



Australian Government

Geoscience Australia

South Pacific Sea Level and Climate Monitoring Project (SPSLCMP)

Survey Report

EDM Height Traversing Levelling Survey

Samoa

May 2008

This project is sponsored by the Australian Agency for International Development (AusAID), managed by the Bureau of Meteorology (BOM) and supported by the National Geospatial Reference Systems Project, Geospatial Earth Monitoring Division, GEOSCIENCE AUSTRALIA.

Geocat # 69403



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Introduction

This report outlines the level survey completed during the visit to Apia, Samoa in May 2008.

Personnel: Manoj Deo – Surveyor - **GEOSCIENCE AUSTRALIA**
Andrick Lal – Surveyor - **SOPAC**

This is the second EDM Height Traversing level survey of the deep bench mark array in Apia, Samoa. The first was completed in October 2006 when the levelling technique comparison surveys were performed.

The 2008 survey is a repeat EDM Height Traversing following the eight previous surveys from 1992 to 2004 undertaken by the National Tidal Centre (NTC) using the Precise Differential Levelling technique.

The Survey

The EDM Height Traversing level survey was carried out between the 7 deep bench marks:

- BM201** Deep driven BM, held fixed and located at the rear of the old Ministry of Resources, Energy and Environment Building along the Apia Port Road.
- BM210** Deep driven BM along Matafagatele Street inside Church grounds.
- BM212** Deep driven BM located at the end of Matafagatele Street and the start of the Main East Coast Road.
- BM213** Deep driven BM outside a shop at the corner of the Main East Coast Road and Vaivase Road.
- BM214** Deep Driven BM located corner of Vaivase and Fuaiupolu Roads.
- BM215** Deep Driven BM located inside church grounds, Plantation Road.
- BM220** Deep Driven BM located in front of Apia Park entrance gate

All the deep driven bench marks were found undisturbed and in good order except **BM211** which has been destroyed by the construction of a concrete footpath outside Apia Park. **BM211** is now replaced by a new deep driven bench mark – **BM220**.

BM210 was difficult to locate as the surrounding measurement references to it have been destroyed - new measurement ties and a new locality diagram for **BM210** have been submitted.



A replacement deep driven Reference Mark - **RM4** was placed near the CGPS Bench Mark – **SAMOBM**. **RM4** replaces the destroyed **RM2** (2006).

Included in the survey were the SEAFRAME Sensor Bench Mark **SAM 17** and **SAM 16** the Project Plaque at the Tide Gauge.

Holding Marks **SAM 139, SAM 166, SAM 168, SAM 170, SAM 186 and SAM 187** were also used. SAM 124 was covered deeply under rubble and a replacement holding mark **SAM 302** was placed.

Seven (7) new permanent holding marks were established during this visit, **SAM 300, SAM 301, SAM 302, SAM 303, SAM 304, SAM 305 and SAM 306**. SAM 300-305 consist of domed stainless steel bolts drilled in concrete and glued in place with quality epoxy resin whereas **SAM 306** is a steel rod driven approximately 1.5m into ground.

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 the levelled distance in kilometres. Project Specification for precision is $2\text{mm} \sqrt{K}$



Bench Mark Locality Map



The Samoa Datum

BM 201 is the adopted reference point for the coastal array.

Reduction of the data was calculated holding **BM 201** fixed at **1.3291675** metres.

This value was determined by NTC in 1993 by adopting the height of **BM48** with an RL of 2.765 metres MSL.



Equipment

LEICA Total Station Model TCA1800 (S/N 424936).

LEICA Precision Prisms GPH1P (2).

LEICA Rigid Tripod.

Stainless Steel Target Poles supported by LEICA telescopic Bi-Poles (2).

LEICA Cast Iron Change Plates (2).

KESTRAL 4000 Pocket Weather Tracker

Method

“Leap-Frog” EDM-Height-Traversing: "Leap-Frog" EDM-Height-Traversing involves the one target remaining at a particular change point for both sightings. To avoid the possibility of the target being placed on a different point the target is not moved between the back-sight and foresight. Two target/reflectors are employed (on reflector rods with struts). As in spirit levelling, it is imperative that the electronic tacheometer (total station) is set up in the middle between the two reflectors. Recorded are the height differences (between the instrument's trunnion axis and the reflector) that are computed by the electronic tacheometers. In consequence, the ambient temperature and pressure must be input into the instrument since the slope distances must be corrected for temperature and pressure (first velocity correction) on-line. See Rüeger & Brunner (1982) and *The Canadian Surveyor*, 36(1): 69-87.

All observations were recorded digitally.

Reduction of the digital data was computed by the Geoscience Australia's levelling program “leveling1.exe”

This program computes the height difference between the two reflectors at any one set-up. Results can also be gained with the EDM Height Traversing method by using a single set-up / single rod configuration. To achieve height differences when using this single rod configuration, a simple comment line is added, indicating this is the case before running the program.

This “single set-up / single rod” configuration is particularly useful when levelling between bench marks which are close together e.g. between the Project Plaque BM and the SEAFRAME Sensor BM.



All levelling bays started and finished with the same reflector and reflector rod, ie an even number of setups when the two reflector rod configuration was used – this eliminates any reflector rod zero error.

Atmospheric readings were obtained using a KESTRAL 4000 Pocket Weather Tracker. These atmospheric readings were recorded manually onto the Samoa Levelling Booking Sheets and entered into the Total Station prior to each level run and approximately every hour thereafter or whenever an obvious change in weather conditions was observed.

Survey Support

The Deputy CEO for the Survey Division of the Ministry of Environment and Natural Resources, Mr. Safuta Toelau and the Senior Surveyor, Mr. Ueligitone Seiuli provided valuable assistance in obtaining Customs clearances for the bench mark replacement gear. Without their support and knowledge of the Customs protocols the commencement of the survey would have been delayed for days.

Other personnel consulted during the visit were Mr. Austelaia Titimaea, Assistant CEO, Meteorology Division, Ministry of Natural Resources & Environment and Ms. Siosina Lui, a climate change Officer in the same division.

Siosina arranged the security access to the port area and also helped in obtaining customs clearance for the survey gear.

Issues

Avoid levelling between SAM166 to the tide gauge bench mark during offloading of ships or increased port activity. Access inside the Ports Authority area is strictly prohibited and arrange security pass through the Met Office or Lands and Surveys staff well in advance.

Levelling along the reclaimed area around the wharf and along Matafagatele Street, especially around Apia Park Stadium to be carried out during quiet traffic periods.

BM 214 is exposed and requires some restoration by placing a cover and box around it.



Description of Marks – Apia, Samoa

BM 201 is the bench mark held fixed with an **RL = 1.3291675 metres MSL**

Bench Marks:

BM210, BM220, BM212, BM213, BM214 and BM215 are all Deep Driven BM's.

Point:

SAM 17 is the SEAFRAME Sensor Bench Mark.

SAM 16 is the Project Plaque at the Tide Gauge

SAMOBM is the Reference Bench Mark for the CGPS Pillar.

SAM 166, SAM 168, SAM 170, SAM 186, SAM 300, SAM 301, SAM 302, SAM 303, SAM 304 and SAM 305 are permanent stainless steel bolt holding marks, drilled in concrete and glued in place.

SAM 187 is a steel rod set in concrete.

SAM 139 is a stainless steel rod in concrete.

SAM 306 is a stainless steel rod driven approximately 1.5m into ground.



Table of Results for 2008 and Comparisons between 2006 and 2008

SAMOA 2008 - EDM Height Traversing Levelling Comparison 2006-2008 and Table of Results

BM201 - Adopted Fixed Height (MSL) 1.3291675 metres

FROM	TO	Levelled Height Difference	Reduced Level 2008	Misclose (mm)	Distance (km)	1mm√K	Reduced Level 2006	Difference (mm) 2006 - 2008
	BM201		1.32917					
BM201	SAM186	0.99406	2.32323	0.050	0.084	0.290	2.32387	-0.640
SAM186	SAM166	-0.10217	2.22106	0.450	0.189	0.435	2.22167	-0.615
SAM166	SAM16	0.15333	2.37438	-0.025	0.252	0.502	2.37507	-0.690
SAM16	SAM17	1.78696	4.16134	0.010	0.03	0.173	4.16287	-1.534
SAM186	SAM168	-0.53582	1.78741	0.150	0.351	0.592	1.78967	-2.265
SAM168	BM210	-0.53324	1.25416	-0.453	0.221	0.470	1.25567	-1.508
BM210	SAM170	0.69473	1.94889	0.338	0.36	0.600	1.95157	-2.677
SAM170	SAM300	-0.47286	1.47603	-0.425	0.199	0.446	<i>*New mark established in 2008</i>	
SAM300	BM220	0.04767	1.52370	-0.138	0.185	0.430	<i>*New mark established in 2008</i>	
BM220	SAM301	0.09791	1.62161	0.425	0.204	0.452	<i>*New mark established in 2008</i>	
SAM301	SAM187	-0.23817	1.38344	0.018	0.192	0.438	1.38457	-1.131
SAM187	SAM302	0.00184	1.38528	0.295	0.201	0.448	<i>*New mark established in 2008</i>	
SAM302	BM212	0.00273	1.38801	0.088	0.246	0.496	1.38977	-1.760
BM212	SAM303	0.70601	2.09402	0.350	0.209	0.457	<i>*New mark established in 2008</i>	
SAM303	BM213	-0.90796	1.18606	-0.025	0.409	0.640	1.18757	-1.510
BM213	SAM304	0.51556	1.70162	-0.025	0.072	0.268	<i>*New mark established in 2008</i>	



SAM304	BM214	6.41986	8.12149	0.250	0.372	0.610	8.12177	-0.285
BM214	SAM305	1.88863	10.01012	-0.088	0.145	0.381	<i>*New mark established in 2008</i>	
SAM305	SAM139	7.65908	17.66919	0.175	0.333	0.577	17.66917	0.023
SAM139	BM215	3.94393	21.61312	-0.125	0.098	0.313	21.61277	0.349
BM215	SAM306	8.39228	30.00540	0.038	0.175	0.418	<i>*New mark established in 2008</i>	
SAM306	SAMOBM	8.18649	38.19189	0.545	0.424	0.651	38.19207	-0.179
SAMOBM	SAMO	0.72835	38.92024	0.025	0.015	0.122	38.92006	0.177
SAMOBM	RM1	-1.73094	36.46095				36.46076	0.192
RM1	RM3	0.50856	36.96951				36.96946	0.050
RM3	RM4	0.44030	37.40981	-0.213	0.093	0.305	<i>*New mark established in 2008</i>	

0.719 5.059 2mm√K allowable misclose = 4.498mm

An internal precision well within the Project Specification of 2mm√K was achieved for all bays levelled.



Combined Comparisons 1993 to 2008

SAMOA - Comparison of the RL's for Precise Differential Levelling (1993 to 2006) and EDM Height Traversing (2006 to 2008)

YEAR	Bench Mark										SAMOBM
	BM201	SAM16	SAM17	BM210	*BM220	**BM211	BM212	BM213	BM214	BM215	
1993.1	1.3292	2.3843	4.1769								
1994.8	1.3292	2.3812	4.1719								
1996.4	1.3292	2.3796	4.1696								
1998.4	1.3292	2.3783	4.1685								
1999.8	1.3292	2.3777	4.1675								
2001.4	1.3292	2.3768	4.1665								
2002.9	1.3292	2.3751	4.1634	1.2535		1.4287	1.3846	1.1826	8.1172	21.6076	38.1869
2004.7	1.3292	2.3757	4.1627	1.2538		1.4297	1.3864	1.1842	8.1189	21.6103	38.1889
2006.8	1.3292	2.3739	4.1620	1.2546		1.4310	1.3884	1.1874	8.1223	21.6130	38.1926
2006.8	1.3292	2.3751	4.1629	1.2557		1.4321	1.3898	1.1876	8.1218	21.6128	38.1921
2008.3	1.3292	2.3744	4.1613	1.2542	1.5237	-	1.3880	1.1861	8.1215	21.6131	38.1919

**BM220 is a newly placed mark in 2008*

***BM211 was destroyed in 2007*



Apia, Samoa 2008 Reduced Levels

Date: 20-27 May 2008

Datum: Mean Sea Level

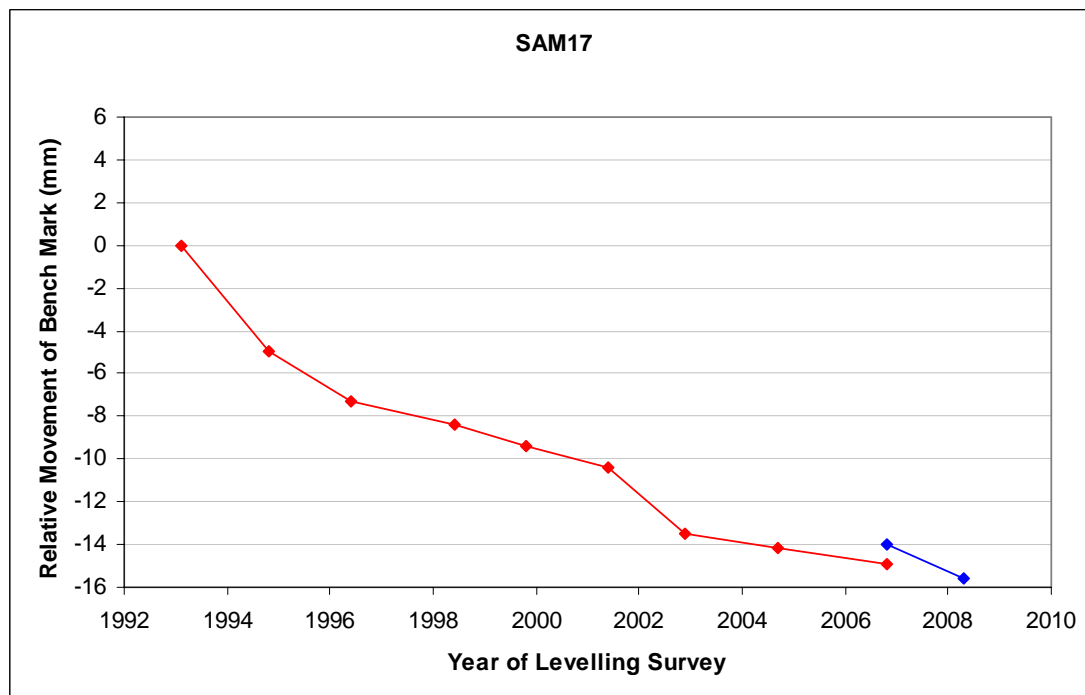
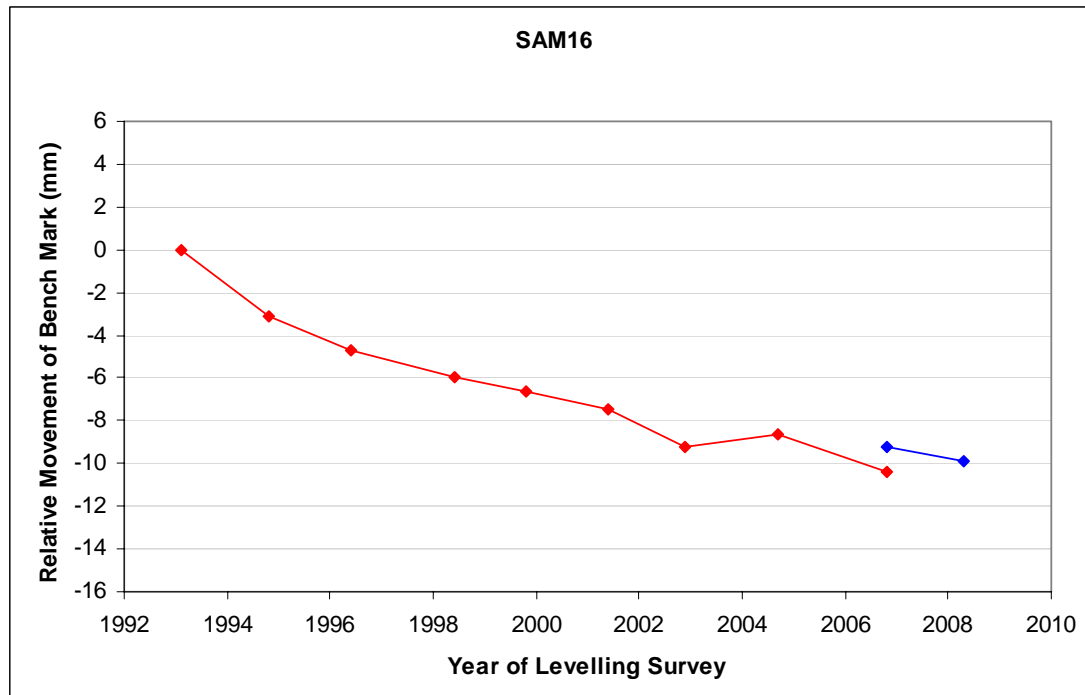
POINT #	2008 levelled diff. ht.	2008 Reduced Level
BM201	0.00000	1.32917 (fixed height)
SAM186	+0.99406	2.32323
SAM166	+0.89189	2.22106
SAM16	+1.04521	2.37438
SAM17	+2.83217	4.16134
SAM168	+0.45824	1.78741
BM210	-0.07501	1.25416
SAM170	+0.61973	1.94889
SAM300	+0.14686	1.47603
BM220	+0.19453	1.5237
SAM301	+0.29244	1.62161
SAM187	+0.05427	1.38344
SAM302	+0.05611	1.38528
BM212	+0.05884	1.38801
SAM303	+0.76486	2.09402
BM213	-0.14311	1.18606
SAM304	+0.37246	1.70162
BM214	+6.79232	8.12149
SAM305	+8.68095	10.0101
SAM139	+16.34003	17.6692
BM215	+20.28395	21.6131
SAM306	+28.67623	30.0054
SAMO	+37.59107	38.9202
SAMOBM	+36.86272	38.1919
RM1	+35.13178	36.4609
RM3	+35.64034	36.9695

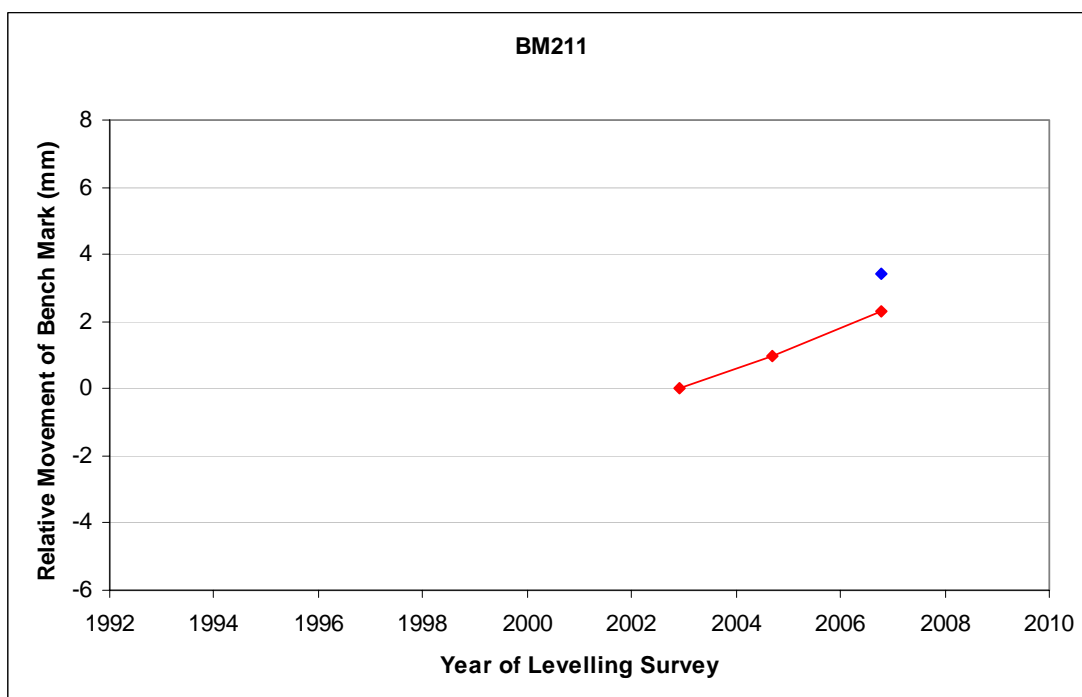
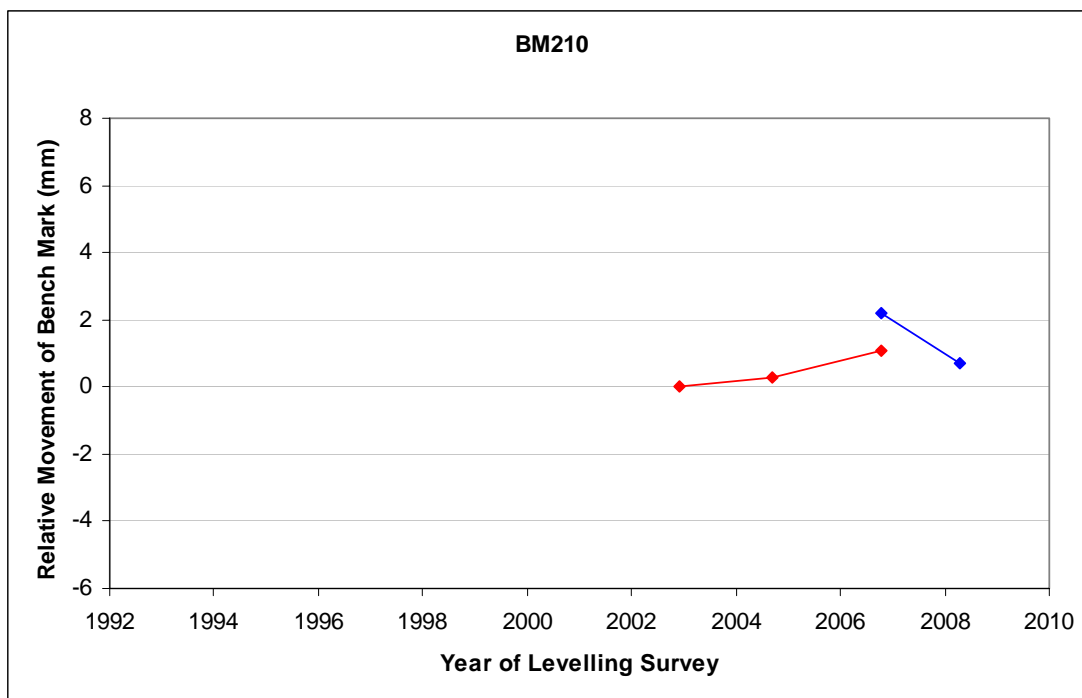


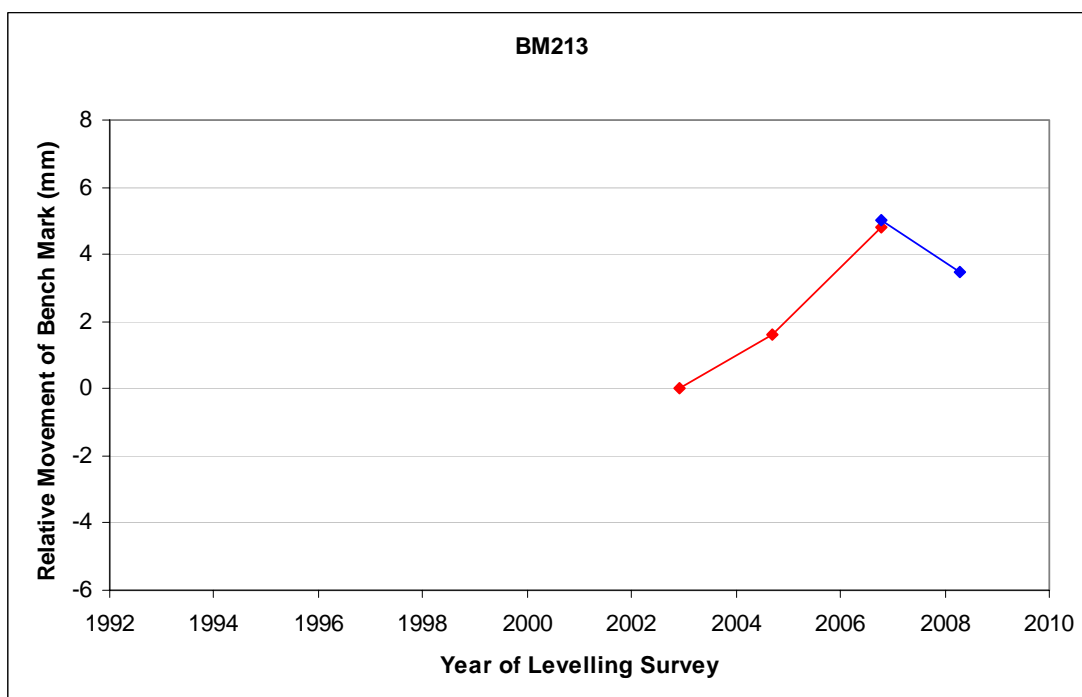
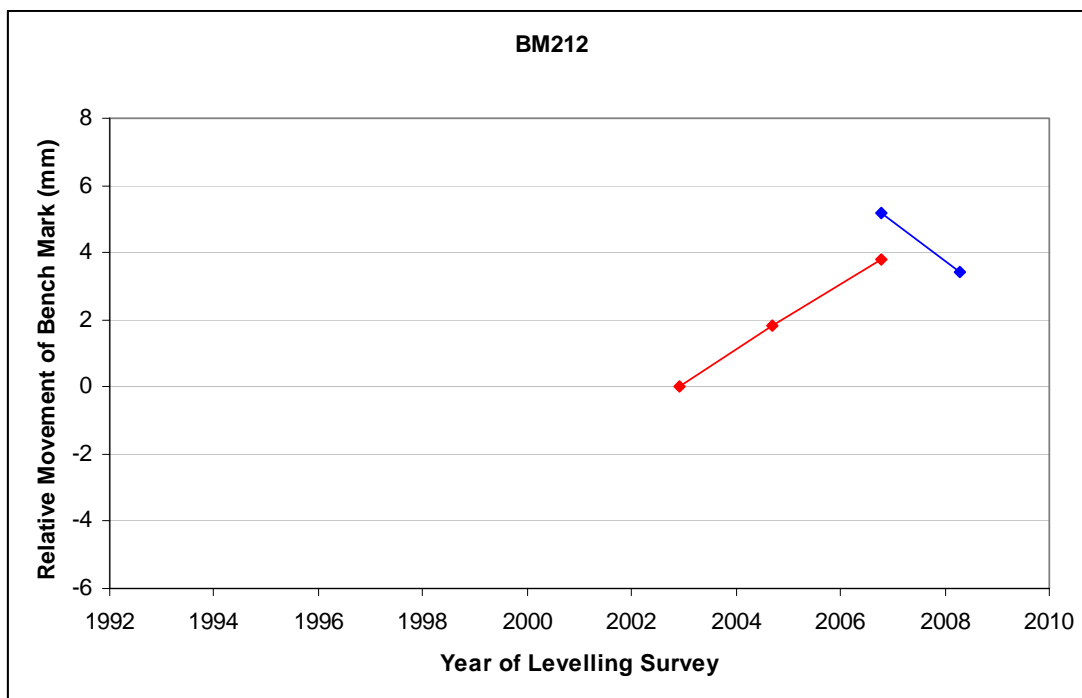
Time Series of Bench Mark movement relative to the Fixed Deep Bench Mark – SAM201

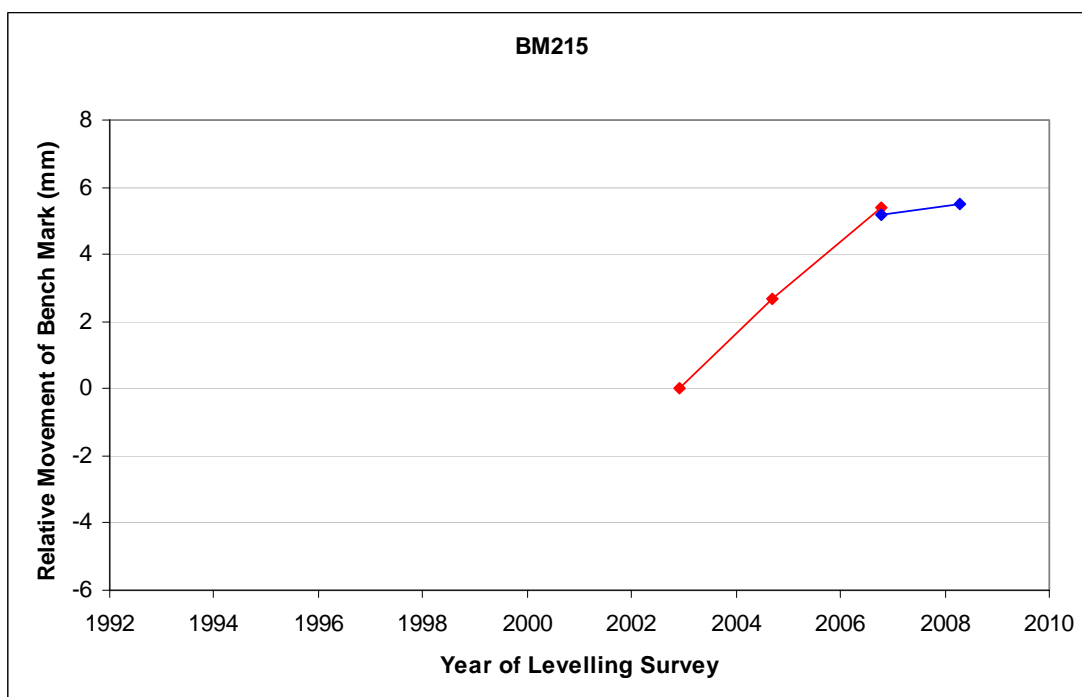
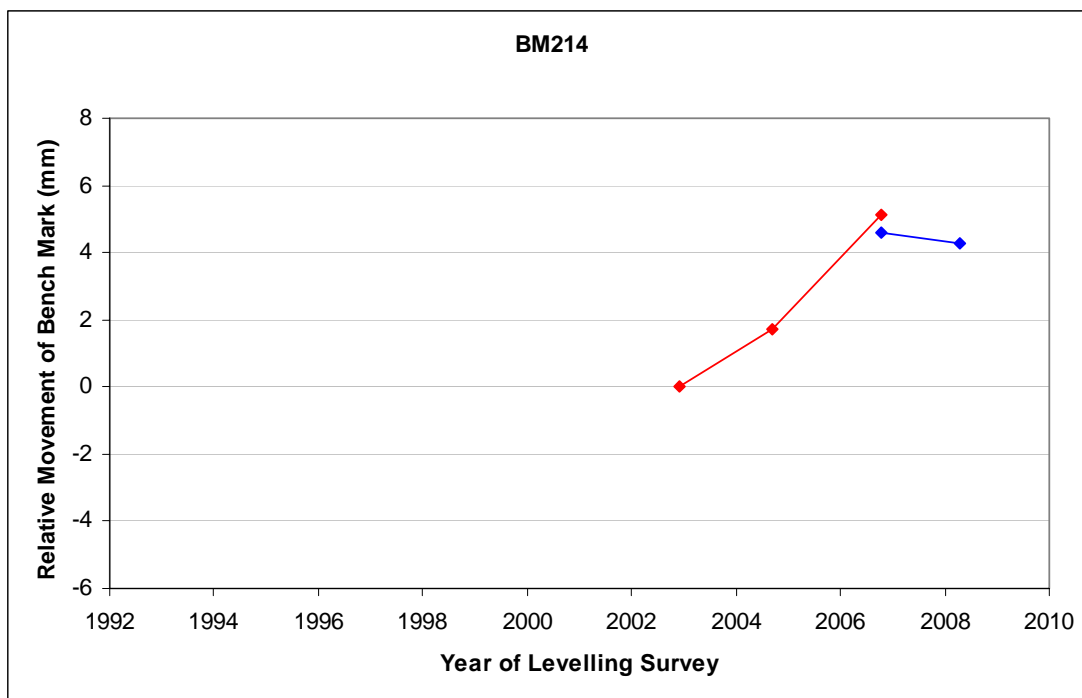
Precise Differential Levelling - 1993 to 2004 (2006)

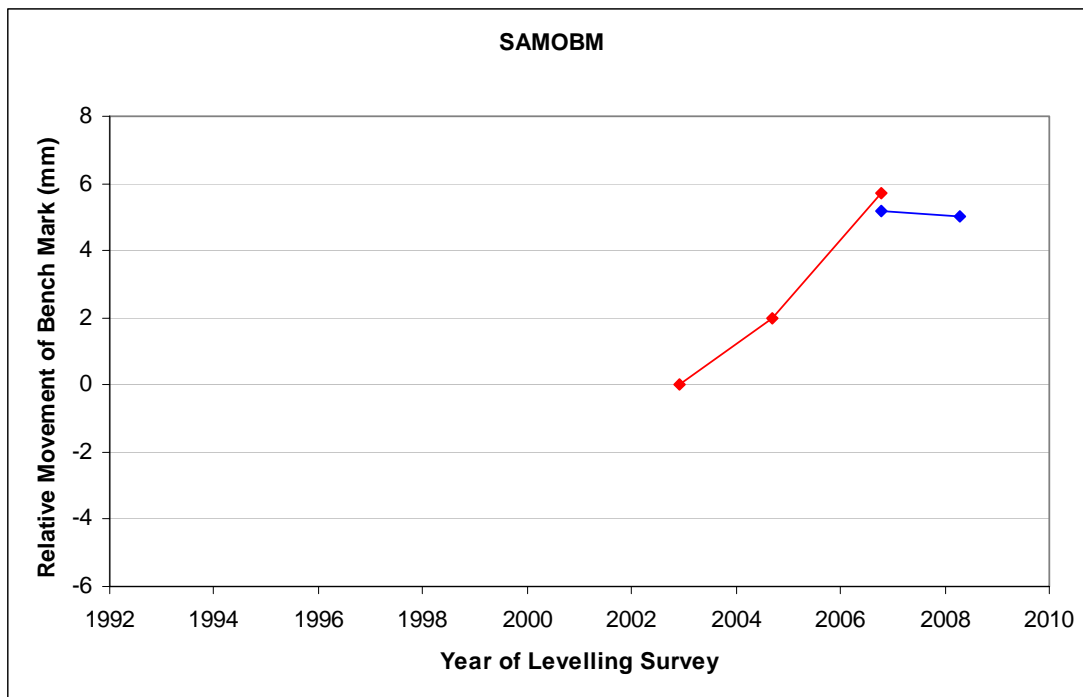
EDM Height Traversing - commenced 2006











Deep BM and TBM's Locality Diagrams



SOUTH PACIFIC SEA LEVEL & CLIMATE MONITORING PROJECT



Survey Bench Mark Record

Bench Mark Number: BM201

Original Bench Mark Established by: National Tidal Centre Australia, Oceanographic Services, Bureau of Meteorology, 25 College Rd, Kent Town, SA. Date: 27-11-91

Existing Bench Mark Established by: Date:

Notes / References: Deep Survey Benchmark
This survey mark is in a good locality for GPS occupation.

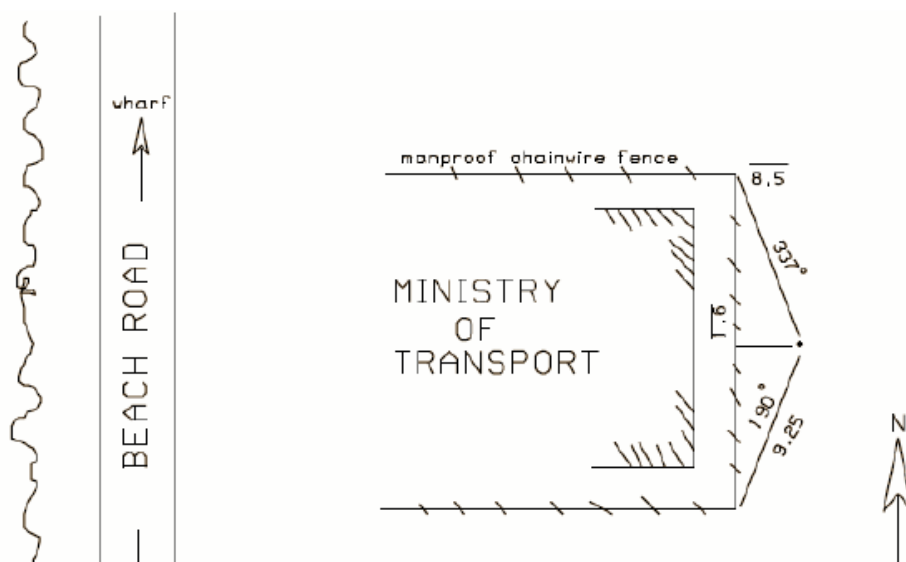
Country: Western Samoa
Island: Upolu

City: Apia

Marking and locality sketch

Bench Mark: 7.4m of 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.2m below ground level.

Locality sketch: Mark approximately 400m from the tide gauge station.



Not to scale

Distances in Metres

Magnetic bearings

Approved by: Geoscience Australia / SOPAC

Date: December 2006





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



Survey Bench Mark Record

Bench Mark Number: BM210

<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> Nov 2002
<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> Western Samoa <i>Island:</i> Upolu	
<i>City:</i> Apia	
<p style="text-align: center;"><u>Marking and locality sketch</u></p> <p>Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.15m below ground level.</p> <p>Locality sketch: Mark approximately 1200m from the tide gauge station.</p> <div style="text-align: center; margin-top: 20px;"> </div>	
<div style="display: flex; justify-content: space-between;"> Not to scale Distances in Metres Magnetic bearings </div>	
<div style="display: flex; justify-content: space-between;"> Approved by: Geoscience Australia / SOPAC Date: December 2006 </div>	





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



Survey Bench Mark Record

Bench Mark Number: BM212

<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> Nov 2002
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
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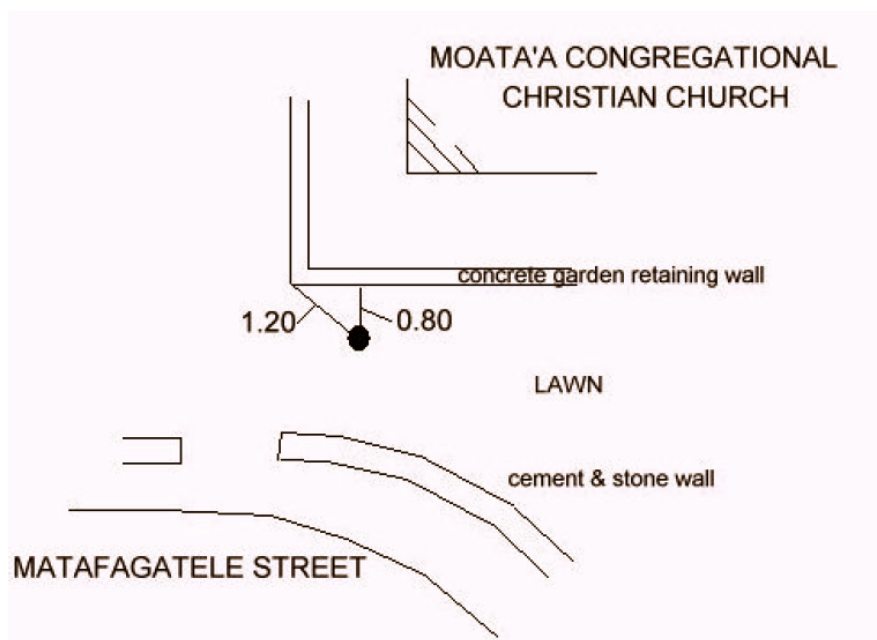
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is not in a good locality for GPS occupation.
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<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
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Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.1m below ground level.

Locality sketch: Mark approximately 2800m from the tide gauge station.



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



Survey Bench Mark Record

Bench Mark Number: BM213

Original Bench Mark Established by:
National Tidal Centre Australia, Oceanographic Services,
Bureau of Meteorology, 25 College Rd, Kent Town, SA.

Date: Nov 2002

Existing Bench Mark Established by:

Date:

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

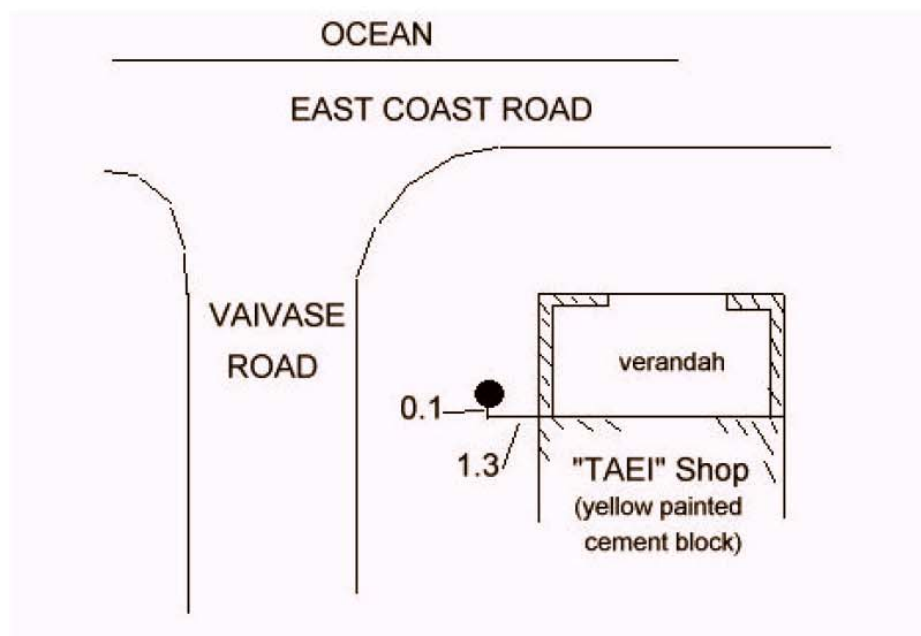
Country: Western Samoa
Island: Upolu

City: Apia

Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for
1.2m. Top of mark 0.5m below ground level.

Locality sketch: Mark approximately 3450m from the tide gauge station.



Not to scale

Distances in Metres

Magnetic bearings

Approved by: Geoscience Australia / SOPAC

Date: December 2006





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



Survey Bench Mark Record

Bench Mark Number: BM214

<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> Nov 2002
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<i>Existing Bench Mark Established by:</i>	<i>Date:</i>
--	--------------

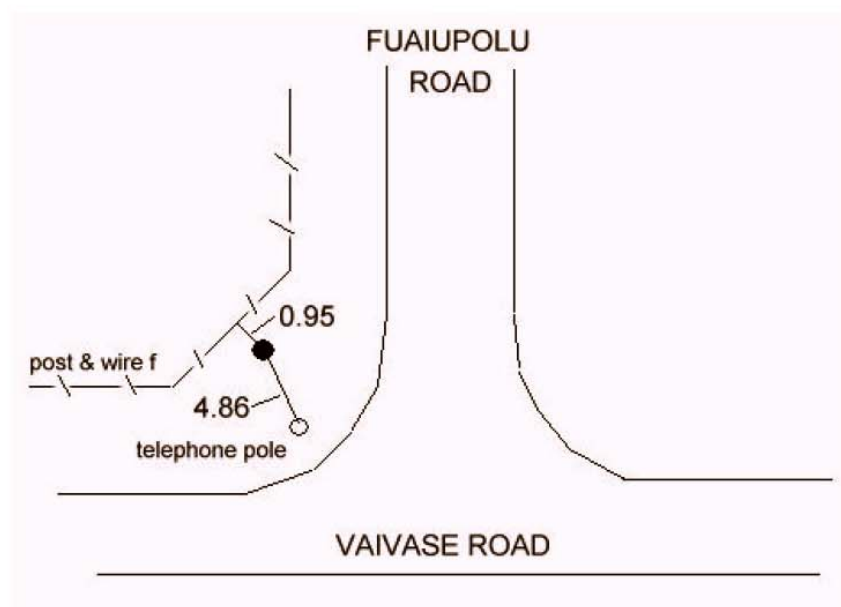
<i>Notes / References:</i> Deep Survey Benchmark This survey mark is in a good locality for GPS occupation.
--

<i>Country:</i> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
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Marking and locality sketch

Bench Mark: 19mm diameter stainless steel capped rod driven to refusal.
 Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark on ground level.

Locality sketch: Mark approximately 3900m from the tide gauge station.



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





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

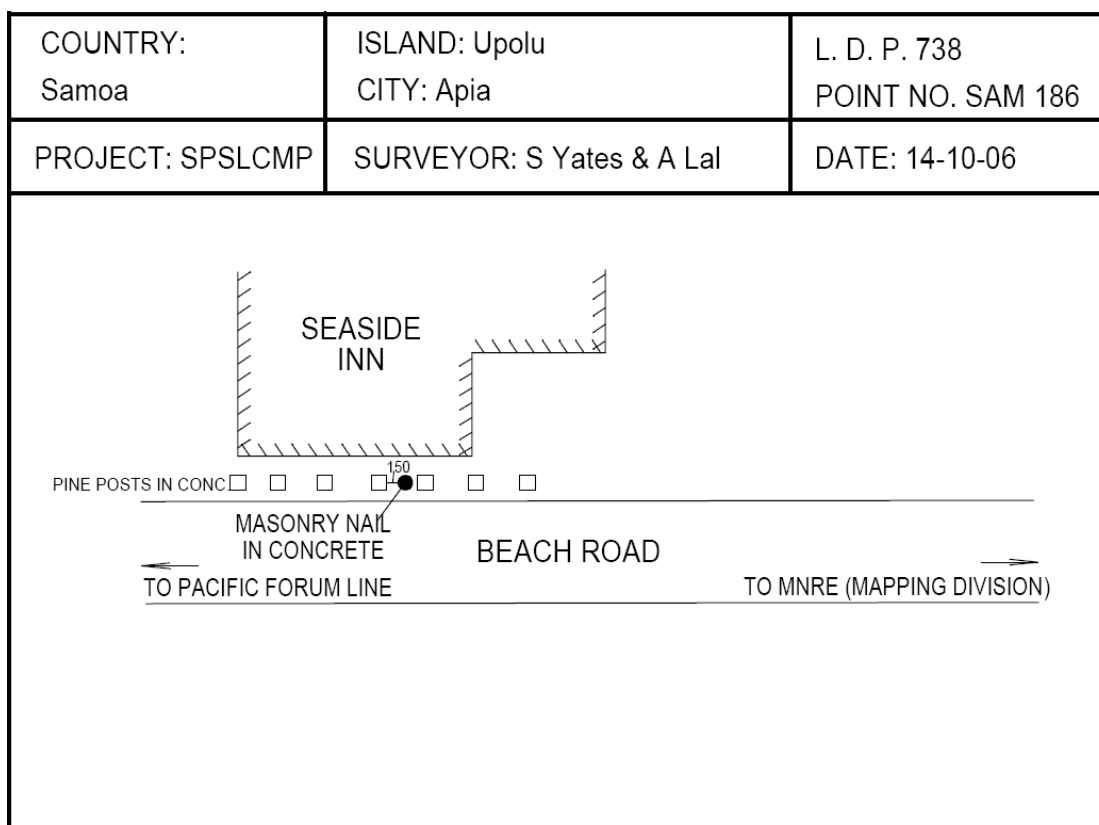
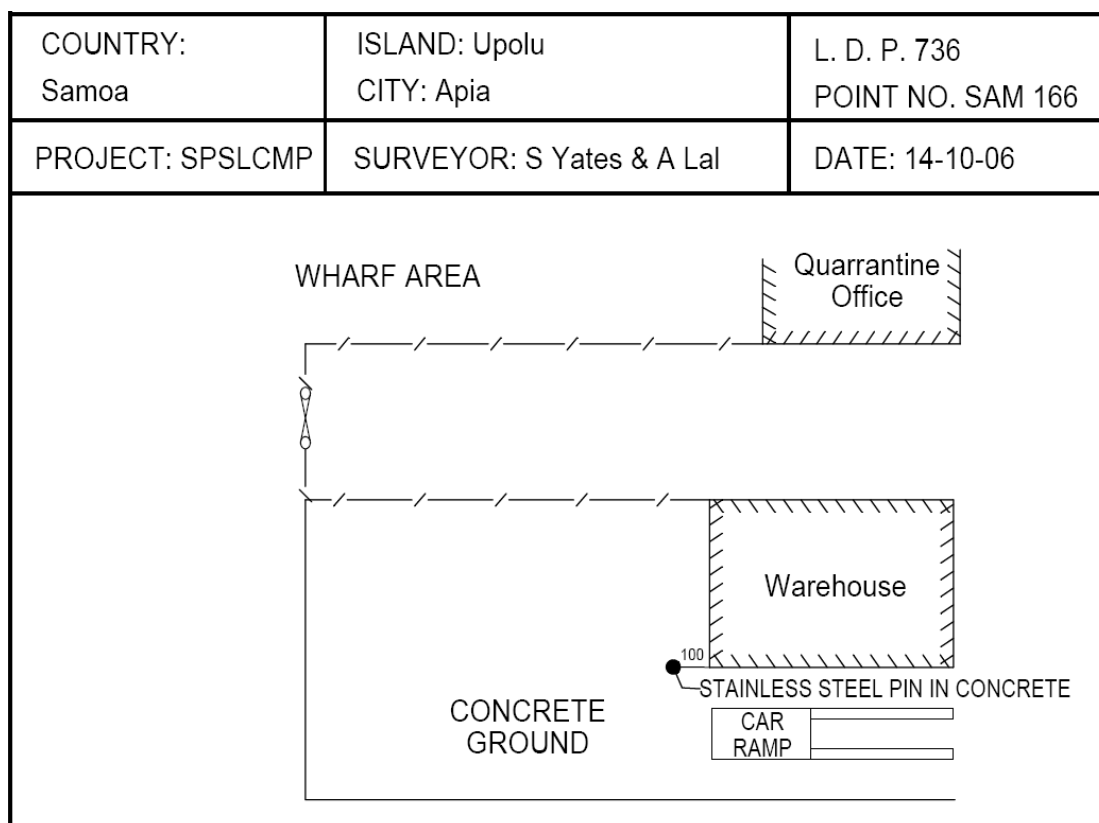


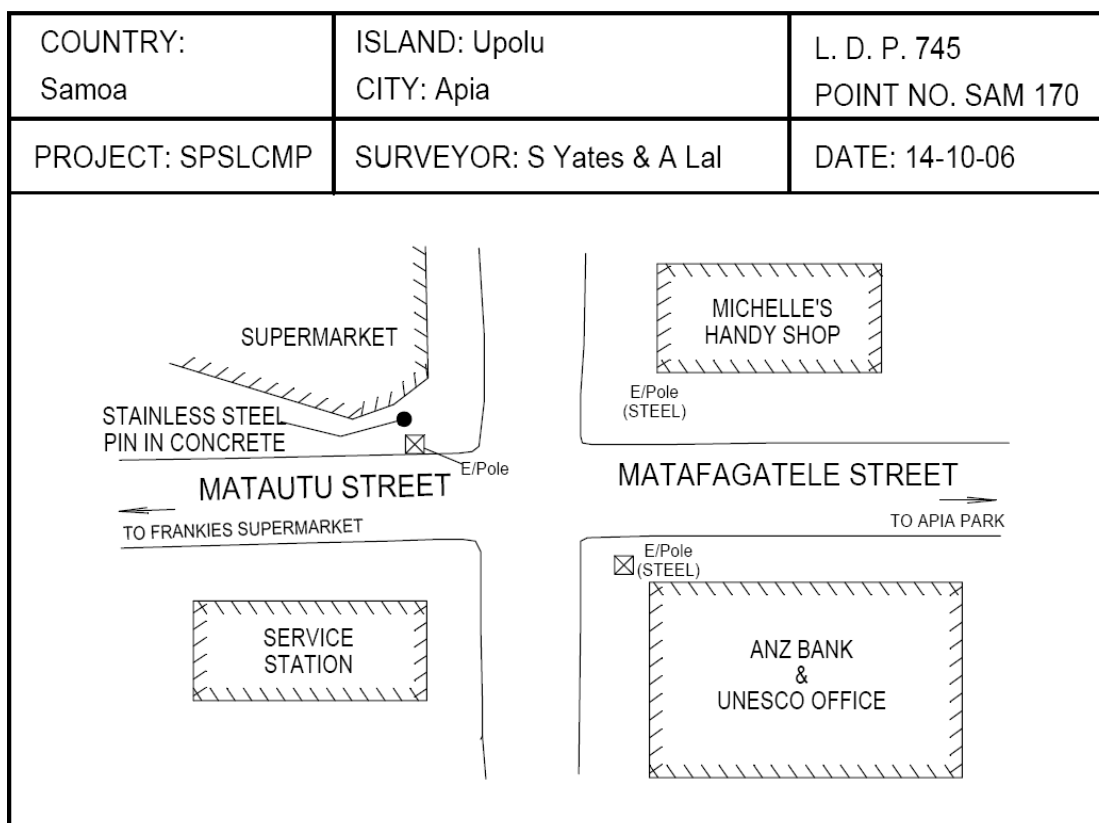
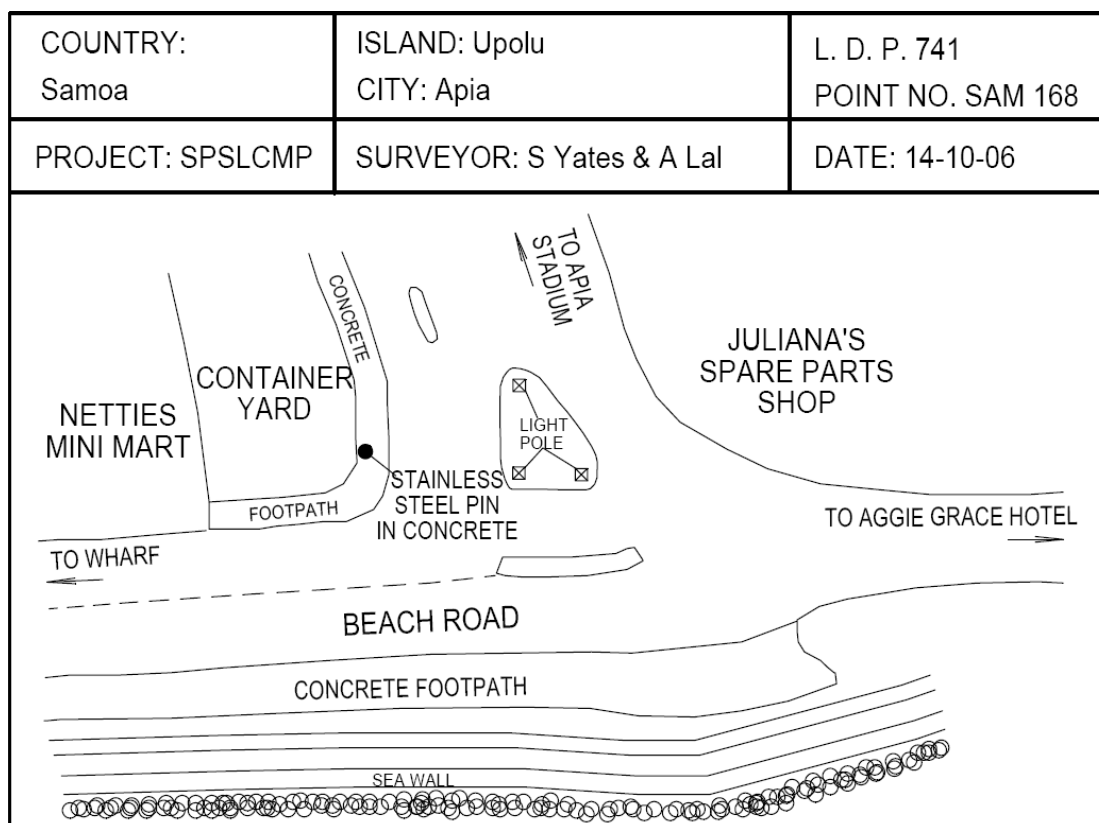
Survey Bench Mark Record

Bench Mark Number: BM215

<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> Nov 2002
<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> Western Samoa <i>Island:</i> Upolu	<i>City:</i> Apia
<p style="text-align: center;"><u>Marking and locality sketch</u></p> <p>Bench Mark: 19mm diameter stainless steel capped rod driven to refusal. Rod sheathed with 50mm diameter PVC pipe, filled with bentonite, for 1.2m. Top of mark 0.2m below ground level.</p> <p>Locality sketch: Mark approximately 4500m from the tide gauge station.</p> <div style="text-align: center; margin-top: 20px;"> </div>	
Not to scale	Distances in Metres
Magnetic bearings	
Approved by: Geoscience Australia / SOPAC	
Date: December 2006	







COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 762 POINT NO. SAM 139
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 15-10-06

COUNTRY: Samoa	ISLAND: Upolu CITY: Apia	L. D. P. 749 POINT NO. VARIOUS
PROJECT: SPSLCMP	SURVEYOR: S Yates & A Lal	DATE: 14-10-06



SAMOBM and SAMO Reference Mark Locality Diagrams

SAMOA PILLAR AND REFERENCE MARKS

Old Fagalii Airport, Plantation Road.

