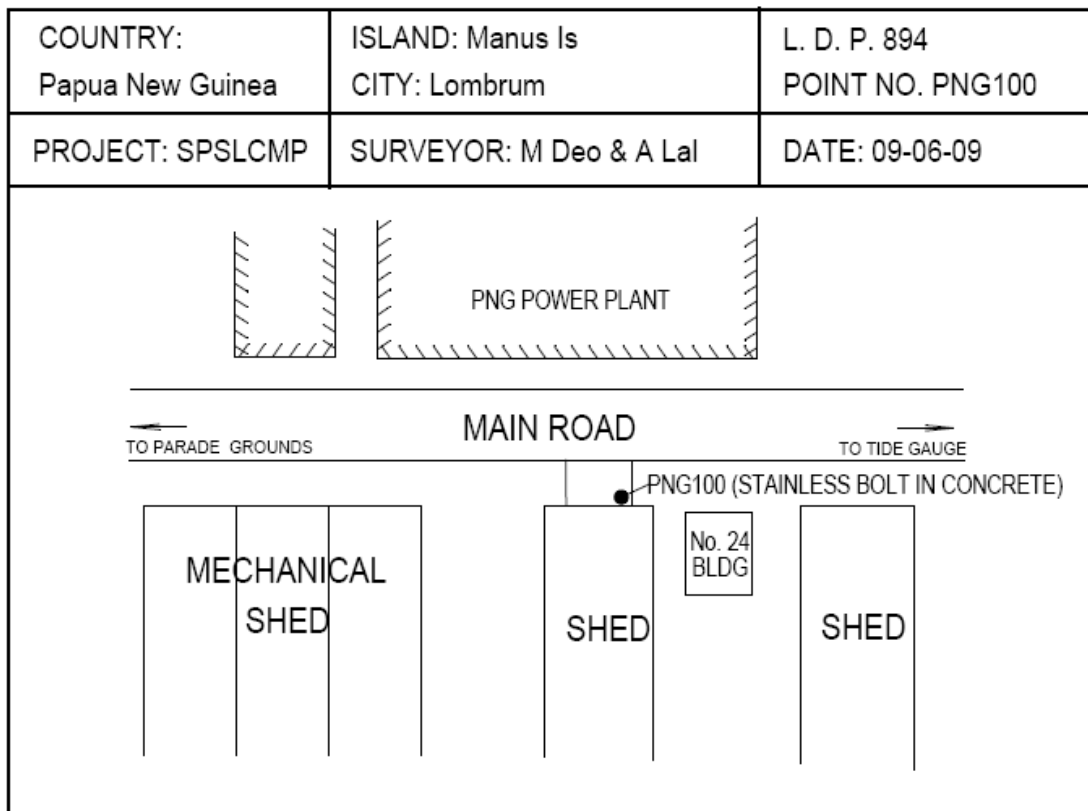


COUNTRY: Papua New Guinea	ISLAND: Manus Is CITY: Lombrum	L. D. P. 892 POINT NO. PNG26
PROJECT: SPSLCMP	SURVEYOR: M Deo & A Lal	DATE: 09-05-02



COUNTRY: Papua New Guinea	ISLAND: Manus Is CITY: Lombrum	L. D. P. 893 POINT NO. PNG28
PROJECT: SPSLCMP	SURVEYOR: M Deo & A Lal	DATE: 09-05-02





7 References

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