Australian Government

Geoscience Australia

COOK ISLANDS

South Pacific Sea Level and Climate Monitoring Project (SPSLCMP)

EDM Height Traversing

(Leap Frog Method)

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Geoscience Earth Monitoring

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Contents

1 Introduction

As part of the South Pacific Sea Level and Climate Monitoring Project (SPSCLMP), Geoscience Australia has been requested to undertake a trial survey using the Electronic Distance Measuring (EDM), height traversing, leap frog method, to determine very accurate differences in height.
This request was from the Australian Agency for International Development (AusAID), through the SPSLCMP manager, Australian Marine Science and Technology (AMSAT).
The results from this method are to be compared to the traditional method of differential levelling using digital level and invar staves.
This report outlines the above survey completed during a visit to the Cook Islands, August 2004.

2 Equipment

LEICA Total Station Model TCA1800 (S/N 424936)
LEICA Precision Prisms GPH1P
LEICA Rigid Tripod
2 x Stainless Steel Target Poles supported by LEICA Bi-Poles
2 x Stainless Steel Change Plates

3 Method

The Total Station "Leap-Frog" method 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. See Annex 1.
Atmospheric readings were supplied by the Cook Islands Meteorological Service. These readings were recorded in the Cook Islands Levelling Field Book and entered into the Total Station prior to each level run and approximately every hour there after.
All observations were recorded digitally.

Methodology Summary

• Preparation

1. Bench Mark recovery and preliminary marking for suitable Instrument and Target Change Points – approximately 3 hours.
2. Daily Collimation Test – 15 minutes.
3. Contacting the Cook Islands Meteorological Service and recording the Atmospheric readings into the field book.

• Observations

1. All observations were recorded digitally using a feature of the LEICA TCA1800 of Automatic Target Recognition (ATR).
2. Atmospheric readings entered into the LEICA TCA1800.
3. Minimal time between observations was maintained.

The total observation time for the Forward and Backward runs was 9.5 hours.

• Tide Gauge Reference Pin Connections

The Observations between **COO56 (**Tide Gauge Pin) and **COO10** were performed adopting the Total Station Levelling method and using calibrated target Poles.
See the Level / Target Pole Calibration details in **ANNEX B**

• Reductions

All observations were reduced using Geoscience Australia's inhouse level reduction software (LEVELLING1).
Prior to the reduction of the observations, the data files were formatted to be compatible with the level reduction software.
The data formatting and level reductions accounted for approximately 1 hour each day.

• Data Backup

All observations and reductions of data were backed up daily on Laptop computer, a Memory Flash Drive and copied to CD.

All the Cook Island levelling data is located on the Geoscience Australia's Network Server - **J:\Survey\Pacific Is\SPSLCMP_2004\Cook_Is**

A Data CD containing – the Tide Gauge Connections, Raw, Output, Delta and Calibration Files as well as a copy of the reduction software used is supplied with this report, its full contents is shown in **ANNEX C**.

• Accountable Time

Total time taken for Preparation, observations and reductions for the Cook Islands Height Monitoring Survey accounted for 17.5 hours.

4 Table of Results

COOK ISLANDS 2004 - Height Differences - Bench Mark to Bench Mark					
Bench Mark		**Delta BM to BM FWD Run**		**Delta BM to BM BWD Run**	**MEAN**
BM26					
	-0.4081		0.0058		
	-0.1924		0.2330		
	0.9310		-1.2193		
	1.2201		-0.9320		
	-0.2326		0.1910		
BM33	-0.0055	**1.3125**	0.4096	**-1.3119**	**1.3122**
BM33					
	0.8773		-0.4025		
BM27	0.4025	**1.2797**	-0.8774	**-1.2799**	**1.2798**
BM27					
	0.6214		0.2015		
	-0.5498		0.3117		
	0.1061		-0.2500		
	0.2471		-0.1060		
	-0.3091		0.5509		
BM34	-0.2016	**-0.0860**	-0.6220	**0.0862**	**-0.0861**
BM34					
	-0.6332		0.0172		
	-0.4963		0.3141		
	-0.3107		0.4875		
BM28	-0.0174	**-1.4576**	0.6385	**1.4572**	**-1.4574**
BM28					
	0.4104		0.2406		
BM35	-0.2406	**0.1698**	-0.4107	**-0.1701**	**0.1699**
BM35					
	0.2785		-0.6434		
	0.1138		-0.0282		
	-0.6860		0.4789		
	-0.4886		0.6958		
	0.0282		-0.1264		
CKISBM	0.6432	**-0.1110**	-0.2659	**0.1108**	**-0.1109**
			Height Difference BM26 to CKISBM		**1.1075**

5 Notes

All the levelling observations performed and recorded at Cook Islands in August 2004 were within the specifications tabled in Special Publications 1 – **Table 3 "EDM Height Traversing Observation Procedures".**
A copy of this table can be found in **ANNEX A** - Pages 7 to 9.

The Cook Islands Level Run started at **BM26**, in the vicinity of the wharf area of Avatiu Harbour, and finished at **CKISBM**, this Bench Mark is part of the CGPS Antenna Mount Monument construction and is located within the perimeter fence of the Cook Islands International Airport – a total distance of 2 kilometres.
CKISBM is approximately 0.3m above the ground level.

The level run from **BM26** to **CKISBM** follows the road to the Airport along the flat coastal verge with a height difference between the BM's of only 1.1075 metres.

The first bay levelled was from **BM26** to **BM33** and runs through the point, **COO10** ("Stainless Steel screw in centre of project plaque") which is set in concrete located adjacent to the Tide Gauge Recorder.
A level connection from **COO10** to **COO5**6 (Tide Gauge Reference Pin) was observed, and the results of this connection can be found on the data CD supplied – Cook2004\levelling\Tide Gauge Connections**COO56_COO10 level.xls**. – See **ANNEX C**
A further 5 levelling bays were observed from **BM33** through to **CKISBM**.

- **BM33 to BM27**
- **BM27 to BM34**
- **BM34 to BM28**
- **BM28 to BM35**
- **BM35 to CKISBM**

Hard copies of the above National Tidal Centre (NTC) Bench Mark descriptions are located in **ANNEX D**.

All times were recorded for the preparation, observations and reductions of the Cook Islands levelling from **BM26** through to **CKISBM** (including the connection COO10 to COO56).
Total time taken was recorded at 17.5 hours

6 Issues

The main issue is time - consideration has to be given to allocation of extra time for the following:

- Meetings - A full day has to be set aside for meetings with the Lands and Survey Department and the Meteorological Office.
- Airport access – Cook Is. International Airport has strict security measures in place and arrangements for access to the CGPS site have to be made, these access arrangements take time and are usually organised through a Lands and Survey Department representative.
- Weather – depending on the time of year, an additional day should be considered to allow for bad weather.

ANNEX A

Table 1 EDM Height Traversing Equipment Characteristics

CLASS	L2A	LA	LB	LC	LD & LE
Electronic Tacheometer (Total Station) requirements	1 mm + 1 ppm distance and 1" zenith angle	2 mm + 2 ppm distance and 1" zenith angle	2 mm + 2 ppm distance and 2" zenith angle	2 mm + 2 ppm distance and 3" zenith angle	3 mm + 2 ppm distance and 5" zenith angle
Accuracy of Level Sensor or compensator	0.5"	0.5"	1"	1.5"	2.5"
Diametrical Circle Reading on Vertical Circle (or equivalent)	Yes	Yes	Yes	Optional	Optional
Entry of Temperature and Pressure for on-line First Velocity Correction	Yes	Yes	Yes	Yes	Yes
Refraction and Earth Curvature Correction enabled	Yes	Yes	Yes	Yes	Yes
Target / Reflector construction: Minimum requirements (see Note 1)	2 Fixed Height Reflector Rods w permanently mounted, balanced and tilting Prism	2 Fixed Height Reflector Rods w permanently mounted, balanced and tilting prism	1 - 2 Fixed Height Reflector Rods w permanently mounted, balanced and tilting prism	1 - 2 Standard Reflector Rods with balanced and tilting Prism	1 - 2 Standard Reflector Rods with balanced and tilting Prism
Reflector Rod Support	Bipod / Two Leg Struts	Bipod/ Two Leg Struts	Bipod/ Two Leg Struts	Bipod/ Two Leg Struts	Optional
Bubble attached to Reflector Rod	Yes	Yes	Yes	Yes	Optional
Solid, portable change points (See Note 2)	No - Route is pre-marked	Yes	Yes	Yes	Yes
Umbrella for instrument	Yes	Yes	Yes	No	No

Notes on Table 1:

1. For Classes L2A, LA and LB the target/reflector must be securely attached to the fixed height reflector rod. If the target/reflector assembly is not permanently attached but screwed and locked into place on each day, the height of reflector must agree to 0.01 mm between multiple attachments. The reflector should be tiltable about a horizontal axis that intersects the symmetry axis well inside the prism ("balanced" prism, NO "zero error" prisms). The height of the triangular target patterns on the left and right of the prism must have the same height as the prism (to 0.01 mm) since pointing on close range (to 60 m) is to the apex of the prism and on longer range to the target.
2. All temporary (change plates) and permanently marked change points must feature a small central hole so that the reflector rod does not slide off.

Table 2 EDM Height Traversing Equipment Testing

CLASS	L2A	LA	LB	LC	LD & LE
System test prior to commencement	Yes	Yes	Yes	Optional	Optional
Calibration of index errors of vertical circle and level sensor	Daily	Daily	Daily	Daily	As required
Staff bubble verticality to be within	10'	10'	10'	10'	10'
Barometers accurate to	2 hPa	2 hPa	2 hPa	2 hPa	2 hPa
Thermometers accuracy	1°C	1°C	1°C	1°C	Optional

Table 3 EDM Height Traversing Observation Procedures

CLASS	L2A	LA	LB	LC	LD & LE
EDM Height Traversing Method (see Note 1)	Leap-Frog	Leap-Frog	Leap-Frog or Reciprocal (see Note 2)	Leap-Frog or Reciprocal (see Note 2)	Leap-Frog or Reciprocal (see Note 2)
Number of sets to target	2	2	1	1	1
Pointings in first set: (In second set, if appl., first FS, then BS)	BS(FL), BS(FR), BS(FR), BS(FL), FS(FL), FS(FR), FS(FR), FS(FL)	BS(FL), BS(FR), BS(FR), BS(FL), FS(FL), FS(FR), FS(FR), FS(FL)	BS(FL), BS(FR), BS(FR), BS(FL), FS(FL), FS(FR), FS(FR), FS(FL)	BS(FL), BS(FR), BS(FR), BS(FL), FS(FL), FS(FR), FS(FR), FS(FL)	BS(FL), BS(FR), BS(FR), BS(FL), FS(FL), FS(FR), FS(FR), FS(FL)
Max Spread per set	1.0 mm	1.5 mm	1.5 mm	1.5 mm	3.0 mm
Height difference recorded to nearest	0.01mm per pointing	0.1 mm per pointing	0.1 mm per pointing	1 mm per pointing	D 1mm, E 5 mm per pointing
Temp. and Pressure measured and entered into the instrument	At start, middle and finish of each ‘levelling ‘run and at pronounced changes of temperature				At start of ‘levelling’ run
Maximum length sight In Leap-Frog EDM Height Traversing	60 m	75 m	90 m	120 m	150 m
Slope distance recorded (for balancing FS and BS distances) to:	0.1 m	0.1 m	0.1 m	1.0 m	1.0 m
Minimum ground clearance of line of sight	1.0 m	1.0 m	1.0 m	0.3 m	0.2 m
BS and FS lengths to be equal within	1 m (set out)	2 m (set out)	5 m (set out)	10 m (set out)	20 m (set out)
Observing times	Sight lengths might have to be reduced to achieve “Max Spread per Set” in poor observing conditions (e. g. heat shimmer)				
Two-way levelling in Leap-Frog EDM Height Traversing	Yes	Yes	Yes (But NOT in reciprocal EDM-Height-Traversing)		
Even number of instrument set-ups between bench marks	Yes in Leap-Frog EDM-Height-Traversing with two reflector rods (Not applicable for Reciprocal EDM-Height-Traversing)				Optional
Minimum number of holding marks used for temporary suspension of levelling	Not to be suspended	Not to be suspended	2	2	1
Minimum number of holding marks used for temporary suspension of levelling > 5 days	Not to be suspended	Not to be suspended	3 overlapping marks re-levelled within $2\sqrt{d}$	3 overlapping marks re-levelled within $2\sqrt{d}$	1
Maximum misclosure (mm) of forward and reverse levelling runs	$2\sqrt{d}$	$4\sqrt{d}$	$8\sqrt{d}$	$12\sqrt{d}$	$D=18\sqrt{d}$ $E=36\sqrt{d}$
	where d is the distance in kilometres between benchmarks				
Minimum number of bench marks used to prove datum	3	3	3	3	2
Maximum misclose (mm) on datum BM’s	$2\sqrt{d}$	$4\sqrt{d}$	$8\sqrt{d}$	$12\sqrt{d}$	$D = 18\sqrt{d}$ $E = 36\sqrt{d}$
	where d is the distance in kilometres between benchmarks				

Notes on Table 3:

"**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.

ANNEX B

CALIBRATION FIGURE for the long Stainless Steel Levelling / Target Pole (Pole “A” and is identified by four turned rings) and the short Stainless Steel Levelling / Target Pole.

CALIBRATION FIGURE = 0.9998 metre

This Calibration figure is the difference in length between the two levelling poles and is applied when the combination of these two poles is used.

• Calibration Figure was determined at the Geoscience Australia’s Antenna Calibration Array using the LEICA TCA1800 Total Station.
• Date of the last calibration for this Leveling Pole combination was 21 September 2004.
• Atmospheric corrections have been applied.

ANNEX C

Contents of Digital Data supplied on CD

Cook2004\levelling
BM26_CKISBM_results.xls

Cook2004\levelling\Calibration Files
4_rings to small pole cal.xls

Cook2004\levelling\Delta Files
bm26_bm33_delta.txt
bm33_bm27_delta.txt
bm27_bm34_delta.txt
bm34_bm28_delta.txt
bm28_bm35_delta.txt
bm35_ckisbm_delta.txt

Cook2004\levelling\Output Files
bm26_bm33_out.txt
bm33_bm27_out.txt
bm27_bm34_out.txt
bm34_bm28_out.txt
bm28_bm35_out.txt
bm35_ckisbm_out.txt

Cook2004\levelling\Raw Files
bm26_bm33.txt
bm33_bm27.txt
bm27_bm34.txt
bm34_bm28.txt
bm28_bm35.txt
bm35_ckisbm.txt
COO56_COO10.txt

Cook2004\levelling\Software
Levelling1.exe

Cook2004\levelling\Tide Gauge Connections
COO56_COO10 level.xls