Trip Report - climate and sea level monitoring in Kosrae to underpin infrastructure decision-making and design

Prepared for Kosrae Project Office
Pacific Adaptation to Climate Change
Kosrae Island Resource Management Authority

February 2012

Authors/Contributors:
Andrew Willsman

For any information regarding this report please contact:

Andrew Willsman
Technician
Dunedin Field Team
+64-3-477 8615
a.willsman@niwa.co.nz

National Institute of Water & Atmospheric Research Ltd
10 Kyle Street
Riccarton
Christchurch 8011
PO Box 8602, Riccarton
Christchurch 8440
New Zealand

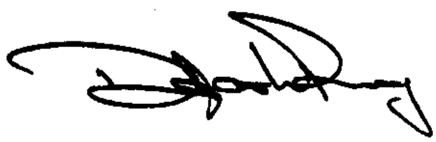
Phone +64-3-348 8987
Fax +64-3-348 5548

NIWA Client Report No:	CHC2012-015
Report date:	February 2012
NIWA Project:	

Contents

Figures

Reviewed by



Doug Ramsay

Approved for release by

Graham Elley

1 Background

This report summarises the installation of sea-level and climate monitoring equipment and associated activities as one component of the Pacific Adaptation to Climate Change (PACC) demonstration project on Kosrae. This purpose of this component is to provide adequate baseline monitoring on Kosrae to ensure fit-for-purpose climate-related information is available to inform future climate sensitive decision-making and planning.

Andrew Willsman from NIWA NZ spent ten working days on Kosrae over the period 16 November 2011 to 25 November 2011. Great support and help from the KIRMA staff (Simpson, Blair, Maxson, Duffy, and Kenye) meant that all the instrumentation was installed, and nearly all of the beach profile benchmarks were found and measured with the GPS survey equipment.

The report contains information on activities carried out during the installation and details of routine operational and maintenance requirements for the instrumentation installed.

2 Completed objectives

2.1 Okat Airport high intensity rainfall monitoring and solar radiation station

The tipping bucket rain gauge (TB3 model from HydroServices Australia, 0.5mm tips) was installed on a concrete block 3 meters from the NOAA 8 inch manual rain gauge, and other data recording and telemetry equipment was installed in an equipment housing located 5 meters to the south of the rain gauge. The Licor solar radiation sensor was installed at the top of the equipment pole. Data is logged on site at 10 minute intervals (Figure 2-1).

Figure 2-1: Installed rainfall and solar radiation station at Okat airport.

The Neon data logger (NRTID=1161, Neon serial number=3326) provides telemetry via the cellular tower located close by at the Okat Bridge. A SIM (phone number = 9707255) from the Neon test unit was installed. At the time of installation it had an unknown amount of credit on it. Simpson Abraham is following up with FSM Telecommunications Corporation (FSMTC) to provide a method to determine the SIM credit balance that does not involve removing the SIM from the Neon and inserting in a cellphone.

Regular two monthly site inspections are recommended for this station and written procedures (Appendix A) for completing these inspections were demonstrated and completed by Blair Charley at the station on 25 November 2011. The Neon units require initialisation to start and if the units require a reset in the future then a procedure to do this is in Appendix B.

Calibration checks on the rain gauges are recommended annually and it should be possible to borrow the calibration kit from Dickson Wichep at the Department of Transport Communications and Infrastructure in Pohnpei. A service of the rain gauge is recommended every two years and it should be possible to send a replacement gauge from New Zealand (for a fee) when this is required. The site runs on solar power and the lead acid 12V battery should be replaced every five years.

Additional sensors such as temperature or a combined temperature, relative humidity, wind speed and direction can also be fitted to this station if required.

Plots of the first week's rainfall (Figure 2-2) and solar radiation data (Figure 2-3) from the Neon website are shown below. Data is available from neon.niwa.co.nz with username and password access which is available from NIWA.

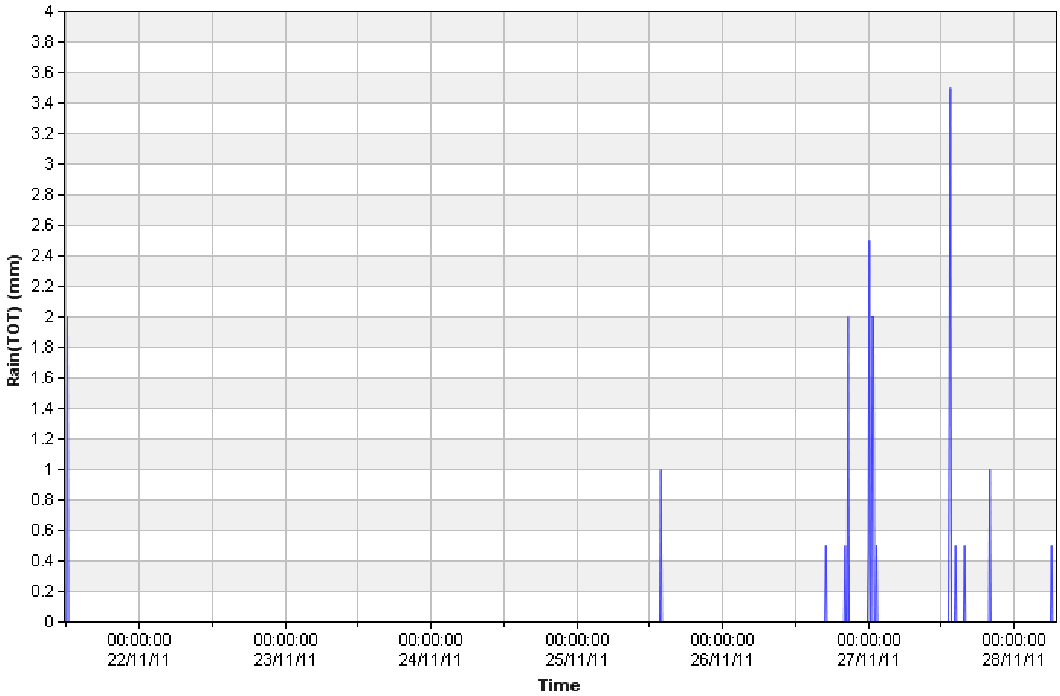


Figure 2-2: Rainfall record 21/11/2011 to 28/11/2011, measured in mm at a 10 minute time interval. Total for this period 20.5 mm.

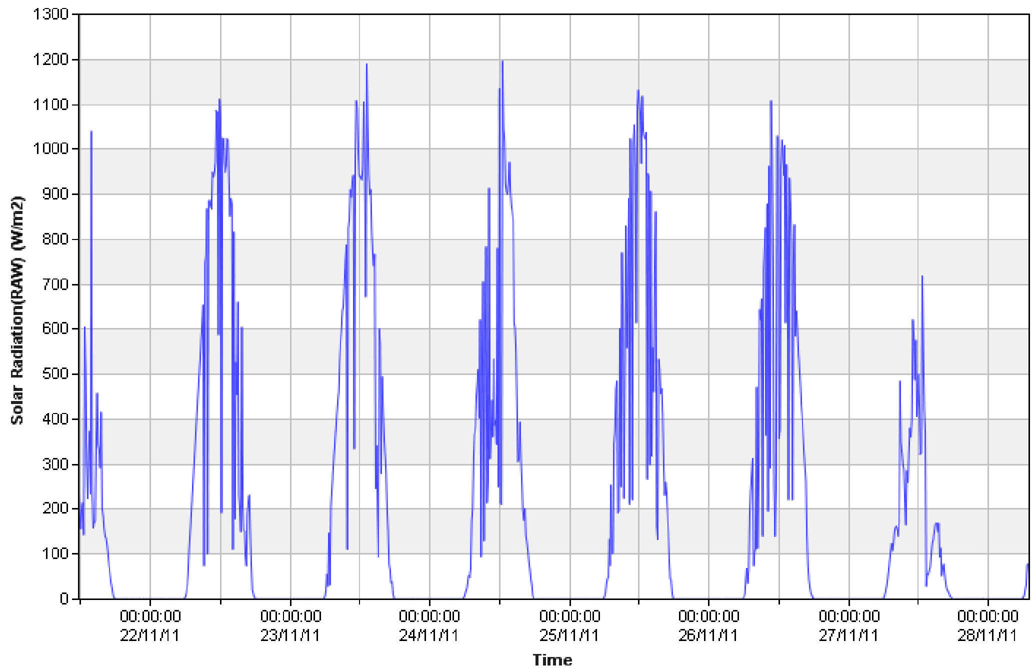


Figure 2-3: Solar radiation record 21/11/2011 to 28/11/2011, measured in W/m^2 at a 10 minute time interval. Note the daily rise and fall, and nights going to 0. Downward spikes during the day are clouds blocking the sun.

2.2 Lelu Harbour sea-level recorder

A sea-level gauge was installed at the Marine Resources dock in Lelu Harbour, and the intention is that this will provide long-term reliable baseline sea-level information and enable sea-levels on Kosrae to be related to the longer-record Seaframe tide gauges at Pohnpei and Majuro . The existing large PVC pipe stilling well was utilised by removing the rusty steelwork on top and installing an equipment housing on top to hold a telemetered Neon logger, water-level encoder, and barometric pressure sensor. A small solar panel, located on the new housing's roof and a 24Ah battery provide a local power supply. The PVC stilling well has a recorder value measuring range from 1.0m at the base of the tower to 5.2m maximum at the underside of the housing.

The Neon data logger (NRTID=1105, Neon serial number=3962) provides telemetry via the nearby cellular tower located on the summit of Lelu Island. A new SIM (phone number = 9707379) was installed on 16 November 2011 with $10 credit loaded. Based on usage at the start of the record we expect that $10 credit will last for 3 months.

Photographs of the completed sea level station are shown in Figure 2-4.

Figure 2-4: Lelu sea level station.

An external reference staff gauge with a recorder range from 1.0m minimum to 4.0m maximum was installed on the concrete wall to provide a reference to check the level of the encoder in the stilling well. An extra dynabolt was installed alongside the staff gauge at the 3.0m mark as a backup reference point if the staff gauge board is destroyed. If required a tape measure can be used to measure from the outer top point of this bolt (Figure 2-5) to get an external gauge height.

Figure 2-5: Backup external reference point is the top of the threaded inner shank of the dynabolt. This has a recorder level of 3.0 m. A tape measure can be used to measure water level from this point if the staff gauge plates are lost.

A benchmark (stainless dynabolt) was installed in the concrete on the eastern outer corner of the wharf (Figure 2-6). A Trimble R8 GPS receiver logged 30s position data over this benchmark for 3 continuous days and partial days later in the week. This data was post processed using the AUSPOS GPS processing service, which uses a combination of international GNSS reference stations in the Pacific and final satellite orbit data to calculate a very precise position and elevation (Appendix E). The position and elevation of this benchmark is noted in Appendix F in GRS80/ITRF2008 (time accurate WGS84) latitudes, longitudes, and ellipsoidal heights, and a geoid height using the 1 minute EGM2008 geoid model. A local vertical datum height has also been derived but this is only based on an inclined plane vertical calibration based on only 3 local Kosrae Survey Department vertical control points (details in Appendix F).

Figure 2-6: Reference benchmark on the corner of the wharf, stainless steel dynabolty in front of the staff.

Levelling between the benchmark and external staff gauge at the site has established the elevation of the recorder zero level in global ellipsoid height, EGM2008 geoid model elevation, and local vertical datum elevation. The results of this are included in Appendix G. So for example to turn the recorder values into:

- global ellipsoidal heights, add 40.748m to all recorded values.
- EGM2008 geoid model elevations, subtract 0.935m from all recorded values
- Local vertical datum elevations, subtract 1.201m from all recorded values.

Regular two monthly site inspections are recommended for this station. Training on the operation and servicing of the recorder was given to Blair Charley in the week following installation, and these procedures are documented in Appendix C. The Neon units required an initialisation procedure to start the first time, and they may require resetting in the future if any changes are made to the recorder programs. The initialisation procedure is documented in Appendix B.

Plots of the first ten days of sea level (Figure 2-7) and barometric pressure data (Figure 2-8) from the Neon website are shown below. Data is available from neon.niwa.co.nz with username and password access which is available from NIWA.

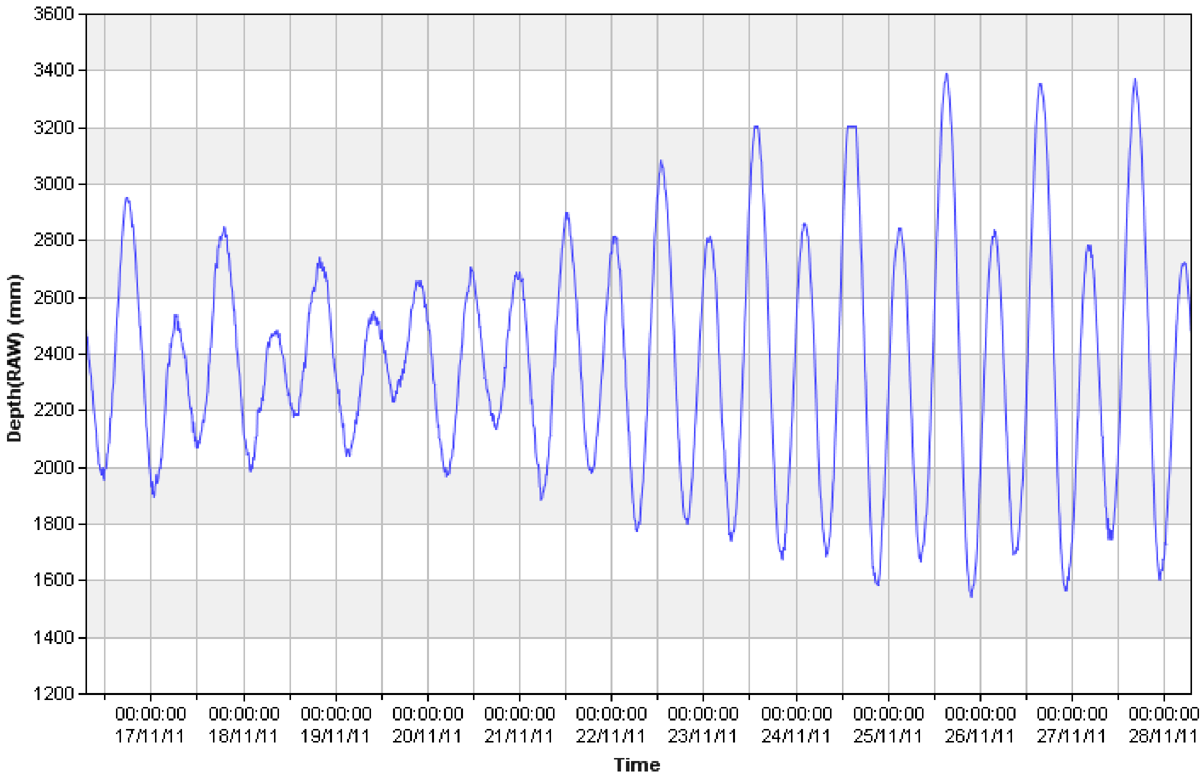


Figure 2-7: Lelu Harbour sea level record 16/11/2011 to 28/11/2011, measured in mm recorded at a 10 minute time interval.

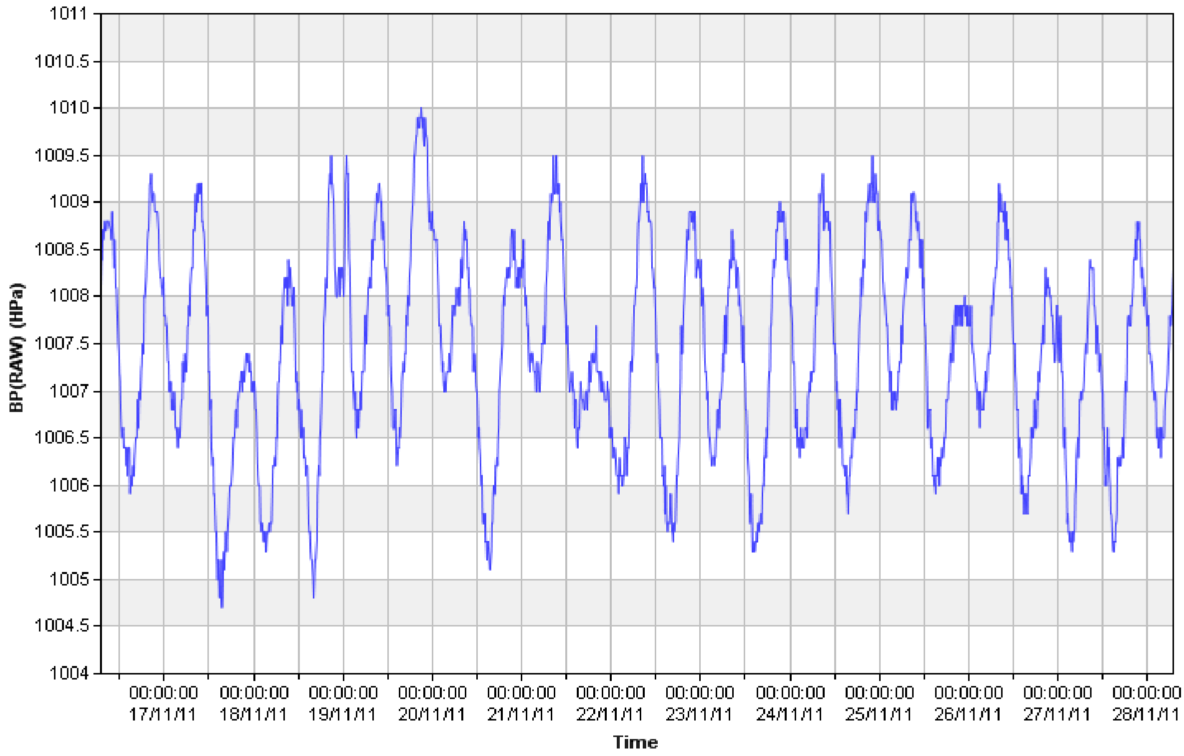


Figure 2-8: Lelu Harbour barometric pressure record 16/11/2011 to 28/11/2011, measured in hectopascals (Hpa) recorded at 10 minute time intervals.

2.3 Temporary sea level monitoring stations

An improved understanding of the variability in tides and sea-levels around Kosrae was required to adequately account for sea-level considerations within the PACC demonstration project and for subsequent completion of the circumferential road. In addition to the semi-permanent Lelu harbour sea-level gauge, short-term (>262 days) sea level gauge installations were built at Okat, Walung and Utwe to establish a better understanding of the variation in Kosrae's tides.

At each temporary sea-level gauge station an external staff gauge, and mounting brackets for a 4inch PVC pipe were installed. This configuration allows easy installation of a submersible pressure transducer that can be shifted between sites. At each site a benchmark was installed and the position and elevation was determined by occupying with a Trimble R8 Rover unit which enabled post correction to the base station. Levelling from this benchmark to each staff gauge meant that all sites could be tied into the same vertical datum.

2.3.1 Okat site installation

The installation at Okat is on the eastern concrete wall of the wharf (Figure 2-9). A benchmark was installed on the concrete deck above and 3m to the North of the cable box (Figure 2-10). A benchmark (stainless dynabolt) was installed in the concrete on the eastern outer corner of the wharf (Figure 2-6). A Trimble R8 GPS receiver logged 30s position data over this benchmark for 1 hour, and this data was post processed to the base station at the Lelu sea level recorder benchmark. The position and elevation of this benchmark is noted in

Appendix F in GRS80/ITRF2008 (time accurate WGS84) latitudes, longitudes, and ellipsoidal heights, and a geoid height using the 1 minute EGM2008 geoid model. Levelling between the benchmark and external staff gauge at the site has established the elevation of the recorder zero level in global ellipsoid height, EGM2008 geoid model elevation, and local vertical datum elevation. The results of this are included in Appendix G.

Figure 2-9: Okat Wharf temporary sea level installation.

Figure 2-10: Okat Wharf benchmark, stainless dynabolt drilled into concrete deck.

A NorthWest Instruments PT2X transducer was installed here on 18 November 2011. It is attached to the well cap with a stainless carabiner and cable and is weighted to hang straight. The spare cable is coiled inside a housing at the top of the wall. The data is retrieved via laptop and the procedure is outlined in Appendix D. The transducer has internal AA batteries that will power the device, allowing greater than 8 months between battery changes (10 minute recording).

To shift the site the transducer, PVC pipe and housing are removed and shifted to the next location.

2.3.2 Walung site installation

A reference staff gauge and mounting brackets were installed at low tide on 20 Nov 2011 on a bridge pile with the greatest depth of water (Figure 2-11). A new benchmark was established on the top concrete surface of the south-eastern corner of the central bridge pier (Figure 2-12). A Trimble R8 GPS receiver logged 30s position data over this benchmark for 1 hour and this data was post processed to the base station at the Lelu sea level recorder benchmark. The position and elevations of this benchmark are in Appendix F in GRS80/ITRF2008 (time accurate WGS84) latitudes, longitudes, and ellipsoidal heights, and a geoid height using the 1 minute EGM2008 geoid model. Levelling between the benchmark and external staff gauge at the site has established the elevation of the recorder zero level in global ellipsoid height, EGM2008 geoid model elevation, and local vertical datum elevation. The results of this are included in Appendix G.

When the transducer is shifted to this location the 3m length of PVC pipe from the Okat site will need to be moved to this location.

Figure 2-11: Walung Bridge reference staff gauge, and mounting brackets for PVC pipe and housing.

Figure 2-12: GPS collecting data over a new benchmark drilled into the concrete top of a pile on the southeastern corner of the central section of the bridge.

2.3.3 Utwe site installation

A reference staff gauge and PVC pipe were installed on the small concrete wharf on the western bank immediately downstream of the bridge (Figure 2-13). A new benchmark was established on the western side of the Utwe bridge (Figure 2-14). A Trimble R8 GPS receiver logged 30s position data over this benchmark for 1 hour, and this data was post processed to the base station at the Lelu sea level recorder benchmark. The position and elevations of this benchmark are in Appendix F in GRS80/ITRF2008 (time accurate WGS84) latitudes, longitudes, and ellipsoidal heights, and a geoid height using the 1 minute EGM2008 geoid model. Levelling between the benchmark and external staff gauge at the site has established the elevation of the recorder zero level in global ellipsoid height, EGM2008 geoid model elevation, and local vertical datum elevation. The results of this are included in Appendix G.

Figure 2-13: Utwe sea level station with two reference staff gauges, and PVC pipe installed.

Figure 2-14: GPS collecting data over a new benchmark drilled into the concrete abutment on the NW corner of Utwe Bridge.

2.4 Surveying the coastal erosion monitoring network

Monitoring shoreline change and erosion on Kosrae is coordinated by KIRMA via a series of beach profiles initially established in 1995 by SOPAC, expanded by KIRMA in 2000 and with some further additions and changes to some profile sites over the last 10 years. The usefulness of the beach profile information is limited at present by:

- The benchmarks marking the start of each profile not being surveyed in to the Kosrae control survey network which would relate levels back to survey datum and enable a proper comparison of shoreline changes around Kosrae.
- A number of benchmarks marking the position of the profiles having been lost resulting in it not possible to continue to measure shoreline change where this has happened. Back-up benchmarks would ensure that some resilience is built in to the monitoring network and help maintain on-going monitoring where 10 to 15 years of data has already been collated.

As the sea-level monitoring gauges were surveyed in to the survey datum using a survey grade RTK-GPS system, the opportunity was taken to also survey in the beach profile benchmarks and where possible, to establish back-up benchmarks for each profile during the same visit.

This task was assisted by Leandro Olano and his team from the Kosrae Survey Department. They provided local projection coordinate benchmark information, and benchmark height details for the 1970's US vertical datum for the island (Figure 2-15). There was no information on how this vertical datum was established in the 1970's, although it is known to be based on Benchmark S1 located on a reef outcrop on the point North of the Nautilus Resort Hotel. From here it appears a levelling run was done around to the Okat Bridge.

Three control stations were occupied with local vertical datum heights, S1 (fundamental), S22 (near the Phoenix Hotel), and K0 on the Okat Bridge.

Figure 2-15: GPS being set up to collect position over benchmark S1 the fundamental benchmark for the Kosrae vertical datum.

The local survey department projection is a transverse Mercator, based on WGS72 coordinates established at an unknown date in the 1970's, written documentation of this could not be found. Four additional horizontal control stations were occupied to try and transform the GPS data to the local projection.

2.4.1 Results

The GPS base station was established initially on benchmark 1 at the Lelu Wharf sea level recorder, and a continuous occupation of 2.5 days was used to establish an ITRF2008 (International Terrestial Reference Frame 2008/GRS80, essentially the same as WGS84 positions) position and elevation (ECEF-earth centred earth fixed). This position was calculated using the AUSPOS online static processing service, based on a number of reference stations and final orbit data (Appendix E). Geodetic elevations for this point are based on the global EGM2008 geoid model.

Most measurements at the beach mark profile benchmarks were made using rover GPS occupations of 10 to 20 minutes in length and these were post processed (PPK) using the continuous observations at the base station. A few RTK measurements were made but the radio performance was poor due to either a faulty radio repeater and/or thick vegetation limiting the radio transmission signal.

Many of the beach profile benchmarks were located in areas with obscured visibility to the sky so some measurements could not be made, in these cases a new benchmark was installed nearby in place with more sky visibility. Results of the GPS measurements are included in Appendix F. The uncertainties in the horizontal and vertical positions are noted for each position and these should be considered when using the data as the uncertainties in positioning are quite large for some of the obstructed benchmarks. Photographs of new benchmarks installed during the survey are included in Appendix I.

By applying an inclined plane vertical site transformation using the three local vertical datum control station (Lelu to Okat) elevations the data were transformed to the Kosrae local vertical datum. It should be noted that there is significant uncertainty in these local datum elevations particularly to the south and west of the island where there was no levelling height control. Deviations between the global ellipsoid minus EGM2008 geoid model elevations and global ellipsoid minus derived local vertical elevations grow large to the south and west towards Utwe and Walung.

Figure 2-16 shows the base station locations and processing lines used to correct the rover observations.

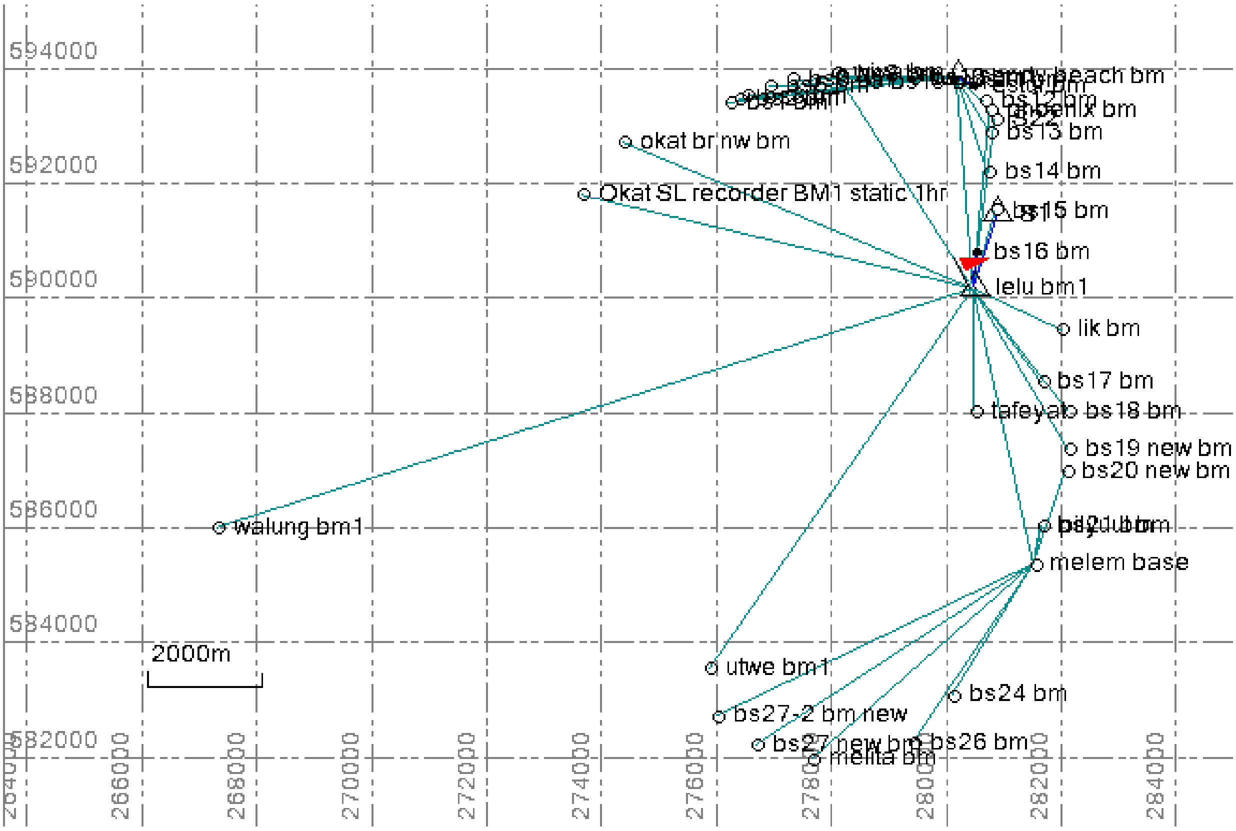


Figure 2-16:Survey line processing map, base located primarily at Lelu BM1, with secondary locations at Melem and Sandy Beach.

The Kosrae Survey Department use a local transverse Mercator projection and it was apparent that this differs from the global referenced transverse Mercator projection (UTM58N) that the GPS uses. A few local control stations were measured during the survey and an attempt was made to transform the GPS data to the local projection. Only four control stations could be used for the transformation as the other 4 stations had large horizontal residuals that suggested they had the wrong coordinates. The transformation parameters (Appendix H) calculated using control stations S1,S22, Estur BM, and K0 indicate a significant difference in the Northings (-48.010m) and Eastings (-29.055m shift) between the projection systems. The horizontal residuals on this transformation remain significant (1.157m) and indicate that there is a lack of cohesive control station data to confidently shift transform the GPS data set to the local horizontal projection.

Appendix A Okat rainfall, solar radiation inspection procedure

Okat Rainfall Station – visit to check at least every 2 months

Take from office: laptop, Keyspan USB to serial converter, 9 pin straight through DB9 cable, Key for box, Tool and cable plastic box

1) Open the box and get the Allen key for raingauge either in box or in tool kit box.

2) Remove raingauge cover, clean the filter, clean the buckets, remove any insects etc, check that it is still level. Tip the buckets twice. Cover back on.

3) Plug into the Neon with the DB9 (white cable) and Keyspan USB to serial.

4) Start Starlog, connect on the right com port, go to test mode. At the next 10 minute log the two tips of rainfall (each tip is 0.5mm) should be logged as 1mm. Note that you do not have to plug into the Neon as you can check this logged value at this time on the Neon website from the office.

5) Check the solar radiation values, if you cover it with your hand it should drop close to zero, sun shining anywhere in the range 200 to 1200 W/m2 depending on sun location and clouds.

6) Fill in the logbook that you have checked the site and completed 2 manual tips. This 1mm of rain can be removed if you like from your local archive once you have the data downloaded onto your PC.

Appendix B Initialising a neon logger

Resetting (initialising) a NEON metering module

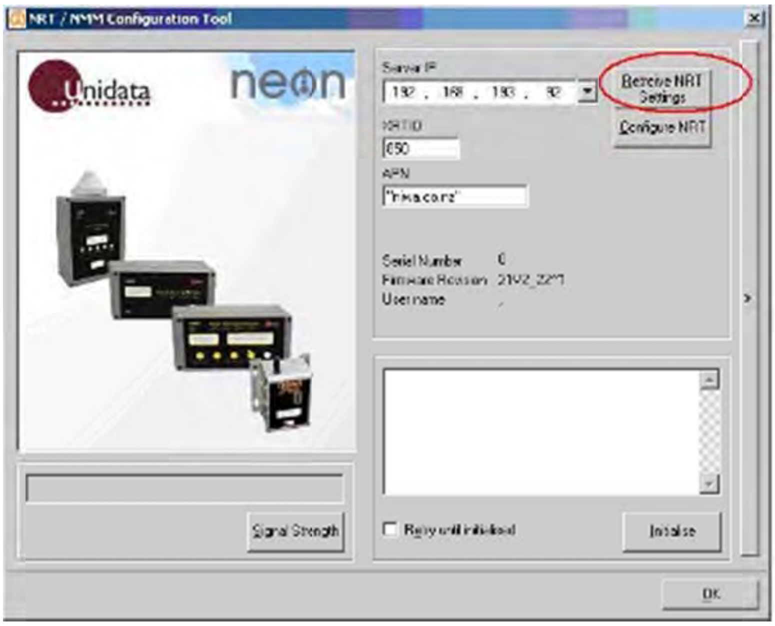
1) Simply connect to your Neon with the correct straight through 9 pin to 9 pin cable. Note you will have to install a USB to Serial port adaptor (Keyspan USA-19HS supplied) and know what com port it is installed on (if you don't know then click>Control Panel>System>Hardware>Device Manager>Ports>+)

2) Start the Starlog software. Choose Select from the left hand column, and then Embedded V4 Scheme from the Window. Double Click on NRT based logger.

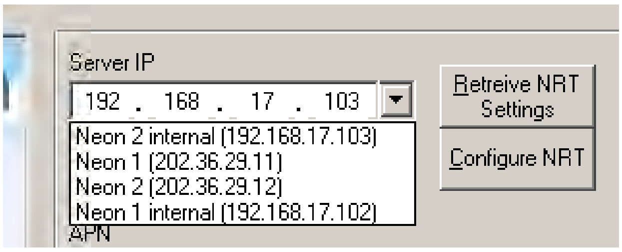
3) Then select Connection icon from left hand column choose the correct com port that you are using on your laptop and press CONNECT.

4) Select the "Configure / Initalise" icon

5) Select the "Retrieve NRT Settings" tab, and your current NRT settings will be displayed as shown below. With Server IP = 202.36.29.11, XRTID = 1161 (rainfall station ESN#3326) and = 1105 (sealevel station ESN#3962). APN = "fsmtc''



This tool allows you to configure NRT's. You can specify the XRTID (1161 (rainfall station) and = 1105 (sealevel station)), and select from the drop down box, which server you want to point the NRT to (202.36.29.11). You will only need to set these if you are sent a new Neon unit.



Additionally, you can also check the signal strength of the NRT.

6) Initialise by pressing the button on the lower right. You also have the option of forcing the NRT to continually try and initialise itself, for a maximum number of 180 retries. This is achieved by selecting the "retry until initialised " tick box

The status window shows the progress of the initialise sequence, or you can select the side bar to see the actual command and response syntax of the modem. This is checking the connection to the logger, then GPRS cell network, then to the Neon server, then it downloads the program to the data logger and starts it logging.

Appendix C Inspection of the Lelu sea level station

Lelu Wharf Station – visit to check at least every 2 months

Take from office: laptop, Keyspan USB to serial converter, 9 pin straight through DB9 cable, Tool and cable plastic box

1) Open box, check the reading in mm on the LCD display of the encoder matches the reading on the external staff gauge. Note this needs to be read in mm and as close as you can to the nearest mm. Each segment either yellow or black is 10mm. See the photo below.

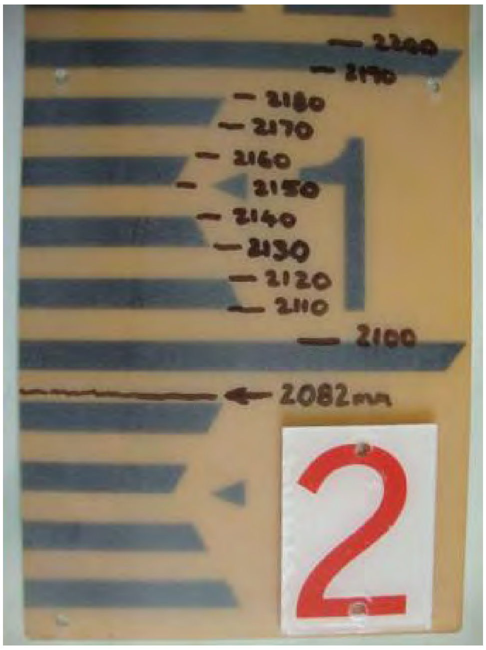
2) If the encoder is not within +/-3mm of the outside level, then firstly check that you have read the outside staff gauge correctly. If it is still out take the front off the encoder (4 large plastic screws) and push the up or down buttons so the display matches outside. Note you will need to keep checking the outside level.

3) If the level does not agree, check that the wheel on the encoder turns freely and no bead on the wire cable is jammed anywhere, or a float or counterweight are stuck (or sunk).

4) If you want to check the Neon with Starlog on the laptop (not required unless there is a fault) the 4 wingnuts holding the encoder in place need to be removed to open the housing. Then remove the Neon cover and plug in using the DB9 (white cable) and Keyspan USB to serial. Start Starlog, connect on the right com port, go to test mode, and check the date time and logged values are correct. (Note if you can't connect check your com port number in Control Panel>System>Hardware>Device Manager >Ports

5) Fill in the logbook with the date, time, encoder values and outside external staff gauge readings, battery voltage.

6) You can manually unload the logger to a CSV file by clicking on Unload.


2200
2190
2180
2170
2160
2150
2140
2130
2120
2110
2100
2082mm
1
2

Appendix D Temporary sea level station inspection procedure

Temporary Sea level Station – visit to check at least every 2 months shift after 8 months (Okat, Walung, Utwe)

Take from office: laptop, Northwest USB serial converter cable, silica gel, AA batteries, Tool and cable plastic box

1) Plug in with black USB to round screw end cable. Check com port number in (Control Panel>System>Hardware>Device Manager >Ports)

2) Start Aqua4Plus choose correct COM port. On a new installation check that Options>Display Units are set to mH20 for water pressure (default is PSI).

3) Follow laminated sheet, Select Sensor and do some readings to check sensor vs external staff gauge reading. Read the external board very carefully as this is critical that it is read correctly (see below photo). Put these values in the log book. Read to the nearest mm if you can.

4) Download the recorded data steps 4, 5, and 6 on laminated sheet.

5) Fill in the log book with file name details. Change the crystals

6) If the sensor is significantly different from the staff gauge, then calibrate the sensor to the external staff gauge. Go to Configure>Field Calibration>Pressure>One point calibration> Take some readings> Put this in the first point box>Wait to stablise (calm day is easier)>Measure >OK

7) Check the sensor window sensor Status = Active as this means it is logging.

For a new installation =sensor shift

1) Change the batteries in a dry place, change the crystals

2) Download old data and Terminate the old Session

3) Calibrate the sensor to the external staff gauge go to Configure>Field Calibration>Pressure>One point calibration> Take some readings> Put this in the first point box>Wait to stablise (calm day is easier)>Measure >OK

4) Create a new session follow steps 1 to 3 (note don’t close down the Sensor Window or you won’t be able to start a session running). The new session should be 10minute logging, # Records 60000 and this should give >416 days of record.

5) Before leaving check the sensor window sensor Status = Active as this means it is logging.


2200
2190
2180
2170
2160
2150
2140
2130
2120
2110
2100
2082mm
1
2

Appendix E AUSPOS GPS processing report for the GPS occupation at the Lelu sea level recorder benchmark

Australian Government
Geoscience Australia

AUSPOS GPS Processing Report

December 5, 2011

This document is a report of the GPS data processing undertaken by the AUSPOS Online GPS Processing Service (version: AUSPOS 2.02) . The AUSPOS Online GPS Processing Service uses International GNSS Service (IGS) products (final, rapid, ultra-rapid depending on availability) to compute precise coordinates in ITRF anywhere on Earth and GDA94 within Australia. The Service is designed to process only dual frequency GPS phase data.

An overview of the GPS processing strategy is included in this report.

Please direct any correspondence to geodesy@ga.gov.au

National Geospatial Reference Systems
Geoscience Australia
Cnr Jerrabomberra and Hindmarsh Drive
GPO Box 378, Canberra, ACT 2601, Australia
Freecall (Within Australia): 1800 800 173
Tel: +61 2 6249 9111. Fax +61 2 6249 9929
Geoscience Australia
Home Page: http://www.ga.gov.au

AUSPOS 2.02 Job Number: # 1116
User: a willsman at niwa co nz

1

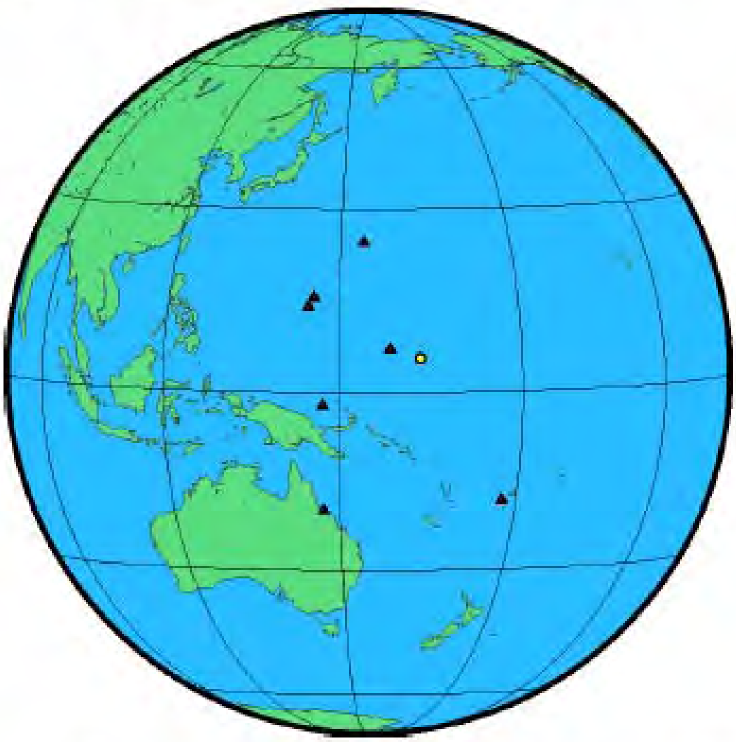
Australian Government
Geoscience Australia

1 User Data

All antenna heights refer to the vertical distance from the Ground Mark to the Antenna Reference Point (ARP).

Station (s)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
1514	15143190.11o	TRM_R8_GNSS NONE	1.522	2011/11/15 21:58:00	2011/11/18 05:46:30

2 Processing Summary



Date	User Stations	Reference Stations	Orbit Type
2011/11/15 21:58:00	1514	CNMR GUAM LAUT MCIL PNGM POHN TOW2	IGS final

AUSPOS 2.02 Job Number: # 1116
User: a willsman at niwa co nz

2

3 Computed Coordinates, ITRF2008

All computed coordinates are based on the IGS realisation of the ITRF2008 reference frame. All the given ITRF2008 coordinates refer to a mean epoch of the site observation data. All coordinates refer to the Ground Mark.

3.1 Cartesian, ITRF2008

Station	X (m)	Y (m)	Z (m)	ITRF2008 @
1514	-6073848.173	1854746.487	589192.002	15/11/2011
CNMR	-5087757.804	3465028.957	1664653.771	15/11/2011
GUAM	-5071312.698	3568363.600	1488904.361	15/11/2011
LAUT	-6075194.606	270923.853	-1917189.315	15/11/2011
MCIL	-5227187.840	2551880.778	2607618.083	15/11/2011
PNGM	-5367942.896	3437431.658	-225885.791	15/11/2011
POHN	-5879158.489	2350292.259	767748.397	15/11/2011
TOW2	-5054583.142	3275504.231	-2091538.906	15/11/2011

3.2 Geodetic, GRS80 Ellipsoid, ITRF2008

Geoid-ellipsoidal separations, in this section, are computed using a spherical harmonic synthesis of the global EGM2008 geoid. More information on the EGM2008 geoid can be found at http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
1514	5 20 09.56695	163 01 08.80527	44.791	3.108
CNMR	15 13 46.91149	145 44 35.12831	64.374	9.057
GUAM	13 35 21.58640	144 52 06.09770	201.917	146.376
LAUT	-17 36 31.72258	177 26 47.69273	89.678	31.718
MCIL	24 17 24.34421	153 58 43.16102	35.653	10.012
PNGM	-2 02 35.62436	147 21 57.62619	116.335	38.761
POHN	6 57 35.80435	158 12 36.39906	90.677	39.386
TOW2	-19 16 09.39565	147 03 20.48386	88.103	30.168

4 Solution Information

4.1 Coordinate Precision - Geodetic, One Sigma

Station	σ East (m)	σ North (m)	σ Up (m)
1514	0.001	0.001	0.003
CNMR	0.001	0.001	0.002
GUAM	0.001	0.001	0.002
LAUT	0.001	0.001	0.003
MCIL	0.001	0.001	0.002
PNGM	0.001	0.001	0.002
POHN	0.001	0.001	0.002
TOW2	0.001	0.001	0.002

4.2 Ambiguity Resolution - per baseline

Baseline	Ambiguities Resolved	Baseline Length (km)
PNGM - TOW2	71.2 %	1898.7
PNGM - POHN	68.6 %	1559.0
GUAM - PNGM	81.4 %	1745.2
1514 - PNGM	84.0 %	1915.1
CNMR - MCIL	73.9 %	1320.0
LAUT - TOW2	75.3 %	3178.0
CNMR - PNGM	77.9 %	1911.4
AVERAGE	75.8%	1932.5

Please note for a regional solution, such as used by AUSPOS, an average ambiguity resolution of 50% or better for the network indicates a reliable solution.

5 Computation Standards

5.1 Computation System

Software	Bernese GPS Software Version 5.0.
GNSS system(s)	GPS only.

5.2 Data Preprocessing and Measurement Modelling

Data preprocessing	Phase preprocessing is undertaken in a baseline by baseline mode using triple-differences. In most cases, cycle slips are fixed by the simultaneous analysis of different linear combinations of L1 and L2. If a cycle slip cannot be fixed reliably, bad data points are removed or new ambiguities are set up A data screening step on the basis of weighted postfit residuals is also performed, and outliers are removed.
Basic observable	Carrier phase with an elevation angle cutoff of 10° and a sampling rate of 3 minutes. However, data cleaning is performed a sampling rate of 30 seconds. Elevation dependent weighting is applied according to $1/\sin(e)^2$ where e is the satellite elevation. The code observable is only used for the receiver clock synchronisation.
Modelled observable	Double differences of the ionosphere-free linear combination.
Ground antenna phase centre calibrations	IGS08 absolute phase-centre variation model is applied.
Tropospheric Model	A priori model is the Saastamoinen-based hydrostatic mapped with the dry-Niell.
Tropospheric Estimation	Zenith delay corrections are estimated relying on the wet-Niell mapping function in intervals of 2 hour. N-S and E-W horizontal delay parameters are solved for every 24 hours.
Tropospheric Mapping Function	Niell
Ionosphere	First-order effect eliminated by forming the ionosphere-free linear combination of L1 and L2.
Tidal displacements	Solid earth tidal displacements are derived from the complete model from the IERS Conventions 2003, but ocean tide loading is not applied.
Atmospheric loading	Not applied
Satellite centre of mass correction	IGS08 phase-centre variation model applied
Satellite phase centre calibration	IGS08 phase-centre variation model applied
Satellite trajectories	Best available IGS products.
Earth Orientation	Best available IGS products.

User: a willsman at niwa co nz

5.3 Estimation Process

Adjustment	Weighted least-squares algorithm.
Station coordinates	Coordinate constraints are applied at the Reference sites with standard deviation of 1mm and 2mm for horizontal and vertical components respectively.
Troposphere	Zenith delay parameters and pairs of horizontal delay gradient parameters are estimated for each station in intervals of 2 hour and 24 hours.
Ionospheric correction	An ionospheric map derived from the contributing reference stations is used to aid ambiguity resolution using the QIF strategy
Ambiguity	Ambiguities are resolved in a baseline-by-baseline mode using Quasi-Ionosphere-Free (QIF) approach.

5.4 Reference Frame

Terrestrial reference frame	IGS08 station coordinates and velocities mapped to the mean epoch of observation.
Australian datum	GDA94 coordinates determined via Helmert transformation from ITRF using the Dawson and Woods (2010) parameters.
Derived AHD	For stations within Australia, AUSGeoid09 is used to compute AHD. AUSGeoid09 is the Australia-wide gravimetric quasigeoid model that has been a posteriori fitted to the Australian Height Datum
Above-geoid heights	Earth Gravitational Model EGM2008 released by the National Geospatial-Intelligence Agency (NGA) EGM Development Team is used to compute above-geoid heights. This gravitational model is complete to spherical harmonic degree and order 2159, and contains additional coefficients extending to degree 2190 and order 2159.

Appendix F GPS data for the sea level station benchmarks, and beach profile benchmarks in ITRF2008/GRS80 ellipsoid height, EGM2008 geoid elevations, and local vertical datum elevations

GNSS Positions from Kosrae Island Survey

	GRS80 ellipsoid, ITRF2008										
Point ID	Easting (UTM58)	Northing (UTM58N)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Latitude(Global GRS80 ellipsiod, ITRF2008)	Longitude(Global GRS80 ellipsiod, ITRF2008)	Height (Global ellipsoid ht)	Solution Type	H. Precision (95%)	V. Precision (95%)	Feature Code
Sea level recorder benchmarks											
lelu bm1	280482.412	590157.402	3.108	2.841	N5°20'09.56695"	E163°01'08.80527"	44.791	AUSPOS	0.001	0.001	BM Sealevel base station
Okat SL bm1	273655.25	591786.745	4.164	3.674	N5°21'01.87081"	E162°57'26.93799"	46.132	Fixed	0.004	0.009	bmÂ·sealevel
utwe bm1	275885.695	583528.669	4.436	3.621	N5°16'33.33454"	E162°58'40.24257"	46.585	Fixed	0.008	0.018	bmÂ·sealevel
walung bm1	267298.678	585993.26	4.014	2.946	N5°17'52.62127"	E162°54'01.17023"	46.313	Fixed	0.007	0.014	bmÂ·sealevel
Beach Profile benchmarks											
bs1 bm	276218.362	593393.812	4.133	3.839	N5°21'54.45204"	E162°58'49.99653"	45.886	Fixed	0.03	0.048	bmÂ·profile
bs2 bm	276406.238	593443.445	4	3.717	N5°21'56.08762"	E162°58'56.09217"	45.742	Fixed	0.296	0.288	bmÂ·profile
bs3 bm	276529.34	593503.114	3.75	3.476	N5°21'58.04288"	E162°59'00.08336"	45.483	Fixed	0.017	0.033	bmÂ·profile
bs5 bm	276916.982	593665.269	3.872	3.622	N5°22'03.36209"	E162°59'12.65414"	45.568	Fixed	0.027	0.045	bmÂ·profile
bs6 bm	277323.995	593790.81	3.783	3.558	N5°22'07.49162"	E162°59'25.85797"	45.444	Fixed	0.025	0.041	bmÂ·profile
bs8 bm	278158.024	593864.182	1.234	1.05	N5°22'09.96862"	E162°59'52.93432"	42.842	Float	0.702	1.159	bmÂ·profile
bs9 bm	278740.852	593754.85	4.068	3.904	N5°22'06.47210"	E163°00'11.87266"	45.646	Float	0.25	0.127	bmÂ·profile
bs10 bm	279439.118	593806.642	3.262	3.131	N5°22'08.23185"	E163°00'34.54275"	44.785	Float	0.134	0.152	bmÂ·profile
bs11 bm	280144.154	593787.35	3.679	3.578	N5°22'07.67844"	E163°00'57.44025"	45.151	Fixed	0.107	0.083	bmÂ·profile
bs12 bm	280658.375	593412.782	4.123	4.025	N5°21'55.54121"	E163°01'14.17856"	45.582	Fixed	0.005	0.011	bmÂ·profile
bs13 bm	280772.603	592872.228	3.076	2.956	N5°21'37.95931"	E163°01'17.94472"	44.563	Fixed	0.013	0.029	bmÂ·profile
bs14 bm	280733.491	592174.627	4.06	3.903	N5°21'15.24975"	E163°01'16.74765"	45.6	Fixed	0.022	0.027	bmÂ·profile
bs15 bm	280871.334	591512.412	3.685	3.5	N5°20'53.71046"	E163°01'21.29318"	45.256	Fixed	0.006	0.013	bmÂ·profile
bs16 bm	280538.661	590788.989	2.692	2.455	N5°20'30.12965"	E163°01'10.56583"	44.332	Fixed	0.104	0.096	bmÂ·profile
bs17 bm	281665.159	588532.349	3.462	3.159	N5°19'16.79799"	E163°01'47.38087"	45.098	Fixed	0.028	0.059	bmÂ·profile
bs18 bm	282141.384	588016.228	3.299	2.991	N5°19'00.04855"	E163°02'02.89822"	44.91	Fixed	0.011	0.021	bmÂ·profile

Point ID	GRS80 ellipsoid, ITRF2008 Easting (UTM58)	Northing (UTM58N)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Latitude(Global GRS80 ellipsiod, ITRF2008)	Longitude(Global GRS80 ellipsiod, ITRF2008)	Height (Global ellipsoid ht)	Solution Type	H. Precision (95%)	V. Precision (95%)	Feature Code
bs19 new bm	282138.292	587346.455	3.892	3.549	N5°18'38.24831"	E163°02'02.86697"	45.52	Float	0.254	0.667	bmÂ·profile
bs20 new bm	282086.954	586959.893	3.201	2.836	N5°18'25.66109"	E163°02'01.23981"	44.844	Fixed	0.014	0.03	bmÂ·profile
bs21 bm	281664.851	586016.426	3.575	3.143	N5°17'54.90933"	E163°01'47.63094"	45.278	Fixed	0.017	0.029	bmÂ·profile
bs24 bm	280115.504	583066.433	3.467	2.816	N5°16'18.73247"	E163°00'57.62818"	45.339	Fixed	0.013	0.019	bmÂ·profile
bs26 bm	279424.999	582233.327	2.998	2.274	N5°15'51.54508"	E163°00'35.29439"	44.924	Fixed	0.026	0.034	bmÂ·profile
bs27 new bm	276700.447	582208.182	3.62	2.774	N5°15'50.44221"	E162°59'06.83505"	45.73	Fixed	0.013	0.023	bmÂ·profile
bs27-2 bm new	276002.493	582703.825	3.179	2.327	N5°16'06.50055"	E162°58'44.12167"	45.326	Fixed	0.011	0.021	bmÂ·profile
lik bm	282018.782	589436.357	3.022	2.781	N5°19'46.25851"	E163°01'58.77020"	44.593	Fixed	0.036	0.04	bmÂ·profile
sandy beach bm	280192.349	593839.986	3.787	3.691	N5°22'09.39670"	E163°00'58.99981"	45.252	Fixed	0.014	0.024	bmÂ·profile
Kosrae Survey Department Control Station benchmarks											
S1	280905.782	591444.116	2.337	2.15	N5°20'51.49114"	E163°01'22.41894"	43.909	Fixed	0.004	0.006	bm ksd-fundamental local vertical datum
S22	280856.497	593098.041	1.545	1.44	N5°21'45.31786"	E163°01'20.64540"	43.008	Fixed	0.007	0.01	bm ksd-fundamental local vertical datum
K0 okat br nw bm	274378.696	592703.944	4.921	4.51	N5°21'31.80087"	E162°57'50.33108"	46.799	Fixed	0.007	0.011	bmÂ·local vertical datum height on this BM
estur bm	280493.44	593690.256	3.226	3.136	N5°22'04.55504"	E163°01'08.79329"	44.677	Fixed	0.007	0.014	bmÂ·ksd
melita bm	277674.976	581956.71	8.771	7.955	N5°15'42.35957"	E162°59'38.50255"	50.819				bmÂ·ksd
pilyuul bm	281676.693	586009.486	3.838	3.406	N5°17'54.68465"	E163°01'48.01618"	45.54	Fixed	0.007	0.012	bmÂ·ksd
tafeyat	280506.916	588020.171	4.014	3.634	N5°19'00.00707"	E163°01'09.82379"	45.775	Fixed	0.006	0.013	bmÂ·ksd
wiya bm	278097.933	593903.13	5.689	5.504	N5°22'11.22990"	E162°59'50.97878"	47.296	Fixed	0.012	0.019	ppk

Appendix G Levelling between the sea level recorder benchmarks and staff gauges

	Staff Gauge Zero elevations (m)			
	Lelu	**Okat**	**Utwe**	**Walung**
Staff gauge zero global ellipsoid height	**40.748**	**42.128**	**42.159**	**41.975**
Staff gauge zero EGM2008 geoid elevation	**-0.935**	**0.16**	**0.01**	**-0.324**
Staff gauge zero local Kosrae vertical datum elevation	**-1.202**	**-0.33**	**-0.805**	**-1.392**

Levelling of new BM and new external Staff Gauge board at Lelu Marine Resources wharf for new sea level recorder 15-Nov-2011

used KIRMA level, tripod and metric staff

A Willsman, S Abraham, B Charley

Backsight	Foresight	Fall	Rise	Height (Global ellipsoid ht)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Comment
1.016				44.791	3.108	2.841	BM1 new on corner of wharf
3.024	3.059	-2.043		42.748	1.065	0.798	2m mark on new SG, note stainless right angle plate at this mark to rest level on
	0.979		2.045	44.793	3.11	2.843	BM1 new on corner of wharf

Lelu

Staff gauge zero ellipsoid height = **40.748**

Staff gauge zero EGM2008 geoid elevation = **-0.935**

Staff gauge zero local vertical datum elevation = **-1.202**

Levelling of new BM and new external Staff Gauge board at Okat wharf for new sea level recorder 16-Nov-2011

used KIRMA level, tripod and metric staff

A Willsman, S Abraham, B Charley

Backsight	Foresight	Fall	Rise	Height (Global ellipsoid ht)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Comment
1.548				46.132	4.164	3.674	BM1 new on corner of wharf
3.547	3.552	-2.004		44.128	2.16	1.67	2m mark on new SG, note stainless right angle plate at this mark to rest level on
	1.544		2.003	46.131	4.163	3.673	BM1 new on corner of wharf

Okat

Staff gauge zero ellipsoid height = 42.128

Staff gauge zero EGM2008 geoid elevation = 0.16

Staff gauge zero local vertical datum elevation = -0.33

Levelling of new BM and new external Staff Gauge board at Utwe downstream RB of bridge for new sea level recorder 18-Nov-2011

used KIRMA level, tripod and metric staff

A Willsman, S Abraham, B Charley

Backsight	Int.	Foresight	Fall	Rise	Height (Global ellipsoid ht)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Comment
0.484					46.585	4.436	3.621	BM1 new on walkway upstream western end of road bridge
	2.912		-2.428		44.157	2.008	1.193	2m mark on new upper SG, note stainless right angle plate at this mark to rest level on
3.419		3.41	-0.498		43.659	1.51	0.695	1.5m mark on new lower SG, note stainless screw on at 1.5m mark
	2.918			0.501	44.16	2.011	1.196	2m mark on new upper SG, note stainless right angle plate at this mark to rest level on
		0.49		2.428	46.588	4.439	3.624	BM1 new on walkway upstream western end of road bridge

Utwe

Staff gauge zero ellipsoid height	**42.159**
Staff gauge zero EGM2008 geoid elevation =	**0.01**
Staff gauge zero local vertical datum elevation =	**-0.805**

Levelling of new BM and new external Staff Gauge board at Walung bridge for new sea level recorder 19-Nov-2011

Backsight	Int.	Foresight	Fall	Rise	Height (Global ellipsoid ht)	Elevation (Geoid model EGM2008)	Elevation (Local Vertical datum)	Comment
1.306					46.313	4.014	2.946	BM1
4.124		4.127	-2.821		43.492	1.193	0.125	Change point, end of eastern lower bracket dynabolt
		1.302		2.822	46.314	4.015	2.947	BM1
0.914					43.492	1.193	0.125	Change point, end of eastern lower bracket dynabolt
	0.931		-0.017		43.475	1.176	0.108	Lower staff gauge 1.5m mark
0.426		0.43		0.501	43.976	1.677	0.609	Upper staff gauge 2m mark
	0.927		-0.501		43.475	1.176	0.108	Lower staff gauge 1.5m mark
		0.91		0.017	43.492	1.193	0.125	Change point, end of eastern lower bracket dynabolt
Walung								
Staff gauge zero ellipsoid height =					**41.975**			
Staff gauge zero EGM2008 geoid elevation =					**-0.324**			
Staff gauge zero local vertical datum elevation =					**-1.392**			

Appendix H Site calibration report for the transformation to the local projection

Project Information		Coordinate System	
Name:	C:\andrew\Kosrae 2011\GPS Survey data\Kosrae local control used for local projection.vce	Name:	UTM
Size:	960 KB	Datum:	ITRF 2005
Modified:	22/02/2012 1:47:09 p.m. (UTC:13)	Zone:	58 North (165E)
Time zone:	New Zealand Standard Time	Geoid:	EGM2008
Reference number:		Vertical datum:	
Description:			

Site Calibration Report

Horizontal Calibration Parameters

Translation east:	-29.055 m
Translation north:	-48.010 m
Rotation:	-0°00'48"
Origin easting:	279158.604 m
Origin northing:	592734.089 m
Scale factor:	0.9997747455

Vertical Calibration Parameters

Vertical shift at origin:	-0.187 m
Slope east:	44.135 ppm
Slope north:	51.283 ppm
Origin easting:	280876.631 m
Origin northing:	591396.800 m

Residual Differences Between GPS And Known Coordinates

Summary

	Maximum residual	Root Mean Square residual	Point
Horizontal	1.157 m	0.744 m	S1
Vertical	0.000 m	0.000 m	S1
Three-dimensional	1.157 m	0.810 m	S1

Point Residuals

Residuals sign: Calculated-Control!

GNSS Point		Calculated Point		Grid Point	
Point	S1	**Point**	S1	**Point**	S1 Local Vdatum
Latitude	N5°20'51.49114"	**Easting**	280876.631 m	**Easting**	280877.726 m
Longitude	E163°01'22.41894"	**Northing**	591396.800 m	**Northing**	591397.174 m
Height	43.909 m	**Elevation**	2.150 m	**Elevation**	2.150 m
		Horiz. residual	1.157 m	**Type**	Horz and Vert
		Vert. residual	0.000 m		
		3D residual	1.157 m		
Point	S22	**Point**	S22	**Point**	S22 Local Vdatum
Latitude	N5°21'45.31786"	**Easting**	280826.975 m	**Easting**	280826.400 m
Longitude	E163°01'20.64540"	**Northing**	593050.341 m	**Northing**	593049.917 m
Height	43.008 m	**Elevation**	1.440 m	**Elevation**	1.440 m
		Horiz. residual	0.714 m	**Type**	Horz and Vert
		Vert. residual	0.000 m		
		3D residual	0.714 m		
Point	okat br nw bm	**Point**	okat br nw bm	**Point**	KO Local Vdatum
Latitude	N5°21'31.80087"	**Easting**	274350.725 m	**Easting**	274350.615 m
Longitude	E162°57'50.33108"	**Northing**	592654.836 m	**Northing**	592655.165 m
Height	46.799 m	**Elevation**	4.510 m	**Elevation**	4.510 m
		Horiz. residual	0.347 m	**Type**	Horz and Vert
		Vert. residual	0.000 m		
		3D residual	0.347 m		
Point	estur bm	**Point**	estur bm	**Point**	Estur local

Latitude N5°22'04.55504" **Longitude** E163°01'08.79329" **Height** 44.677 m	**Easting** 280463.863 m **Northing** 593642.339 m **Elevation** 3.136 m **Horiz. residual** 0.496 m **Vert. residual** ? **3D residual** ?	**Easting** 280463.453 m **Northing** 593642.060 m **Elevation** 3.136 m **Type** Horizontal
Point tafeyat **Latitude** N5°19'00.00707" **Longitude** E163°01'09.82379" **Height** 45.775 m	**Point** tafeyat **Easting** 280478.647 m **Northing** 587973.535 m **Elevation** 3.634 m **Horiz. residual** ? **Vert. residual** ? **3D residual** ?	**Point** tafeyat local **Easting** 280694.890 m **Northing** 588150.745 m **Elevation** 3.634 m **Type** (Ignored)
Point melita bm **Latitude** N5°15'42.35957" **Longitude** E162°59'38.50255" **Height** 50.819 m	**Point** melita bm **Easting** 277648.746 m **Northing** 581910.785 m **Elevation** 7.955 m **Horiz. residual** ? **Vert. residual** ? **3D residual** ?	**Point** Merita local **Easting** 277312.946 m **Northing** 581950.958 m **Elevation** 7.955 m **Type** (Ignored)

Date: 22/02/2012 2:06:18 p.m.	Project: C:\andrew\Kosrae 2011\GPS Survey data\Kosrae local control used for local projection.vce	Trimble Business Center

Appendix I Photographs on new benchmarks installed at the beach profile sites

New Benchmark at beach profile 27

New Benchmark at profile 27-2

New Benchmark at beach profile 19

New benchmark at beach profile 20