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EDM Height Traversing Levelling Survey Report

Funafuti, Tuvalu, May 2012

S. J. K. Yates, A. Lal

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GEOSCIENCE AUSTRALIA
RECORD 2014/29

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Australian Government
Geoscience Australia

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1 Introduction

This report outlines the level survey completed during the visit to Funafuti, Tuvalu between 22 and 29 May 2012.

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

This is the fifth Electronic Distance Measurement (EDM) height traversing levelling survey of the deep bench mark array in Funafuti Atoll, Tuvalu. The previous levelling surveys using this technique were performed in 2005, 2007, 2009 and 2010.

Precise Differential Levelling surveys were performed on eight occasions between 1993 and 2003 by the National Tidal Centre Australia (NTCA) and the survey in 2005 included a comparison between the precise differential levelling and EDM height traversing technique. This report contains a comparison between the 2010 and 2012 EDM height traversing results as well as a combined comparison since the first levelling survey in 1993.

2 The Survey

The EDM Height Traversing level survey was carried out between the six deep driven bench marks:

BM22

BM23

BM24

BM26

BM27

BM28

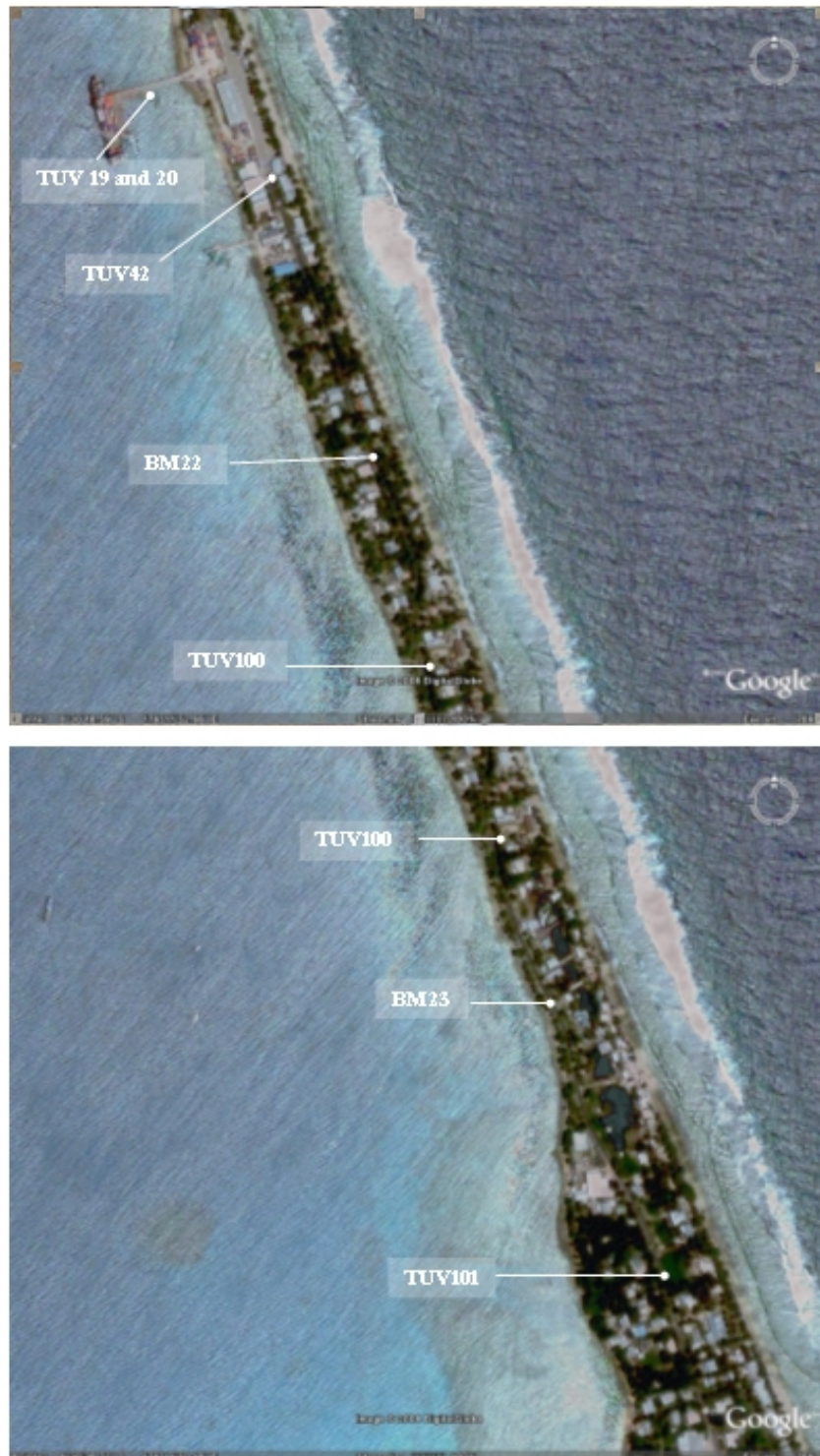
Included in the survey was the Continuous Global Navigation Satellite System (CGNSS) Station bench mark, TUVABM, the Sea Level Fine Resolution Acoustic Measuring Equipment (SEAFRAME) Sensor Bench Mark - TUV20 and the Project Plaque point – TUV19, at the Tide Gauge. Also included were permanent Holding Marks TUV42, TUV100, TUV61, TUV48, TUV74, TUV73 and TUV101. Five new permanent holding marks were established in 2012 – TUV102 to TUV106

All the other deep driven bench marks were located and found undisturbed and in good order.

The EDM Height Traversing levelling technique was performed to the Class L2A, as per the Inter-Government Committee on Surveying and Mapping (ICSM), Standards and Practices for Control Surveys, SP1, Ver. 1.5, May 2002.

After reduction an internal precision of $1\text{mm } \sqrt{K}$ or better was achieved, where K is levelled distance in kilometres. Project Specification precision is $2\text{mm } \sqrt{K}$

2.1 Bench Mark Locality Diagram





2.2 The Tuvalu Datum

The Datum for the survey is the University of Hawaii Tide Staff Zero (TSZ).

Reduction of the data has been calculated holding BM22 fixed at 3.22540 metres TSZ, this value was determined by the NTCA in 1993 by:

Adopting the height of UH 1

RL = 3.0072 metres TSZ

Adopting the height of BM22 as derived from the 1993 survey

RL = 3.22540 metres.

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 Funafuti 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 Survey Support

The Acting Director of the Tuvalu Meteorological Service, Mr. Tauala Katea and his staff provided valuable support during our visit.

Special mention to Mr. Faatasi Malologa – Director, Lands and Survey Department for arranging the car hire and also providing us with a surveyor for field assistance for the survey.

2.6 Issues

No issues or concerns of any importance with regards to the levelling survey were encountered during the 2012 survey.

Please note that due to fewer flights to Funafuti, it is advisable to book 2 cargo seats for the survey equipment to and from Funafuti as DHL cannot guarantee the air freight to arrive.

2.7 Description of Marks – Funafuti, Tuvalu

BM22 is the bench mark held fixed with an RL = 3.22540 metres

The height of BM22 was derived in 1993 by NTC by means of:

1993 Adopting the height of UH 1

RL = 3.0072 metres TSZ.

1994 Adopting the height of BM22 from the 1993 survey.

RL = 3.22540

Bench Marks:

BM22, BM23, BM24, BM26, BM27 and BM28 are all Deep Driven BM's

* BM25 has been destroyed.

TUV20 is the SEAFRAME Sensor Bench Mark

TUV19 is the Project Plaque point

TUVABM is the Reference Bench Mark for the CGPS Pillar.

TUV42, TUV100, TUV101, TUV61, TUV48, TUV74 and TUV73 are all permanent stainless steel bolt holding marks, drilled in concrete and glued in place. The holding marks TUV102 to TUV106 are all new marks established in 2012 and are stainless steel bolts glued in place.

3 Comparisons

3.1 Comparisons between 2012 and 2010 EDM Surveys

Table 3.1 Tuvalu EDM Height Traversing Levelling Comparison 2012 - 2010 and Table of Results

BM22 - Adopted fixed height (TSZ)		3.22540						
FROM	TO	Levelled Height Difference	Reduced Level 2012	Misclose (mm)	Distance (Km)	1mm/K	Reduced Level 2010	Difference (mm) 2012 - 2010
BM22	TUV102	0.5359	3.7613	0.17	0.208	0.46	New Mark 2012	
TUV102	TUV42	-0.0001	3.7612	0.36	0.119	0.34	3.7613	-0.00012
TUV42	TUV103	-0.1844	3.5768	0.17	0.157	0.40	New Mark 2012	
TUV103	TUV19	-0.0887	3.4881	-0.01	0.082	0.29	3.4889	-0.00081
TUV19	TUV20	0.9695	4.4576	-0.04	0.011	0.10	4.4592	-0.00157
BM22	TUV44	0.1001	3.3255	-0.18	0.189	0.43	Not levelled in 2010	
TUV44	TUV100	-0.3915	2.9340	0.04	0.064	0.25	2.9346	-0.00058
TUV100	BM23	0.2041	3.1381	-0.21	0.236	0.49	3.1394	-0.00128
BM23	TUV104	-0.1538	2.9844	0.00	0.175	0.42	New Mark 2012	
TUV104	TUV101	0.1067	3.0911	-0.37	0.199	0.45	3.0928	-0.00171
TUV101	TUV105	-0.2670	2.8241	-0.03	0.214	0.46	New Mark 2012	
TUV105	TUV61	0.0526	2.8767	0.15	0.111	0.33	2.8791	-0.00241
TUV61	TUV48	0.1836	3.0603	0.10	0.119	0.34	3.0629	-0.00264
TUV48	TUV49	0.1868	3.2470	0.37	0.161	0.40	Not levelled in 2010	
TUV49	TUV74	-0.6632	2.5838	-0.21	0.084	0.29	2.5860	-0.00220
TUV74	BM24	1.2117	3.7955	-0.18	0.107	0.33	3.7976	-0.00214
TUV74	TUV73	-0.2858	2.2980	-0.36	0.199	0.45	2.3004	-0.00241
TUV73	TUV106	-0.0906	2.2074	-0.18	0.199	0.45	New Mark 2012	
TUV106	TUV71	0.0340	2.2414	0.18	0.099	0.31	Not levelled in 2010	
TUV71	BM28	-0.0253	2.2161	-0.07	0.109	0.33	2.2188	-0.00266
BM28	TUV69	-0.0008	2.2154	-0.05	0.202	0.45	Not levelled in 2010	
TUV69	BM27	0.0007	2.2161	-0.74	0.135	0.37	2.2184	-0.00231
BM27	BM26	0.8916	3.1077	0.06	0.12	0.35	3.1108	-0.00312
BM27	TUVABM	0.5257	2.7418	0.12	0.146	0.38	2.7442	-0.00243
Total misclose for all bays levelled				-0.90	3.445	1.86		

An internal precision of 1mm/K was achieved for all bays levelled - this is well within the Project Specification of 2mm/K

Table 3.2 TUVALU Reference Mark levels

FROM	TO	Levelled Height Difference	Reduced Level 2012	Misclose (mm)	Distance (Km)	1mm/K	Reduced Level 2010	Difference (mm) 2012 - 2010
TUVABM	RM1	-0.6545	2.0873	-0.04	0.028	0.17	No 2010 RL's for Reference Marks available	
TUVABM	RM2	-0.5828	2.1590	-0.03	0.032	0.18		
TUVABM	RM3	-0.8097	1.9320	0.12	0.027	0.16		
Total misclose for all bays levelled				0.05	0.087	0.51		

3.2 Combined Comparisons 1993 to 2012

Table 3.3 Tuvalu - Comparison of the RL's for Precise Differential Levelling (1993 – 2005) and EDM Height Traversing (2005 - 2012)

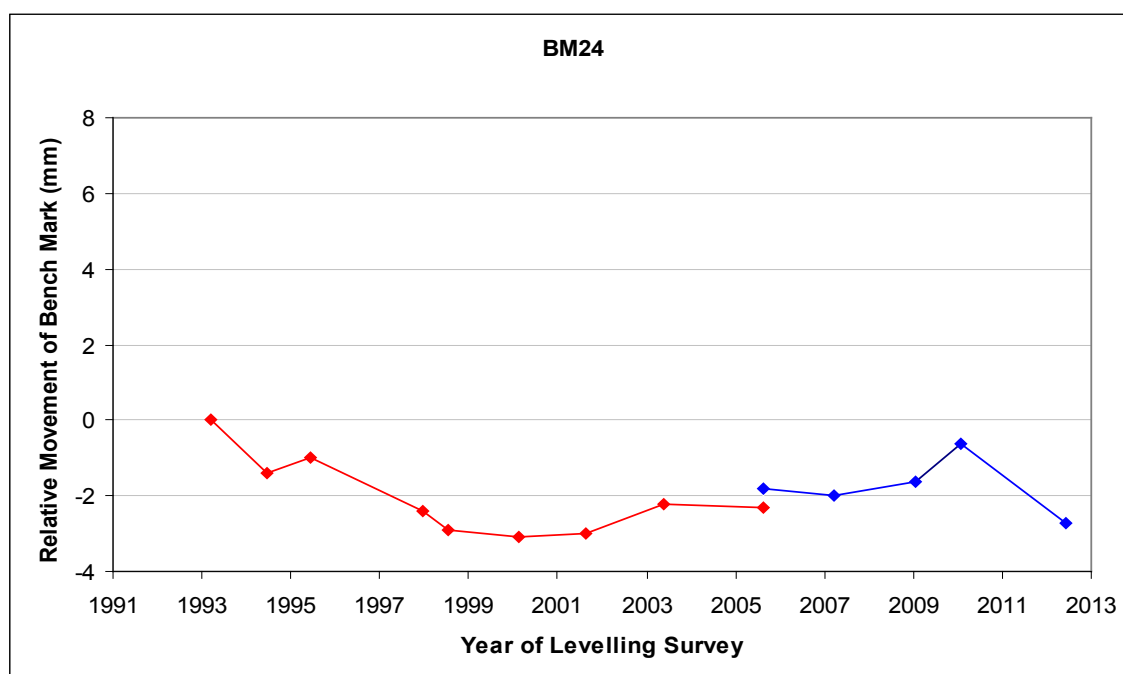
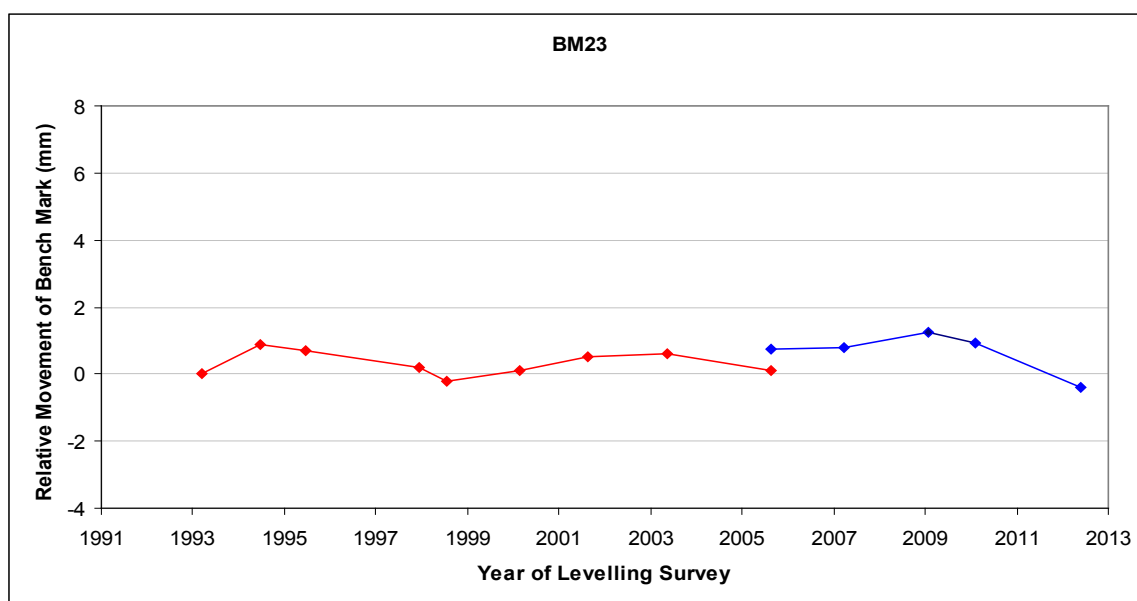
YEAR					MARK					
	BM22	BM23	BM24	BM25	BM26	BM27	BM28	TUV19	TUV20	TUVABM
1993	3.2254	3.1385	3.7982					3.4813	4.4599	
1994	3.2254	3.1394	3.7968					3.4826	4.4603	
1995	3.2254	3.1392	3.7972					3.4833	4.4609	
1997	3.2254	3.1387	3.7958					3.4834	4.4608	
1998	3.2254	3.1383	3.7953					3.4848	4.4615	
2000	3.2254	3.1386	3.7951					3.4842	4.4600	
2002	3.2254	3.1390	3.7952					3.4848	4.4599	
2003	3.2254	3.1391	3.7960	3.5369	3.1099	2.2165		3.4851	4.4593	2.7414
2005	3.2254	3.1386	3.7959	3.5379	3.1102	2.2176		3.4864	4.4592	2.7425
2005 EDM	3.2254	3.1393	3.7964	3.5373	3.1099	2.2177		3.4867	4.4593	2.7432
2007 EDM	3.2254	3.1393	3.7962	Destroyed	3.1079	2.2157		3.4879	4.4596	2.7407
2009 EDM	3.2254	3.1397	3.7966		3.1082	2.2162	2.2171	3.4877	4.4588	2.7418
2010 EDM	3.2254	3.1394	3.7976		3.1108	2.2184	2.2188	3.4889	4.4592	2.7442
2012 EDM	3.2254	3.1381	3.7955		3.1077	2.2161	2.2161	3.4881	4.4576	2.7418

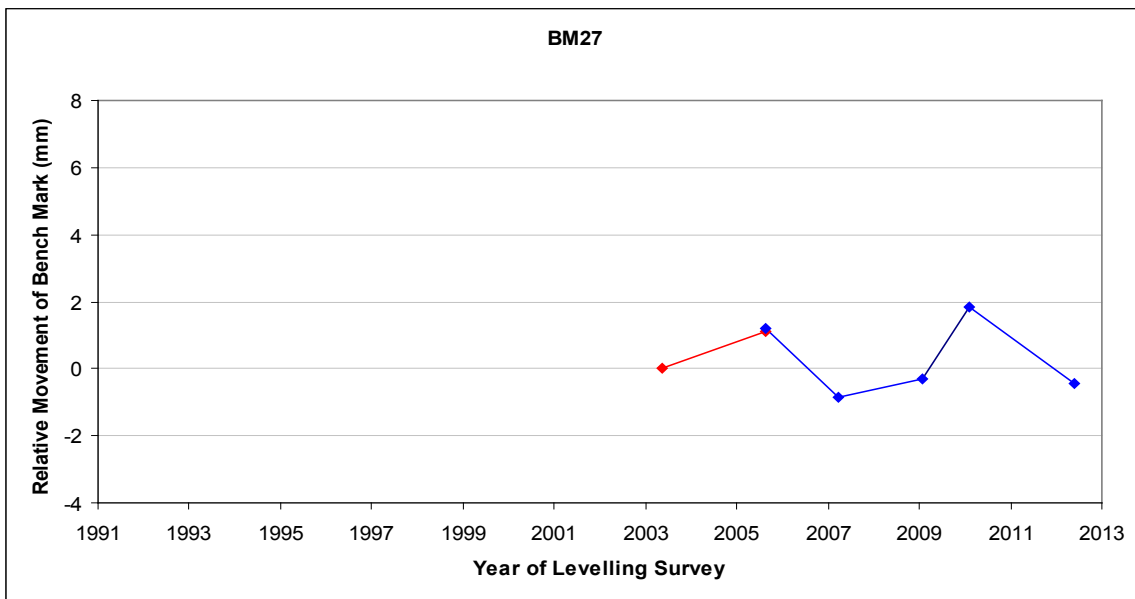
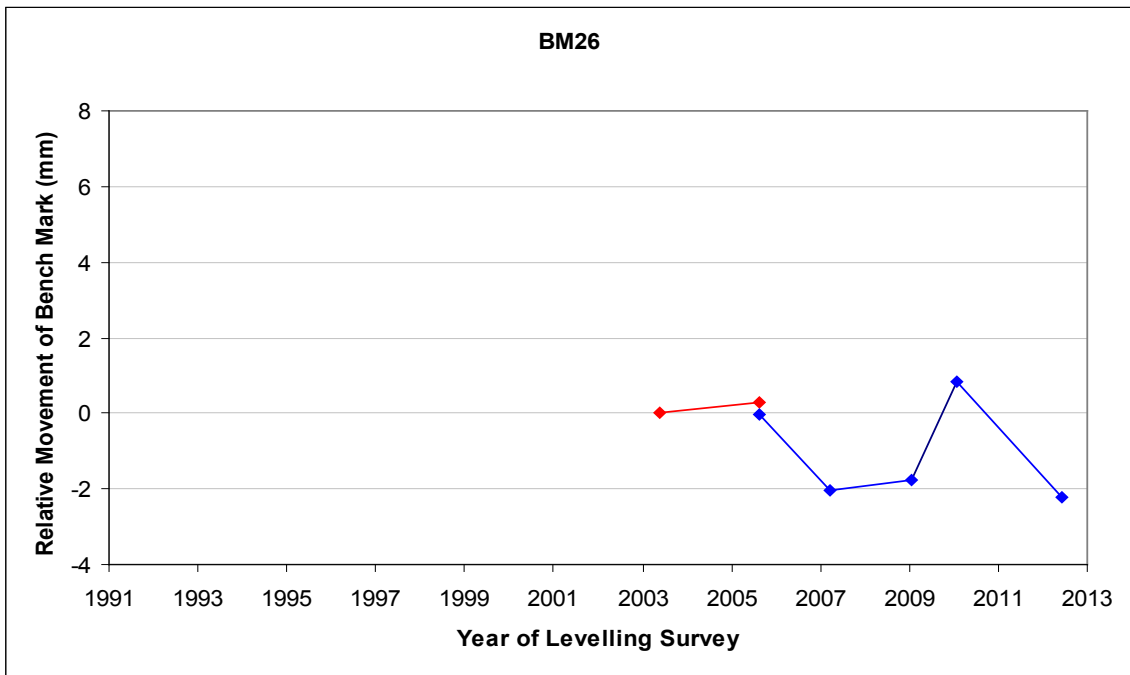
*The RL of the Reference Point TUVA (ARP) is derived from adding the static height difference of 0.9645 m (TUVABM to TUVA) to the levelled RL of TUVABM.

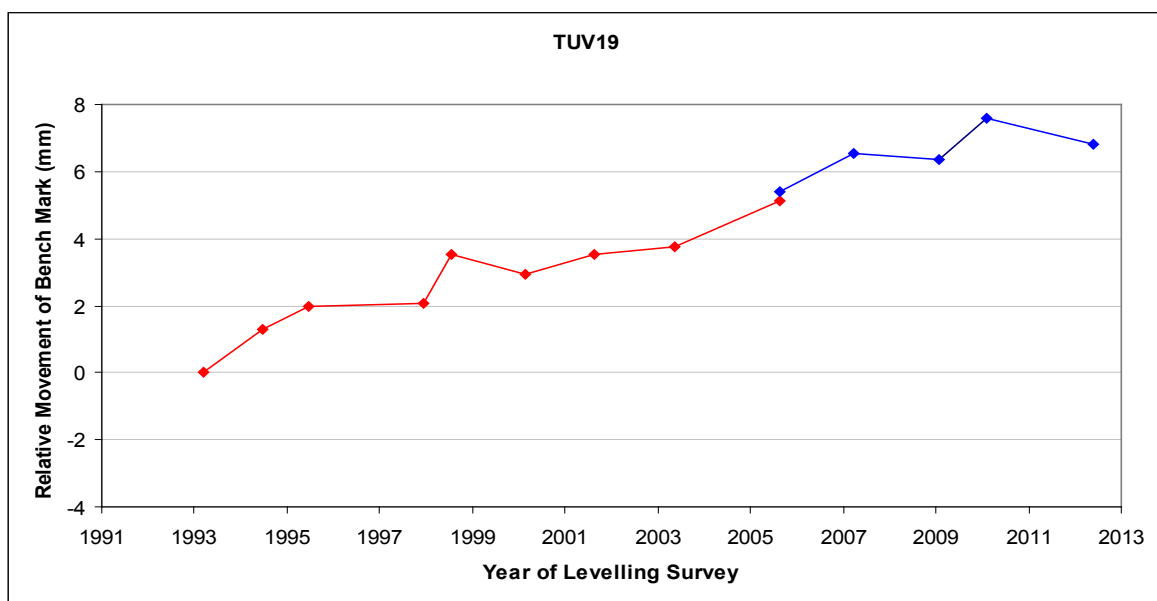
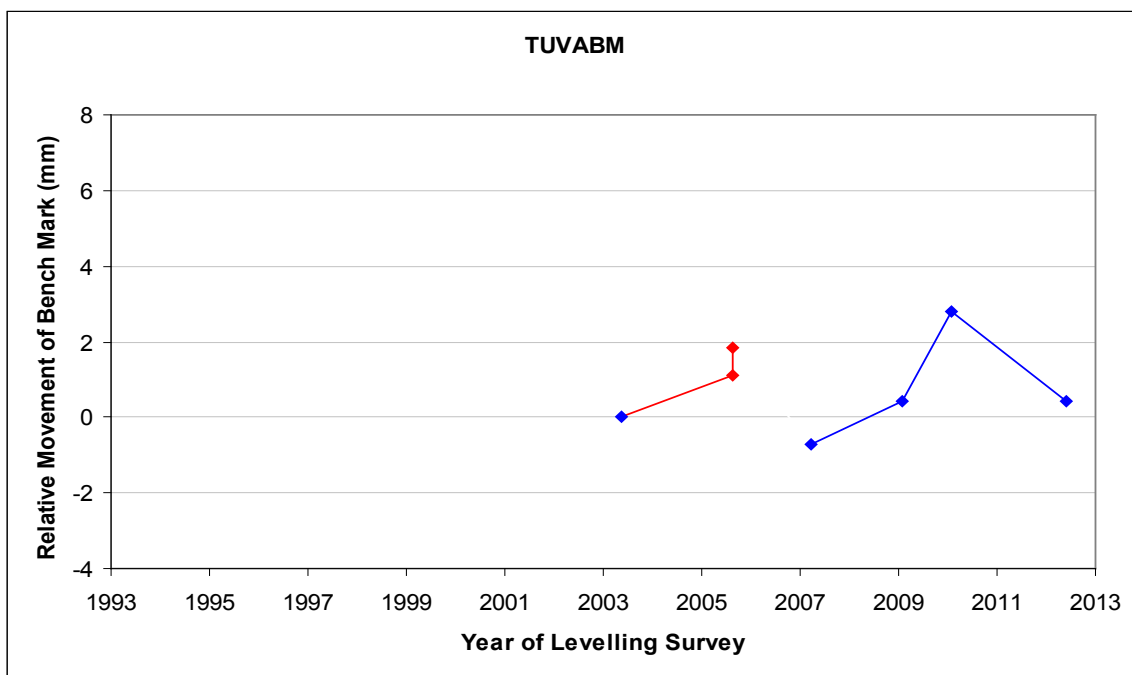
The 2012 Reduced Level of TUVA is 3.7063 m

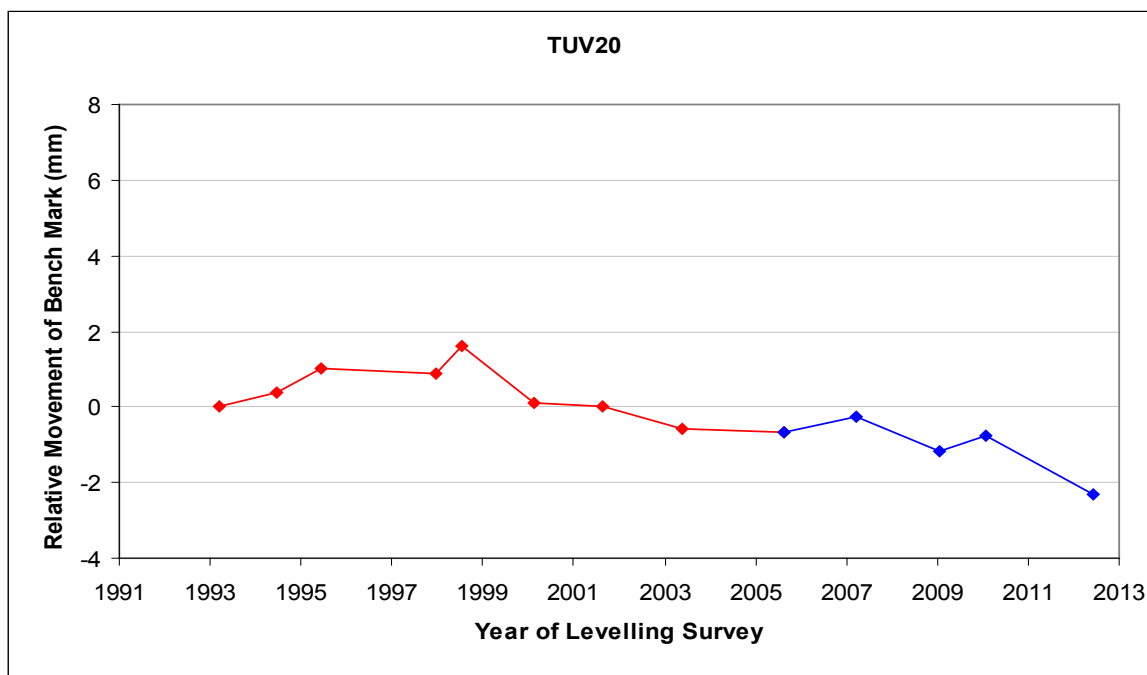
3.3 Time Series of Bench Mark Movement relative to Fixed Deep Bench Mark BM22

Precise Differential Levelling: 1993 - 2005 ◆ — ◆
EDM Height Traversing: 2005 onwards ◆ — ◆









4 Deep Bench Mark Locality Diagrams



SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT



Survey Bench Mark Record

Bench Mark Number: BM22

Original Bench Mark Established by: National Tidal Centre Australia, Oceanographic Services,
Bureau of Meteorology, 25 College Rd, Kent Town, SA. *Date:* 04-02-92

Existing Bench Mark Established by: *Date:*

Notes / References: Deep Survey Benchmark
This survey mark is not in a good locality for GPS occupation.

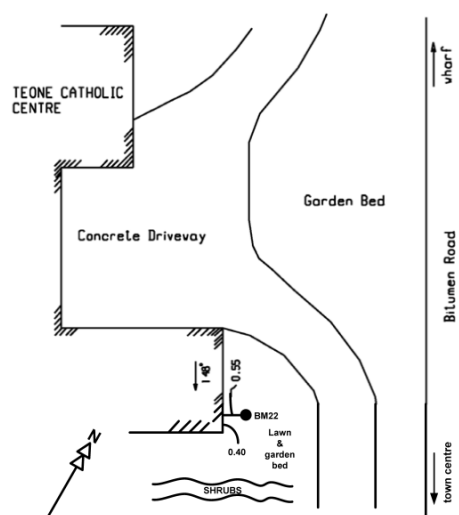
Country: Tuvalu
Island: Funafuti

Atoll: Fongafale

Marking and locality sketch

Bench Mark: 2.2m of 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for
0.6m. Top of mark 0.25m 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: November 2006



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



Survey Bench Mark Record

Bench Mark Number: BM23

<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> 03-02-92
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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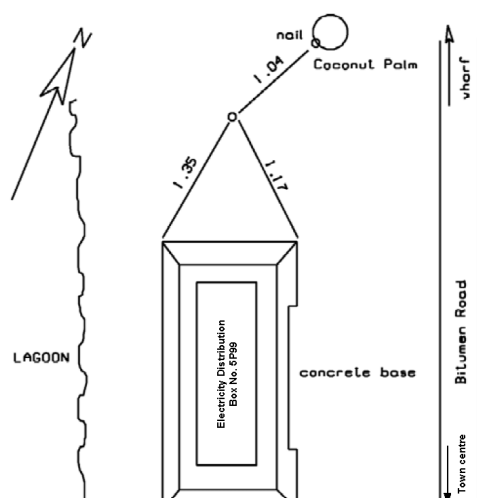
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Tuvalu <i>Island:</i> Funafuti	<i>Atoll:</i> Fongafale
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Marking and locality sketch

Bench Mark: 1.0m of 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.6m. 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
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Approved by: Geoscience Australia / SOPAC

Date: November 2006



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



Survey Bench Mark Record

Bench Mark Number: BM24

<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> 03-02-92
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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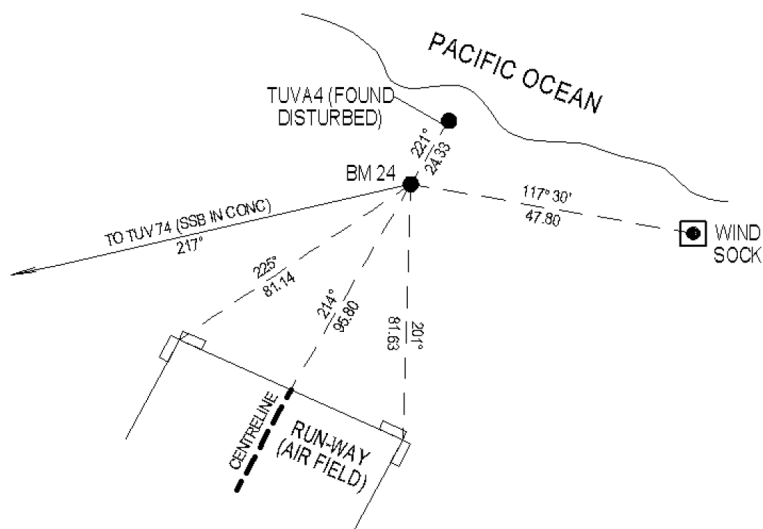
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
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<i>Country:</i> Tuvalu <i>Island:</i> Funafuti	<i>Atoll:</i> Fongafale
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Marking and locality sketch

Bench Mark: 3.8m of 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.8m. Top of mark 0.15m below ground level.

Locality sketch: Mark approximately 2000m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: November 2006
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: BM26

<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> 15-05-03
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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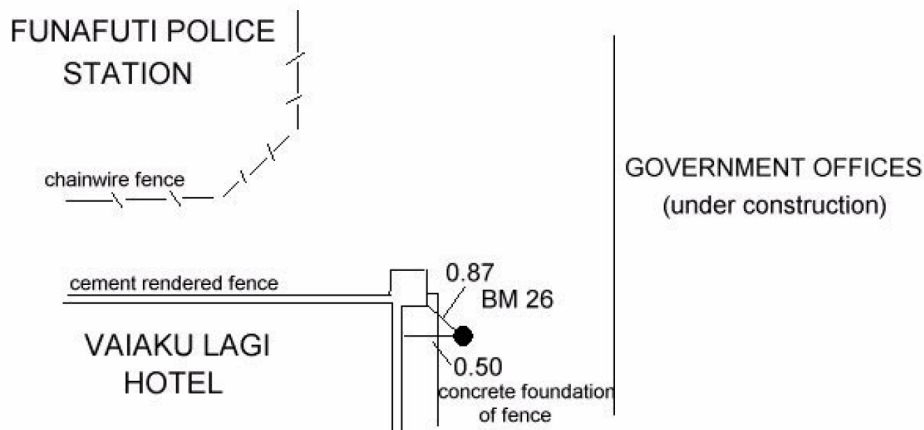
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
--

<i>Country:</i> Tuvalu <i>Island:</i> Funafuti	<i>Atoll:</i> Fongafale
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Marking and locality sketch

Bench Mark: 3.3m of 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.5m. Top of mark 0.1m below ground level.

Locality sketch: Mark approximately 3100m from the tide gauge station.



Not to scale	Distances in Metres	Magnetic bearings
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Approved by: Geoscience Australia / SOPAC	Date: November 2006
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**SOUTH PACIFIC SEA LEVEL
&
CLIMATE MONITORING PROJECT**



Survey Bench Mark Record

Bench Mark Number: BM27

<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> 15-05-03
<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> Tuvalu <i>Island:</i> Funafuti	<i>Atoll:</i> Fongafale
<u>Marking and locality sketch</u> Bench Mark: 2.4m of 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 0.5m. Top of mark 0.1m below ground level. Locality sketch: Mark approximately 3200m from the tide gauge station.	
Not to scale Distances in Metres Magnetic bearings	
Approved by: Geoscience Australia / SOPAC Date: November 2006	



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



Survey Bench Mark Record

Bench Mark Number: BM28

<i>Original Bench Mark Established by:</i> Geoscience Earth Monitoring Geodetic Operations Geoscience Australia, Cnr Jerrabomberra Ave & Hindmarsh Drive, Australia	<i>Date:</i> 17-01-09
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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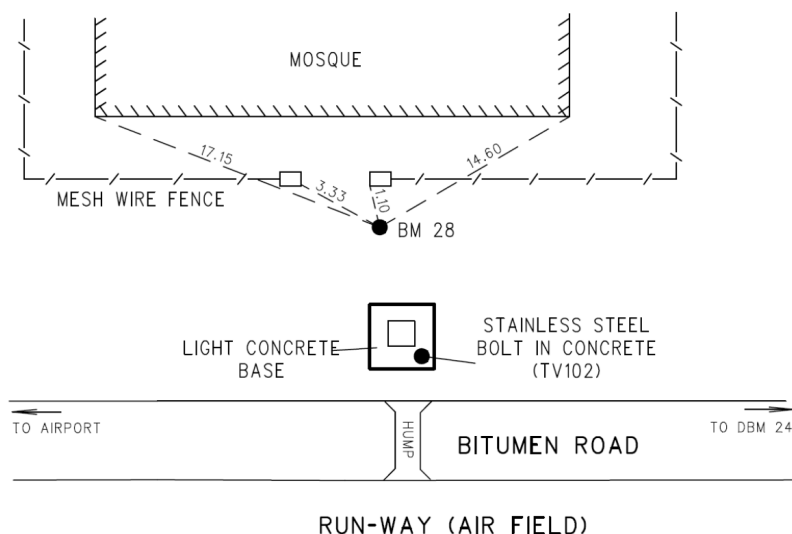
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
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<i>Country:</i> Tuvalu <i>Island:</i> Funafuti	<i>Atoll:</i> Fongafale
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Marking and locality sketch

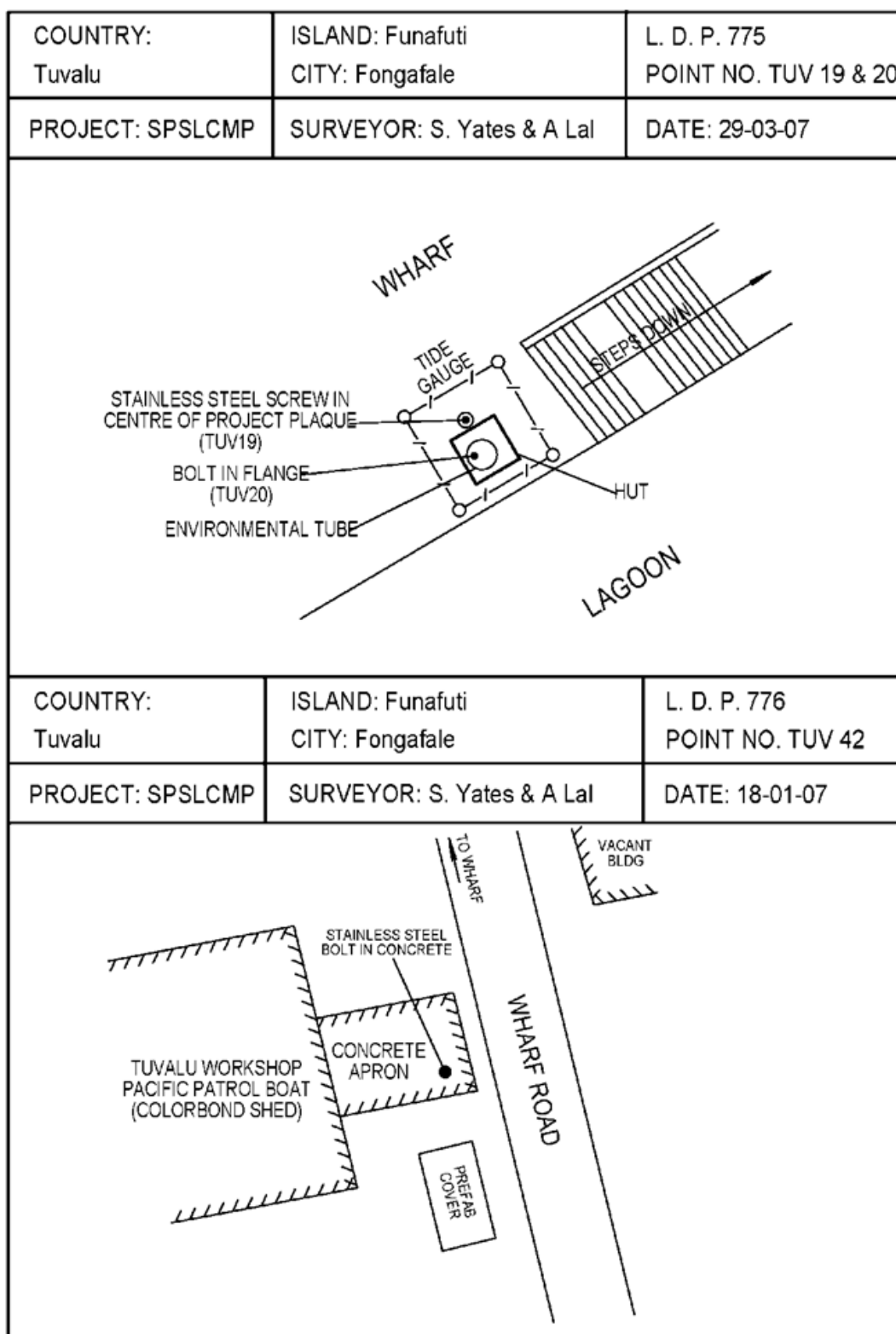
Bench Mark: 2.14m of 13mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 200mm diameter PVC pipe, Top of mark 0.1m below ground level.

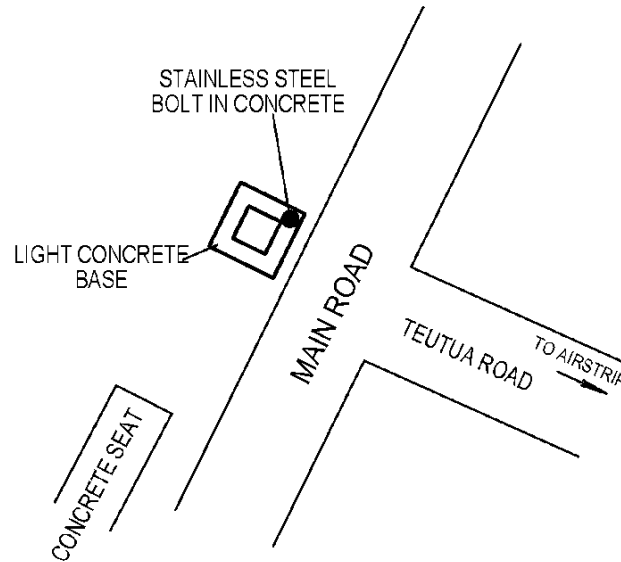
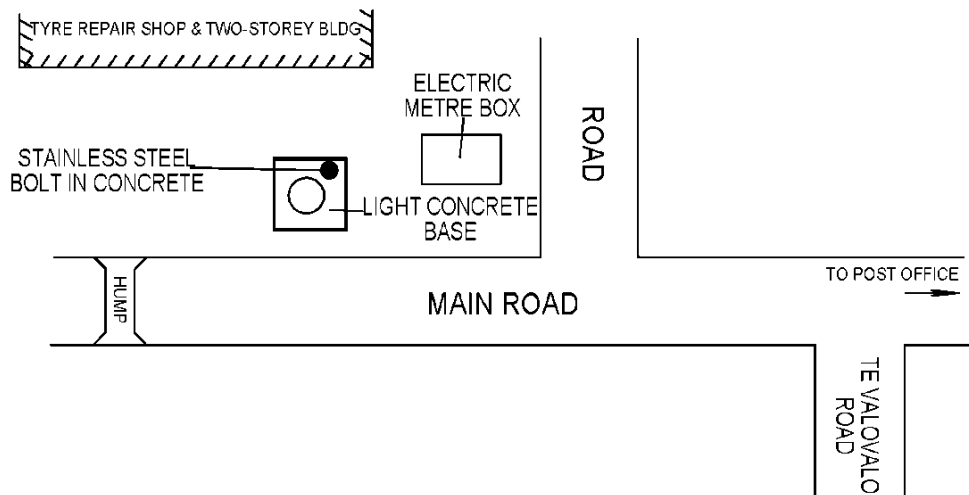
Locality sketch: Mark approximately 600m from the CGPS station.

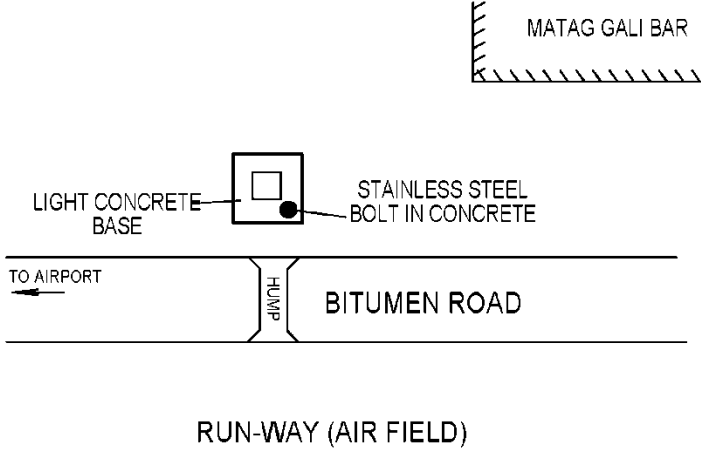
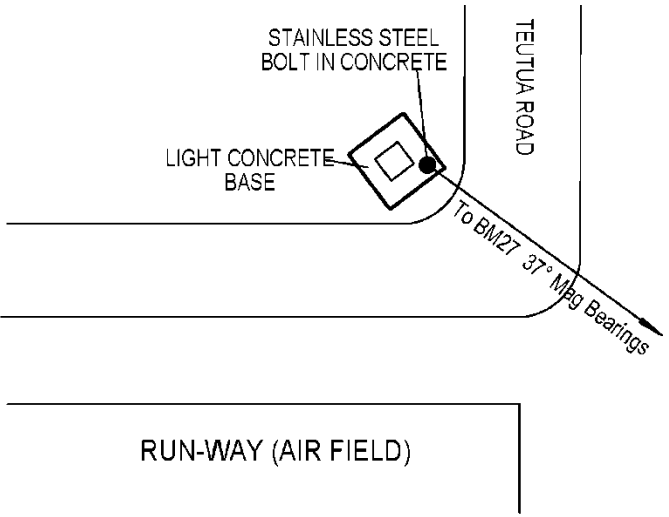


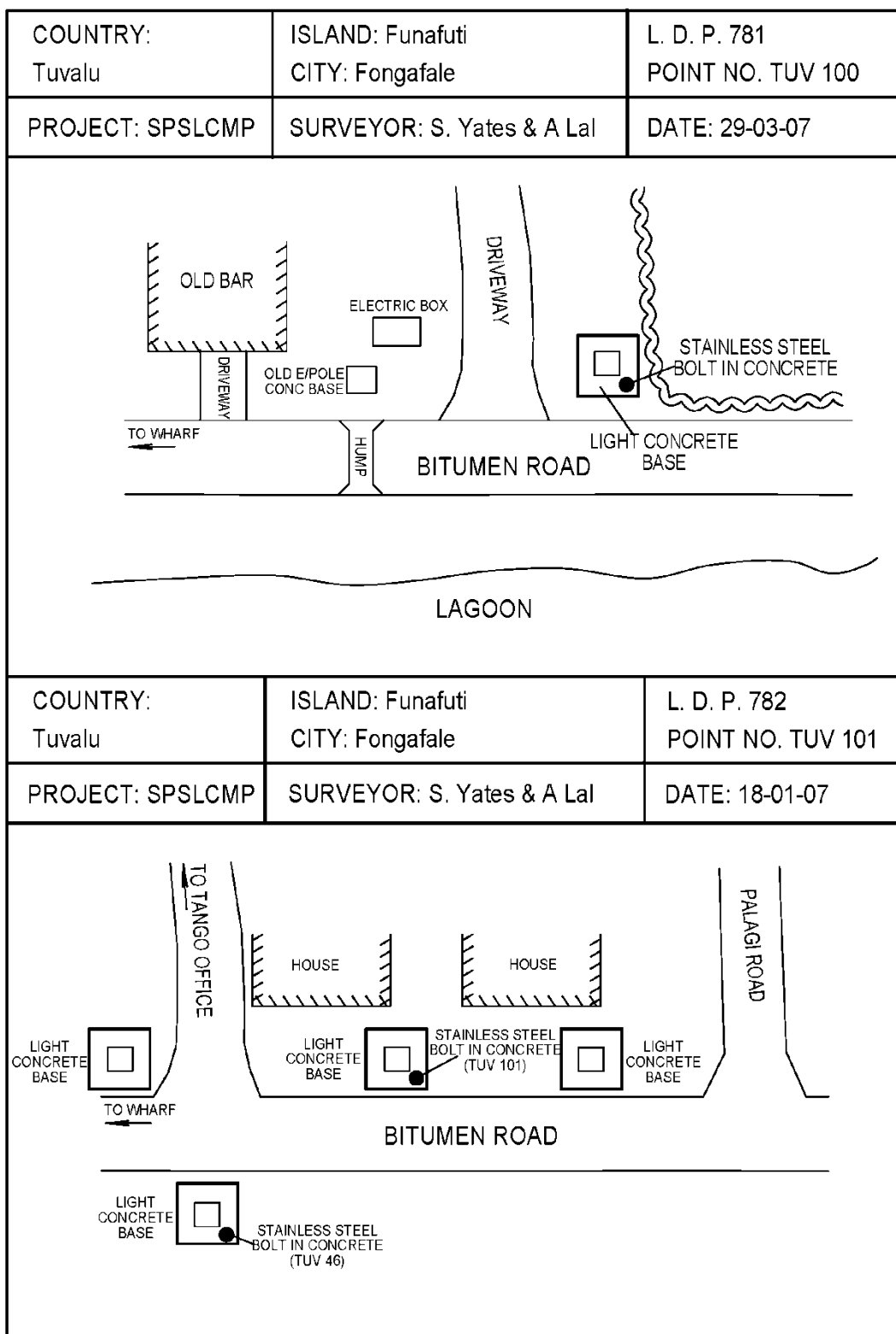
Not to scale	Distances in Metres	Magnetic bearings
Approved by: Geoscience Australia / SOPAC		Date: January 2009

5 Permanent Holding Mark Locality Diagrams



COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 777 POINT NO. TUV 48
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07
 Diagram of Point TUV 48: A stainless steel bolt is embedded in a light concrete base. The base is located near a concrete seat and a main road. The main road intersects with Teutua Road, which leads towards an airstrip.		
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 778 POINT NO. TUV 61
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07
 Diagram of Point TUV 61: A stainless steel bolt is embedded in a light concrete base. The base is located near a tyre repair shop and two-storey building, an electric metre box, and a road. The main road intersects with Te Valovalo Road, which leads towards a post office. A hump is also visible on the main road.		

COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 779 POINT NO. TUV 73
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07
 MATAG GALI BAR LIGHT CONCRETE BASE STAINLESS STEEL BOLT IN CONCRETE TO AIRPORT HUMP BITUMEN ROAD RUN-WAY (AIR FIELD)		
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 780 POINT NO. TUV 74
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 18-01-07
 STAINLESS STEEL BOLT IN CONCRETE LIGHT CONCRETE BASE TEUTUA ROAD To BM27 37° Mag Bearings RUN-WAY (AIR FIELD)		



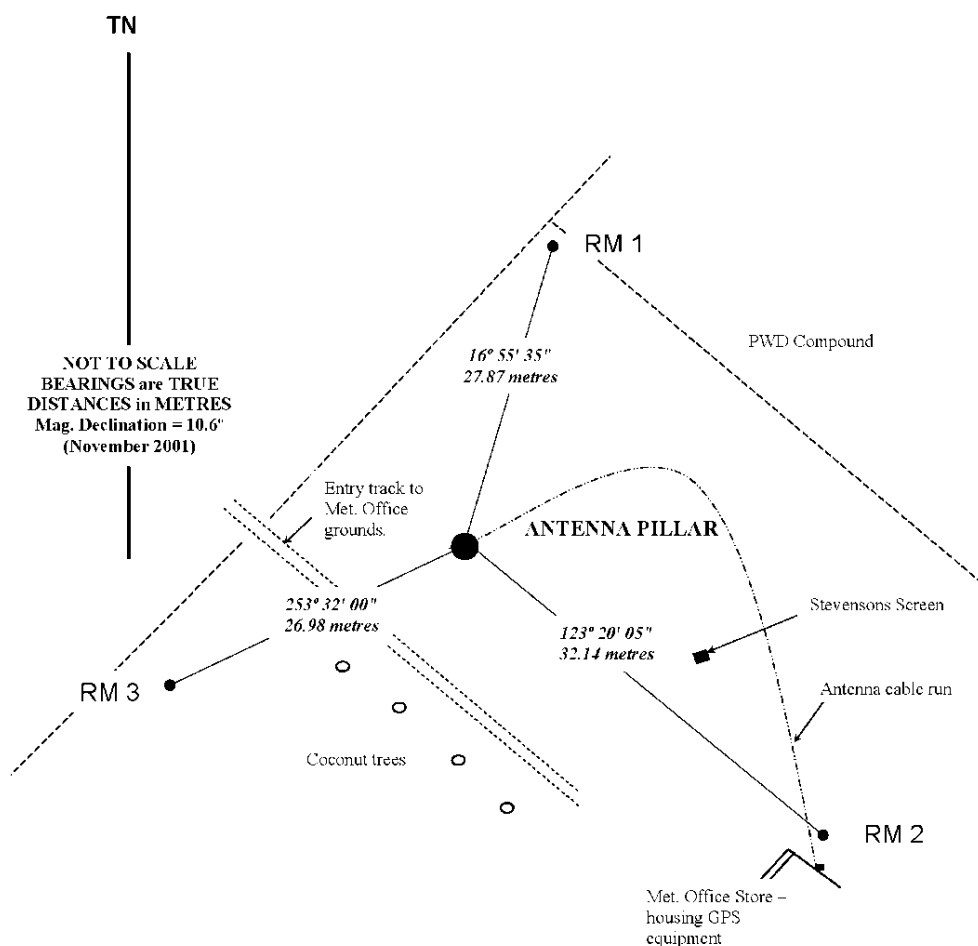
COUNTRY: Tuvalu	ISLAND: Funafuti CITY: Fongafale	L. D. P. 783 POINT NO. TUV 102
PROJECT: SPSLCMP	SURVEYOR: S. Yates & A Lal	DATE: 29-03-07
MOSQUE LIGHT CONCRETE BASE STAINLESS STEEL BOLT IN CONCRETE TO AIRPORT HUMP BITUMEN ROAD RUN-WAY (AIR FIELD)		

6 TUVABM and TUVA Reference Mark Locality Diagrams

TUVALU CGPS Station, Funafuti – Reference Marks

REFERENCE MARKS

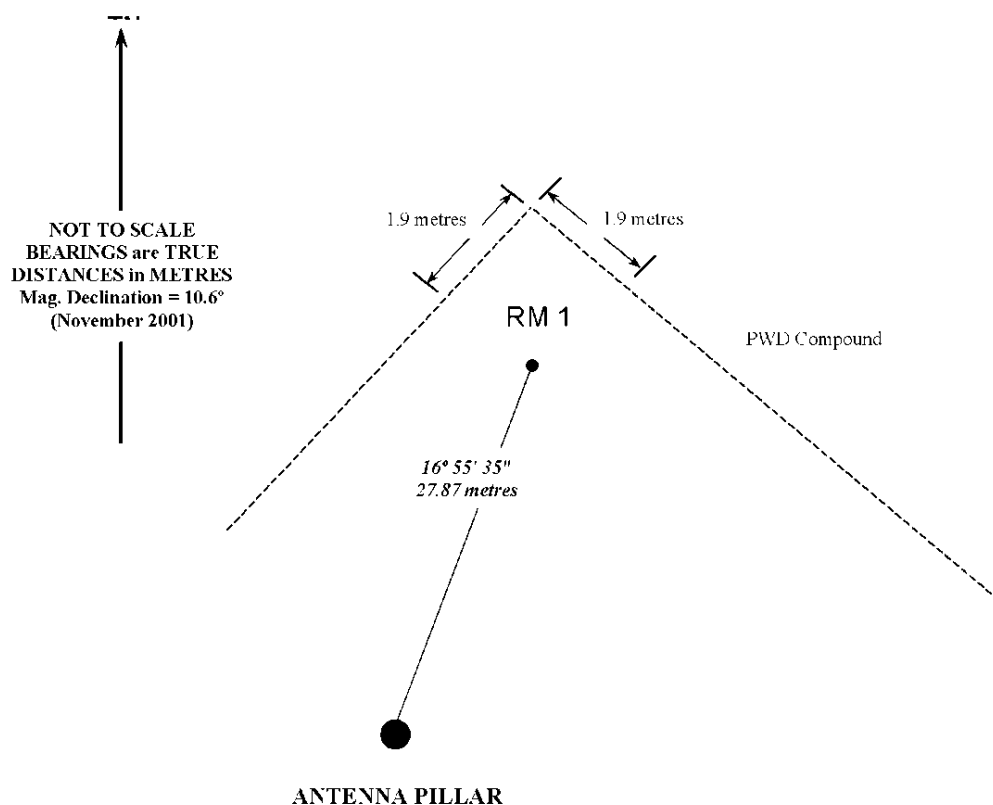
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



TUVALU CGPS Station, Funafuti – RM 1

REFERENCE MARKS

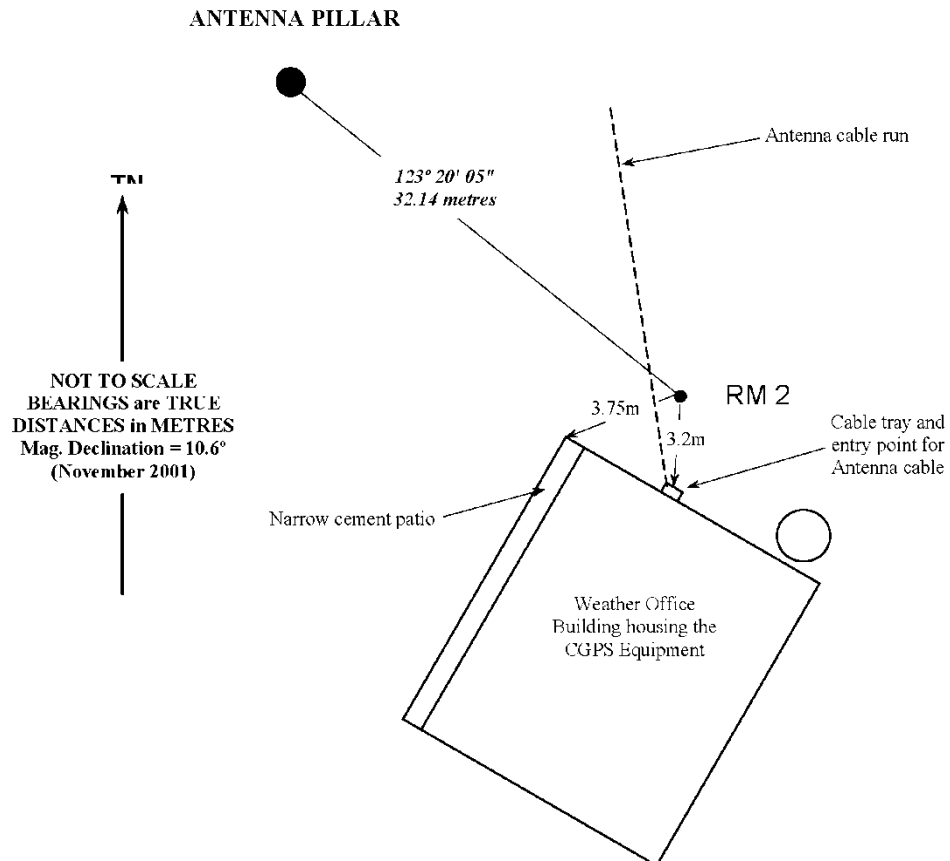
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



TUVALU CGPS Station, Funafuti – RM 2

REFERENCE MARKS

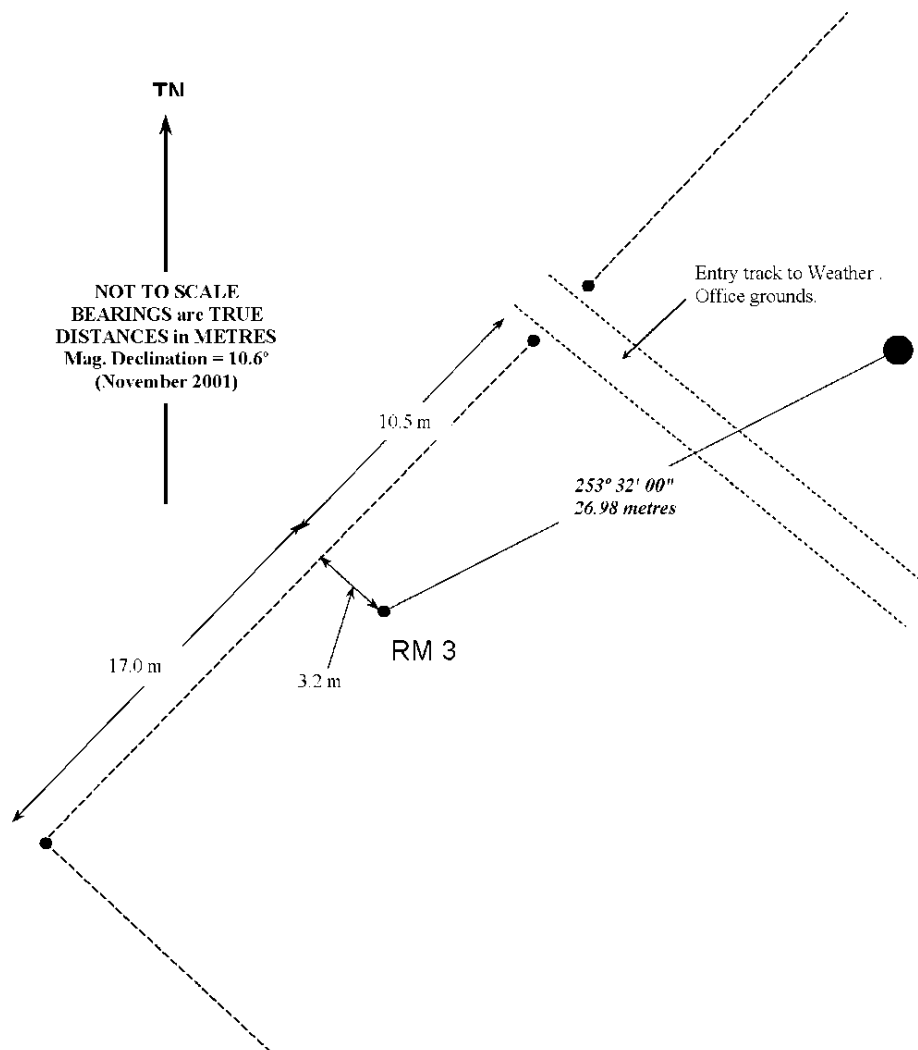
All RM's are capped 20 mm stainless steel rods driven to refusal and protected by 150 mm PVC pipe within circular poly carbonate valve boxes. The valve box lids are approximately 50mm below ground level.



TUVALU CGPS Station, Funafuti – 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.



7 References

- Rüeger, J.M. & Brunner, F.K. 1982, 'EDM Height Traversing versus Geodetic Levelling', The Canadian Surveyor, vol. 36, no. 1, pp. 69-87.
- Inter-Government Committee on Surveying and Mapping (ICSM) 2002, Standards and Practices for Control Surveys, SP1, Ver. 1.5, May 2002.