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Antarctic Geodesy Field Report 2010/2011

Ryan Ruddick, Sam Griffiths and Nicholas Brown

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by

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Contents

Acronyms

AAD – Australian Antarctic Division
AAGN – Australian Antarctic Geodetic Network
AAT – Australian Antarctic Territory
AGSO – Australian Geological Survey Organisation
ANARE – Australian National Antarctic Research Expeditions
ANU – Australian National University
AOA – Allen Osborne Associates
APREF – Asia-Pacific Reference Frame
ARGN – Australian Regional GNSS Network
CHINARE – Chinese National Antarctic Expedition
CONGO – Cooperative Network for GIOVE Observation
CORS – Continuously Operating Reference Station
DMT – Dorne Margolin Type
EDM – Electronic Distance Measurement
GA – Geoscience Australia
GIANT –Geodetic Infrastructure for Antarctica
GIOVE – Galileo In-Orbit Validation Element
GNSS – Global Navigation Satellite System
GPS – Global Positioning System
IGS – International GNSS Service
ITRF – International Terrestrial Reference Frame
MSL – Mean Sea Level
MQZ – Magnetic Quiet Zone
NGRS – National Geospatial Reference Systems (Section of Geoscience Australia)
NTC – National Tidal Centre
PCMEGA – Prince Charles Mountains Expedition of Germany and Australia
RM – Reference Mark
SCAR – Scientific Committee on Antarctic Research
TGBM – Tide Gauge Bench Mark
UTAS – University of Tasmania

Executive Summary

Geoscience Australia's (GA) involvement in Antarctica has primarily been focused on the maintenance and enhancement of geodetic infrastructure within the Australian Antarctic Territory (AAT). Such infrastructure provides a fundamental reference frame for the region and supports earth monitoring science applications on local, regional and continental scales. These foundations have furthered the development of geodesy throughout the continent and provided information on the contemporary motion of the Antarctic plate for comparison with long-term geological records. Primary Antarctic geodetic control also contributes to a greater understanding of global earth movement through contribution to the International Terrestrial Reference Frame (ITRF) solutions.

This report focuses on the field work undertaken during the 2010/11 Antarctic summer by Geoscience Australia surveyors at the Davis, Mawson and Macquarie Island research stations, as well as several remote sites in Eastern Antarctica. At each of the research stations, upgrades and local monitoring surveys were performed at the Continuously Operating Reference Stations (CORS), which form part of the Australian Regional Global Navigation Satellite Systems Network (ARGN) and also contribute to the International GNSS Service (IGS). Remote Global Positioning Systems (GPS) sites in the Grove Mountains, Bunger Hills, Wilson Bluff and Mt Creswell were also visited for equipment upgrades and data retrieval. Additional surveys were undertaken directed at enhancing the spatial infrastructure around both the Larsemann and Vestfold Hills. Support was also provided to a number of different Australian Antarctic Division (AAD) projects.

1. Introduction

Geoscience Australia's (GA) Antarctic geodesy program primarily aims to maintain and enhance the geodetic infrastructure of the AAT and through international collaboration develop geodetic infrastructure across the entire Antarctic continent. The program also aims to provide information on the contemporary motion of the Antarctic continent for comparison with the long-term geological records, with special emphasis on the Australia-Antarctic separation and movement of the Macquarie Ridge and mid ocean-ridge.

These aims are achieved through the operation of continuous Global Navigation Satellite System (GNSS) sites at each of the four main Australian research stations and at strategically placed rock outcrops throughout the territory, and also through the extension and maintenance of a comprehensive geodetic control network. Such infrastructure is combined with that of other international polar communities to help source a common geospatial reference frame, which is largely achieved through the continual calculation and realisation of the International Terrestrial Reference Frame (ITRF) and adoption of its 2000 realisation.

Integration of the project amongst the wider polar community is achieved through GA's association within the Scientific Committee on Antarctic Research (SCAR) and more specifically the Geodetic Infrastructure for Antarctica program (GIANT). This association has provided the existing Antarctic Geodetic program with a great opportunity to be incorporated as a platform for many scientific applications on both a national and international scale.

The further scientific continuation of geodetic programs, including both the densification of control networks and an improvement in analysis capabilities, will be used to provide greater understanding of the Antarctic both regionally and as part of a global system. Geodetic techniques in both measurement and analysis within Antarctica are continually aiding the broader research community and the inclusion of improved geodetic control within the ITRF is aiding in further refining this product.

1.1 PROJECT PROGRESS

Over the course of GA's involvement within the Antarctic and Sub-Antarctic there have been a number of critical achievements. The establishment of four Continuously Operating GNSS Stations (Casey, Mawson, Davis and Macquarie) are fundamental to a number of applications, including the continual refinement of the ITRF and their contribution to the Australian Regional GNSS network (ARGN) http://www.ga.gov.au/earth-monitoring/geodesy/gnss-networks.html. The maintenance and operation of these stations still remains highest priority within the scope of the core Geodesy program.

In addition to these four fundamental sites, remote continuous GNSS installations are also managed in the Grove Mountains, Bunger Hills and within the Prince Charles Mountains at Mt Creswell and Wilson Bluff. The data collected at these sites not only densifies the geodetic network in Antarctica but also supports geodynamic research into plate motion as well as the response of the Earth's crust to ice loading or unloading. Combined with GNSS reference stations established via the greater polar community, these sites help to meet earth-monitoring objectives throughout the greater continent (via velocity fields) and contribute to the densification of a precise reference frame for both Earth and Antarctica. In order to maintain this GNSS network bi-annual visits are generally made to upgrade equipment and retrieve data.

Whilst the acquisition and analysis of continuous GNSS sites is of fundamental priority, the collation, processing and adjustment of a wider array of geodetic infrastructure also remains an objective of the program. Over the course of GA's involvement with the Antarctic program over

460 marks have been established and re-established using a combination of measurement techniques including traditional terrestrial, Doppler and GNSS combinations. The resultant Australian Antarctic Geodetic Network (AAGN) consists of adjusted coordinates, relevant to the latest ITRF solution. The AAGN database is maintained by GA and made available through both National Geospatial Reference System (NGRS) Section and AAD data centre.

1.2 AUSTRALIAN ANTARCTIC GEODETIC NETWORK

Within the scope of the GIANT program (http://www.scar.org/researchgroups/geoscience/giant/) an aim has been adopted to develop a unified datum for the greater Antarctic region. Within the AAT, ITRF positions have been adopted for the permanent Global Positioning System (GPS) tracking stations at Casey, Davis, Macquarie Island and Mawson and used with the GRS80 ellipsoid to define an Australian Antarctic Geodetic Datum. This provides a single, accurate, globally compatible datum for the AAT. The datum process is continually being realised across the continent with the collation of geodetic infrastructure from other nations. Whilst no official datum has ever been realised upon Antarctica, the coverage of geodetic infrastructure across the polar communities has allowed for a common geospatial reference to be adopted, usually by coordinating to the latest ITRF solution. To avoid a plethora of individual national datum's being used across Antarctica (although they may be based on ITRF) and to avoid the confusion of a dynamic system of datum's, it has been proposed to standardise on the use of ITRF2000 (at an epoch of 2000.0) as an Antarctic datum. Each permanent base station defined in ITRF2000 will also have computed velocities so that observations taken at different epochs in the future can be translated back into the Antarctic 2000 datum. At this stage this concept is still being adopted by GIANT participants; however a review maybe adopted in the immediate future to switch to a more current ITRF solution.

The Australian Geodetic network currently consists of a series of survey marks placed on solid rock outcrops throughout the AAT. The majority of these marks were established using terrestrial-surveying techniques from the 1960's onwards. Over the last 20 years GPS has been used where possible to strengthen the network since GPS (and indeed GNSS in a greater capacity) can be used over much longer distance with far greater accuracy, without the need for inter-visibility.

Currently, the absolute accuracies of most remote survey marks within the AAGN, relative to the ITRF2000, are in the order of decimeters to metres. This is due to the methods and limitations of traditional terrestrial surveying employed from the 1960's. Since the mid 1990's the accuracies of these marks are gradually being improved to the centimeter and sub-centimetre level using geodetic quality GNSS observations (Brolsma and Corvino 2007, updated 2008).

The network is now comprised of 462 stations that have been observed (and re-observed) via techniques including Transit Doppler, Terrestrial Surveying and GNSS survey campaigns. The resulting network has been rigorously adjusted through custom geodetic survey adjustment, adopting fixed ITRF 2000 coordinates from 7 continuously operating IGS stations. Raw campaign GNSS data can also be found within the internal GA directory N:\geodesy_data\gnss\data\campaign\antarctica.

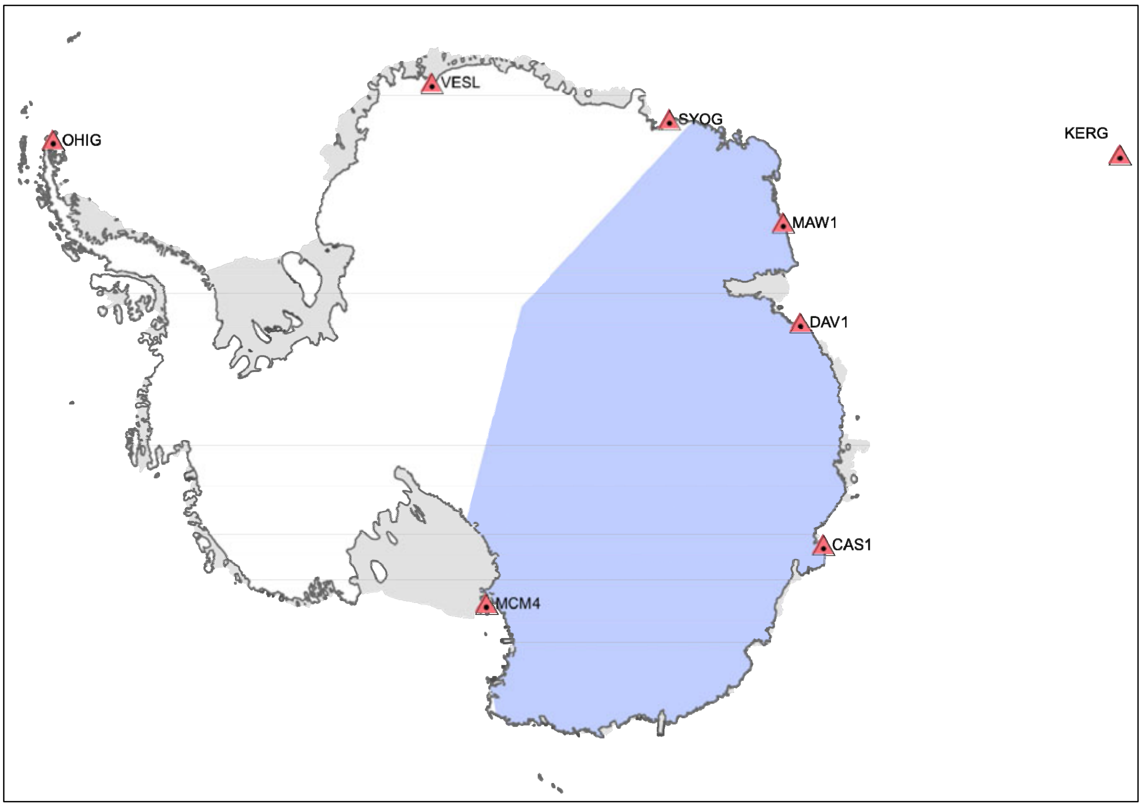
2. Australian Regional GNSS Network

Geoscience Australia operates four CORS in the AAT at each of the primary research stations as shown in Figure 2.1. These sites are part of the ARGN and provide important contributions to both the Asia-Pacific Reference Frame (APREF) and the IGS.

During the 2010/11 summer upgrades were made to the equipment at all of the sites and local monitoring surveys were undertaken at Davis, Mawson and Macquarie Island (Table 2.1). The local monitoring surveys were undertaken to support the distinction between localised site deformation and large-scale tectonic movement.

Table 2.1: *Australian operated permanent GNSS installations.*

SITE	RECIEVER TYPE	ANTENNA TYPE	DOME NUMBER
AUS099 (Davis)	LEICA GRX1200GGPRO	LEIAR25	66010M001
AUS100 (Casey)	LEICA GRX1200GGPRO	AOAD/M_T	66011M001
AUS64 (Mawson)	LEICA GRX1200GGPRO	AOAD/M_T	66004M001



Figures 2.1: *Location map of the four CORS sites operated by GA (red triangles) and the other IGS sites located in the Antarctic and sub-Antarctic regions (white triangles).*

2.1 DAVIS STATION

The CORS at Davis (DAV1) was installed in 1992 on the control mark AUS099 and forms part of the AAGN and IGS. The antenna is located in the magnetic quiet zone behind the atmospheric and space physics building, where the receiver is housed. The control mark has three reference marks located nearby that are used for routine local monitoring surveys (Figure 2.2).

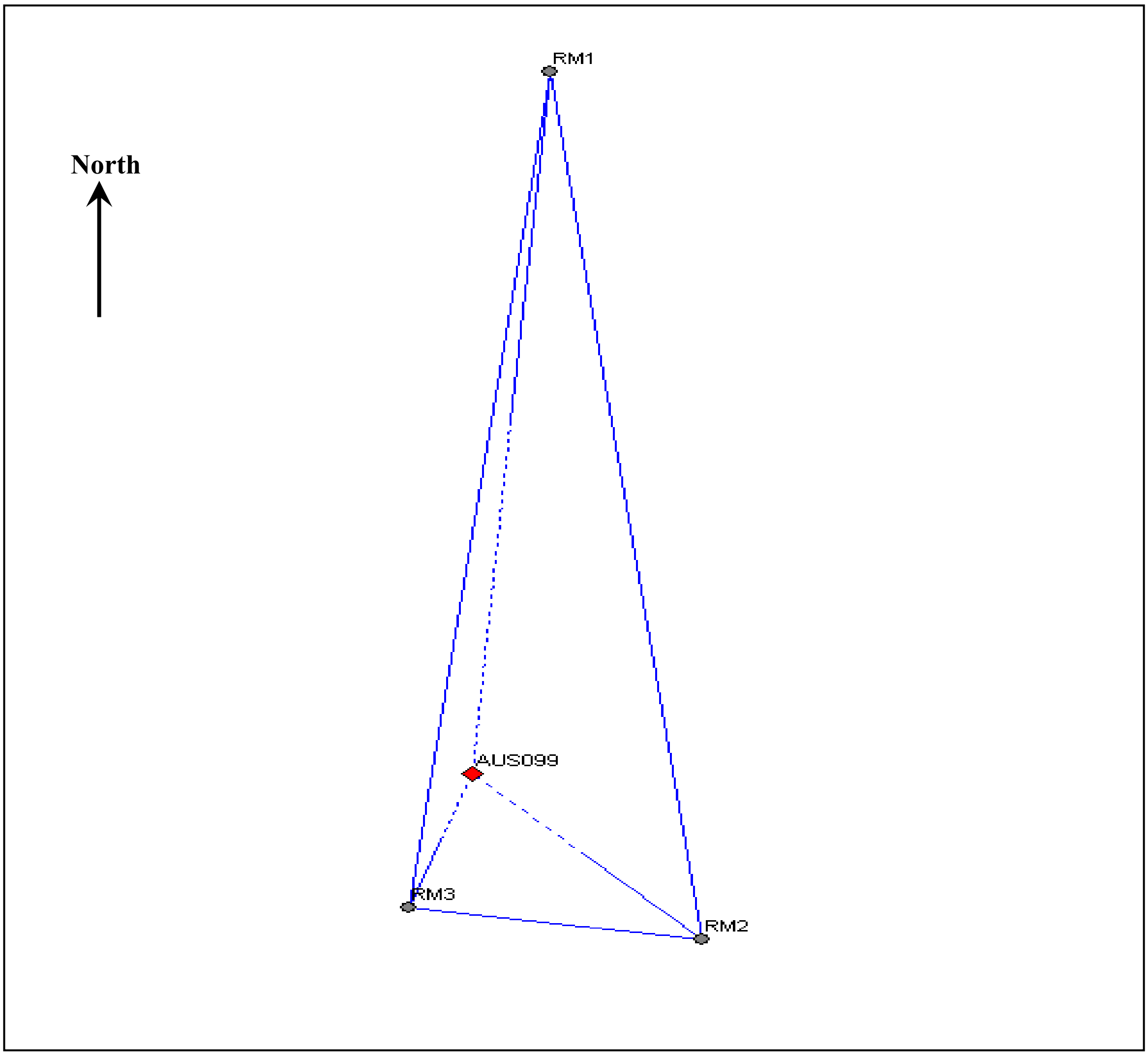


Figure 2.2: *Site diagram of the Davis CORS setup.*

2.1.1 Equipment Upgrade

The equipment upgrades at Davis were undertaken in two steps the first on 1 December 2010, where the power system was upgraded and a Leica GRX1200+GNSS receiver installed as the secondary receiver to contribute to the Cooperative Network for GIOVE Observation (CONGO) under the site name DAVE. The second upgrade was undertaken on 21 February 2011, where the ASH701945G_M antenna was replaced with a broader-spectrum LEIAR25.R3 antenna. This final change was made at the request of the CONGO project to allow complete tracking of the Galileo In-Orbit Validation Element (GIOVE) satellites.

The setup at Davis now consists of two GNSS receivers, a Leica GRX1200GG Pro (Primary – DAV1) and a Leica GRX1200+GNSS (Spare – DAVE). Both receivers are connected to the antenna via a 12 volt 4 port powered antenna splitter and ~85 m of LMR400 cable. The antenna is a Leica AR25.R3 covered by a LEIT style radome (Figure 2.3). Two 12 volt 78 amp hour GelTech batteries provide power to the equipment via a custom designed 4 switch power distribution box. The batteries are charged by a 12V charger connected to mains power. A PC running the standard ARGN Fedora 6 build and operating off mains power is also present to interface with the receivers if required. A True Time external frequency is connected to both receivers at 10 MHz. A Paroscientifc Met-4 AWS is connected to the primary receiver (Figure 2.5). Both the external frequency and AWS are powered via the power distribution box, with the external frequency having a 12-24 V DC_DC convertor. A spare antenna (ASH701945G_M) and radome (AUST) are situated on top of the rack.

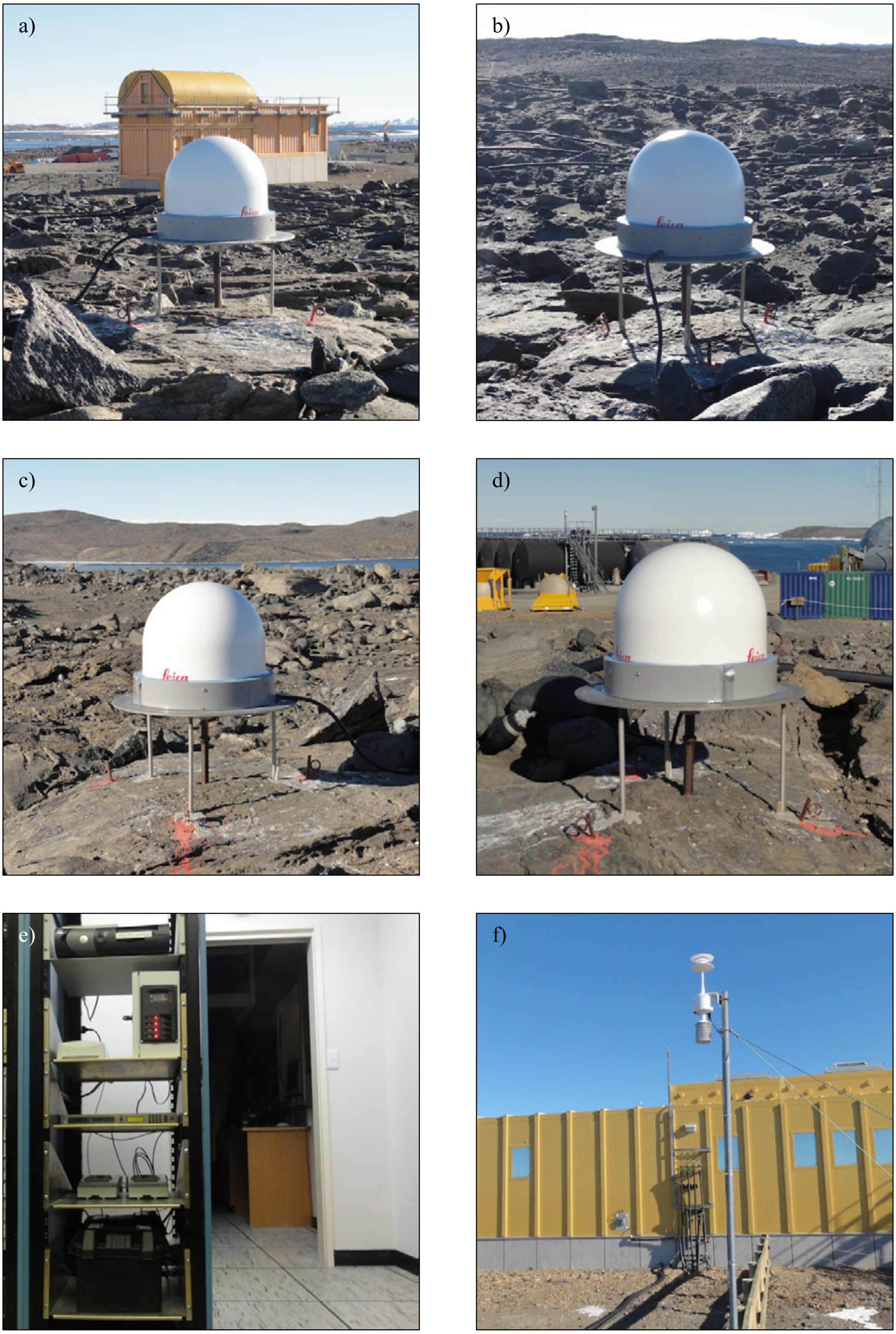


Figure 2.3: *a) the Davis CORS antenna facing north, b) east, c) south, d) west, e) the equipment rack and f) meteorological station.*

2.1.2 Local Monitoring Survey

A local monitoring survey was conducted at the Davis ARGN on 21 November 2010 in nil-wind conditions. The survey was performed using the indirect method with observations made between AUS099 (DAV1) and the three already established reference marks. Five sets of observations were completed at each reference mark, using a Leica TCA2003 total station and Leica precision prism sets. A set consists of a round of face left observations, followed by a reverse round of face right observations to each of the visible survey marks. For each observation a horizontal direction, zenith angle and slope distance was recorded. At each instrument set-up atmospheric conditions (temperature, pressure, and relative humidity) were recorded. Atmospheric corrections were applied during the post-processing stage and not directly into the instrument. Instrument and target heights were measured using either an offset tape or steel rule. Survey tripods were centred and levelled using a zenith-nadir optical plummet. Height differences between the reference marks were obtained from a precise level survey (see section 3.0).

Table 2.2: *Comparison of orthometric height differences between the main pillar (AUS099) and the reference marks from 1996 to 2011. All units are metres.*

AUS099 TO ...	1996	2001	2005	2007	2009	2011
AUS099-RM1	-2.3270	-2.3271	-2.3266	-2.3265	-2.3269	-2.3272
AUS099-RM2	-0.4440	-0.4440	-0.4435	-0.4437	-0.4440	-0.4445
AUS099-RM3	-0.9480	-0.9485	-0.9474	-0.9473	-0.9477	-0.9484

The survey observations were adjusted using a classical least squares approach in SNAP (Land Information New Zealand). Observation precisions were specified based on previous experience with the instrumentation and survey techniques. A vertical angle and horizontal angle precision of 1 second and a slope distance precision of 1 mm + 1 ppm were applied. The network was fixed using the known ITRF2000@2000.0 coordinates of AUS099 and aligned using the azimuth from AUS099 to AUS099-RM1 (Johnston and Digney 2001). The comparison of the orthometric height differences are in Table 2.2. The final geodetic and Cartesian coordinates are shown in Table 2.3 and 2.4 respectively.

The survey adjusted well and shows very good agreement between the previous monitoring surveys (Table 2.5). Horizontal and height differences all agree at the 1 mm level. It has previously been reported that there may be some longitudinal movement of AUS099-RM3 (Ruddick and Woods, 2009); this survey shows no evidence of movement. In conclusion there does not appear to be any significant horizontal or vertical local deformation at the site.

Table 2.3: *Final geodetic coordinates from the 2010 Davis local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Heights are based on the Davis MSL 1983. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ	HEIGHT (M)	σ
AUS099 (DAV1)	-68 34 38.3620	F	77 58 21.4090	F	44.4159	F
AUS099-RM1	-68 34 36.9441	0.2	77 58 21.6999	0.0	42.0887	0.1
AUS099-RM2	-68 34 38.6974	0.1	77 58 22.2745	0.1	43.9714	0.1
AUS099-RM3	-68 34 38.6337	0.1	77 58 21.1721	0.2	43.4675	0.1

Table 2.4: *Final Cartesian coordinates from the 2010 Davis local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
AUS099 (DAV1)	486854.5496	F	2285099.2912	F	-5914955.7010	F
AUS099-RM1	486859.6716	0.2	2285139.1463	0.0	-5914937.4882	0.1
AUS099-RM2	486842.9120	0.1	2285091.7147	0.1	-5914959.0824	0.1
AUS099-RM3	486855.4685	0.1	2285090.7278	0.2	-5914957.8932	0.1

Table 2.5: *Comparison between the previous Davis local monitoring surveys.*

YEAR	AUS099 TO ...	Δ EAST	Δ NORTH	Δ UP	RANGE
2001	AUS099-RM1	3.2954	43.9333	-2.3267	44.1181
2007	AUS099-RM1	3.2954	43.9331	-2.3266	44.1179
2009	AUS099-RM1	3.2954	43.9320	-2.3270	44.1168
2010	AUS099-RM1	3.2954	43.9328	-2.3273	44.1176
Std Dev		0.0000	0.0006	0.0003	0.0006
2001	AUS099-RM2	9.8021	-10.3904	-0.4442	14.2912
2007	AUS099-RM2	9.8020	-10.3916	-0.4437	14.2920
2009	AUS099-RM2	9.8019	-10.3910	-0.4441	14.2915
2010	AUS099-RM2	9.8033	-10.3908	-0.4445	14.2923
Std Dev		0.0007	0.0005	0.0003	0.0005
2001	AUS099-RM3	-2.6849	-8.4194	-0.9476	8.8878
2007	AUS099-RM3	-2.6841	-8.4211	-0.9473	8.8891
2009	AUS099-RM3	-2.6833	-8.4201	-0.9477	8.8880
2010	AUS099-RM3	-2.6832	-8.4192	-0.9484	8.8872
Std Dev		0.0008	0.0009	0.0005	0.0008

2.2 MAWSON STATION

The CORS at Mawson (MAW1) was installed in 1992 on the control mark AUS064 and forms part of the AAGN and IGS. The antenna is located on a rock outcrop in the magnetic quiet zone behind the cosray building, where the receiver is housed. The control mark has three reference marks located nearby that are used for routine local monitoring surveys (Figure 2.4).

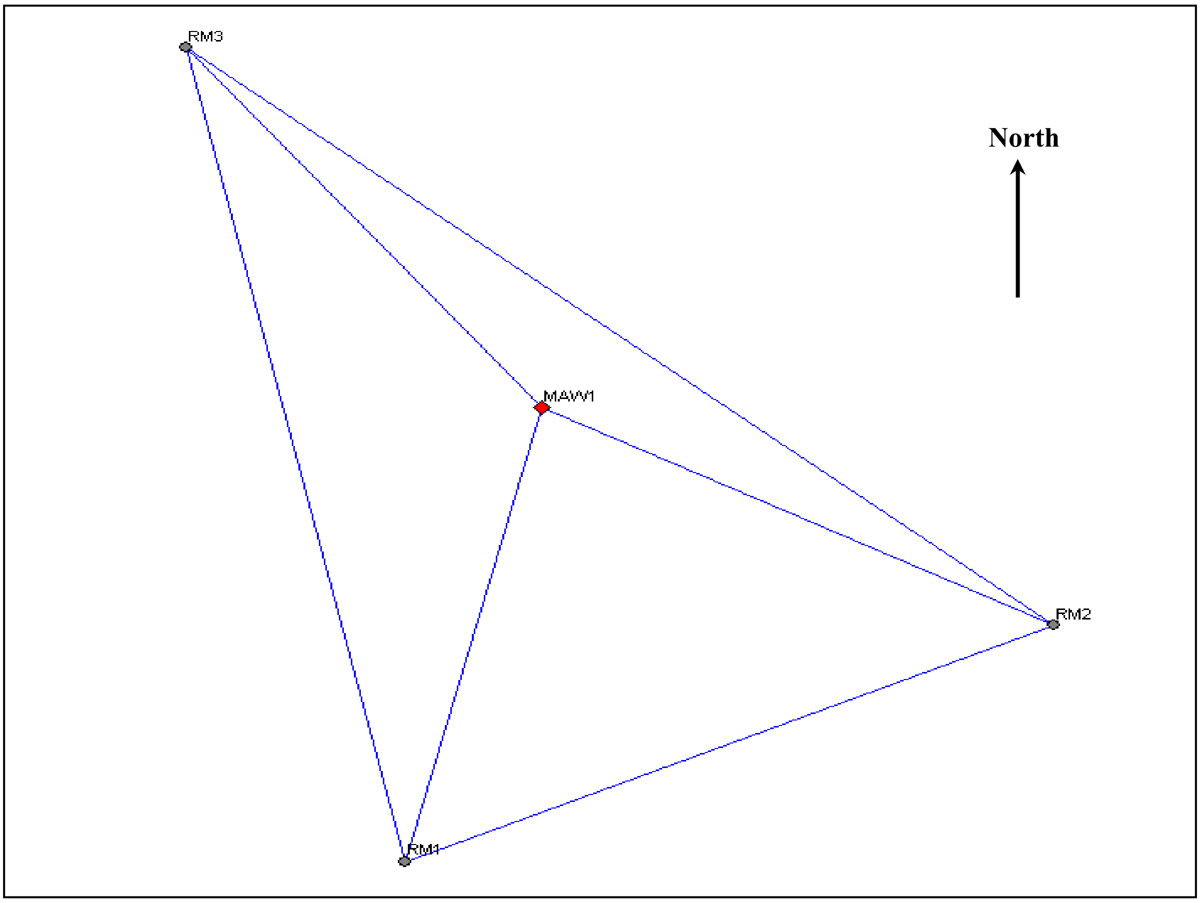


Figure 2.4: *Site diagram of the Mawson CORS setup.*

2.2.1 Equipment Upgrade

The equipment upgrade at Mawson was undertaken on 9 December 2010, where the power system was upgraded. This included the installation of new 12 v batteries and a custom designed 4 port power distribution box. During the upgrade there was a short data outage experienced.

The setup at Mawson now consists of two GNSS receivers, a Leica GRX1200GG Pro (Primary) and an Ashtech UZ-12 (Spare). Both receivers are connected to the antenna via a 12 volt 4 port powered antenna splitter. The antenna is AOAD/M_T covered by an AUST style radome mounted on a large aluminium ground plane (Figure 2.5). Two 12 volt 78 amp hour GelTech batteries provide power to the equipment via a custom designed 4 switch power distribution box. The batteries are charged by a 12V charger connected to mains power. A PC running the standard ARGN Fedora 6 build and operating off mains power is also present to interface with the receivers if required. The Ashtech UZ-12 is connected to the PC via a serial cable mounted on /dev/ttyS0. A spare antenna (ASH701945G_M S/N. CR5200348019) and radome (SCIS) are situated on top of the rack.

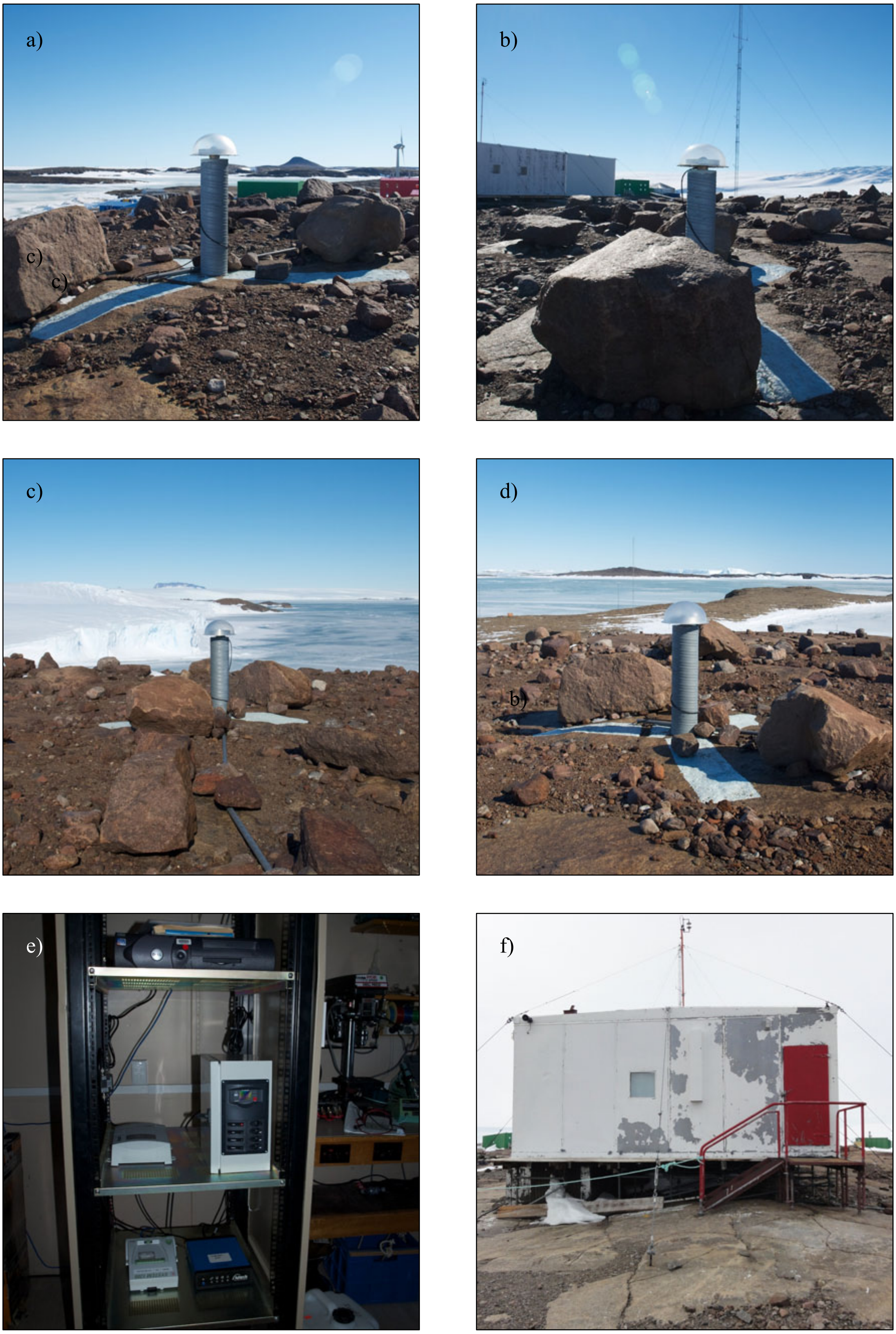


Figure 2.5: *a) The Mawson CORS antenna facing north, b) east, c) south, d) west, e) the equipment rack and f) cosray building where the equipment is housed.*

2.2.2 Local Monitoring Survey

A local monitoring survey was conducted at the Mawson ARGN site on 7 December 2010 in light-wind conditions. The survey was performed using the 'direct' method with observations made between AUS064 (MAW1) and three already established reference marks. The 'direct' method requires the antenna to be removed, prior to this the orientation of the antenna was marked and the number of shims recorded. Five sets of observations were completed at each reference mark, using a Leica TCA2003 total station. A set consists of a round of face left observations, followed by a reverse round of face right observations to each of the visible survey marks. For each observation a horizontal direction, zenith angle and slope distance was recorded. At each instrument set-up atmospheric conditions (temperature, pressure, and relative humidity) were recorded. Atmospheric corrections were applied during the post-processing stage and not directly into the instrument. Instrument and target heights were measured using either an offset tape or steel rule. Survey tripods were centred and levelled using a zenith-nadir optical plummet. Height differences between the reference marks were obtained from a precise level survey (see section 3.2).

Table 2.6: *Comparison of orthometric height differences between the main pillar (AUS099) and the reference marks from 1996 to 2011. All units are metres.*

AUS064 TO ...	1997	2001	2007	2011
AUS064-RM1	2.3650	2.3666	2.3655	2.3657
AUS064-RM2	0.4890	0.4901	0.4894	0.4899
AUS064-RM3	3.4540	3.4553	3.4544	3.4545

The survey observations were adjusted using a classical least squares approach in SNAP (LINZ). Observation precisions were specified based on previous experience with the instrumentation and survey techniques. A vertical angle and horizontal angle precision of 1 second and a slope distance precision of 1 mm + 1 ppm were applied. The network was fixed using the known ITRF2000@2000.0 coordinates of AUS064 and aligned using the azimuth from AUS064 to AUS064-RM3 (Johnston and Digney 2001). The comparison of the orthometric height differences are shown in Table 2.6. Table 2.7 and Table 2.8 list the final geodetic and Cartesian coordinates respectively.

The survey adjusted well and shows good agreement between the previous monitoring surveys (Table 2.9). Horizontal and height differences all agree at the 1 mm level. It appears that there may be some minor westerly movement of AUS064-RM1, this should be observed in the future but at the moment is of no cause for concern. It should also be noted that the survey techniques used in the survey prior to 2001 were not of the same precision as those in current use.

Table 2.7: *Final geodetic coordinates from the 2010 Mawson local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Heights are based on the Mawson MSL 1951. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ	HEIGHT (M)	σ
AUS064 (MAW1)	-67 36 17.1592	F	62 52 14.5766	F	59.1460	F
AUS064-RM1	-67 36 17.9501	0.2	62 52 14.0788	0.0	56.7803	0.1
AUS064-RM2	-67 36 17.5384	0.1	62 52 16.4564	0.1	58.6564	0.1
AUS064-RM3	-67 36 16.5320	0.1	62 52 13.2732	0.2	55.6915	0.1

Table 2.8: *Final Cartesian coordinates from the 2010 Mawson local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
AUS064 (MAW1)	1111287.1710	F	2168911.2733	F	-5874493.6049	F
AUS064-RM1	1111281.6646	0. 2	2168887.6266	0.0	-5874500.7530	0.1
AUS064-RM2	1111262.3666	0. 1	2168911.5677	0.1	-5874497.6282	0.1
AUS064-RM3	1111308.4692	0. 1	2168919.0679	0.2	-5874483.0079	0.1

Table 2.9: *Comparison between the previous Mawson local monitoring surveys.*

YEAR	AUS064 TO ...	Δ EAST	Δ NORTH	Δ UP	RANGE
2001	AUS064-RM1	-5.8799	-24.5031	-2.3674	25.3097
2006	AUS064-RM1	-5.8810	-24.5031	-2.3655	25.3098
2010	AUS064-RM1	-5.8823	-24.5027	-2.3657	25.3097
Std Dev		0.0012	0.0002	0.0010	
2009	AUS064-RM2	22.2110	-11.7473	-0.4910	25.1310
2004	AUS064-RM2	22.2107	-11.7473	-0.4895	25.1307
2002	AUS054-RM2	22.2097	-11.7483	-0.4897	25.1303
Std Dev		0.0007	0.0006	0.0008	
2009	AUS064-RM3	-15.4006	19.4305	-3.4570	25.3335
2004	AUS064-RM3	-15.4002	19.4303	-3.4544	25.3327
2002	AUS064-RM3	-15.4006	19.4307	-3.4546	25.3333
Std Dev		0.0002	0.0002	0.0014	

2.3 CASEY STATION

The CORS at Casey (CAS1) was installed in 1992 on the control mark AUS100 and forms part of the AAGN and IGS. The antenna is located in the magnetic quiet zone on a rock outcrop approximately 200 m from the operations building, where the receiver is housed. The control mark has three reference marks located nearby that are used for routine local monitoring surveys. The equipment changes were undertaken by the supervising communication and technical officer and as such no local monitoring survey was undertaken. The results from the previous survey in 2009 showed no signs of any horizontal or vertical local deformation.

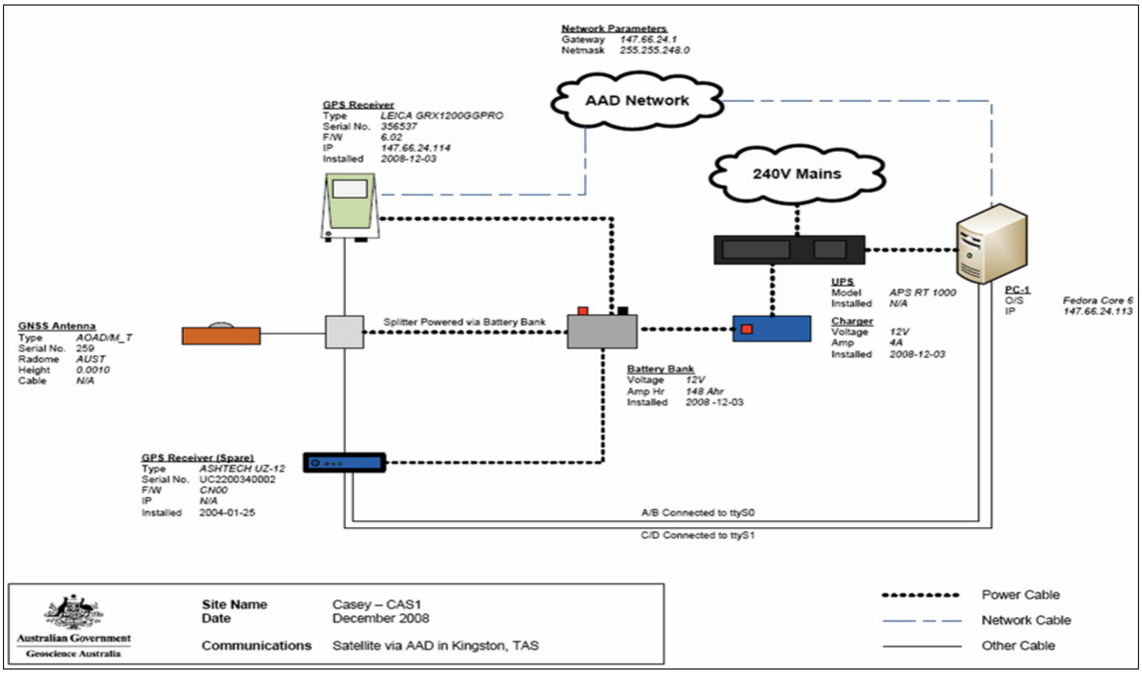


Figure 2.6: *Installation configuration of the Casey CORS setup.*

2.3.1 Equipment Upgrade

The GPS equipment at Casey has for the past ten years been located in the Summer Logistics Room, within the Operations Building. In 2008 a request was made for our equipment to be moved into the main communications equipment rack, to free up space and provide easy access to the communications officers who maintain the equipment. The equipment was moved during October 2010 by the AAD station communication officers, as the equipment was originally located in this rack no additional antenna cable lengths were added.

The setup at Casey (Figure 2.6) now consists of two GNSS receivers, a Leica GRX1200GG Pro (Primary) and a Ashtech UZ-12 (Spare). Both receivers are connected to the antenna via a 12 volt 4 port powered antenna splitter. The antenna is an ASH701945G_M covered by a AUST style radome (Figure 2.7). Two 12 volt 78 amp hour GelTech batteries provide power to the equipment. The batteries are charged by a 12V charger connected to mains power. A PC running the standard ARGN Fedora 6 build and operating off mains power is also present to interface with the receivers if required. A spare antenna (ASH701945G_M) and radome (SCIS) are situated on top of the rack.

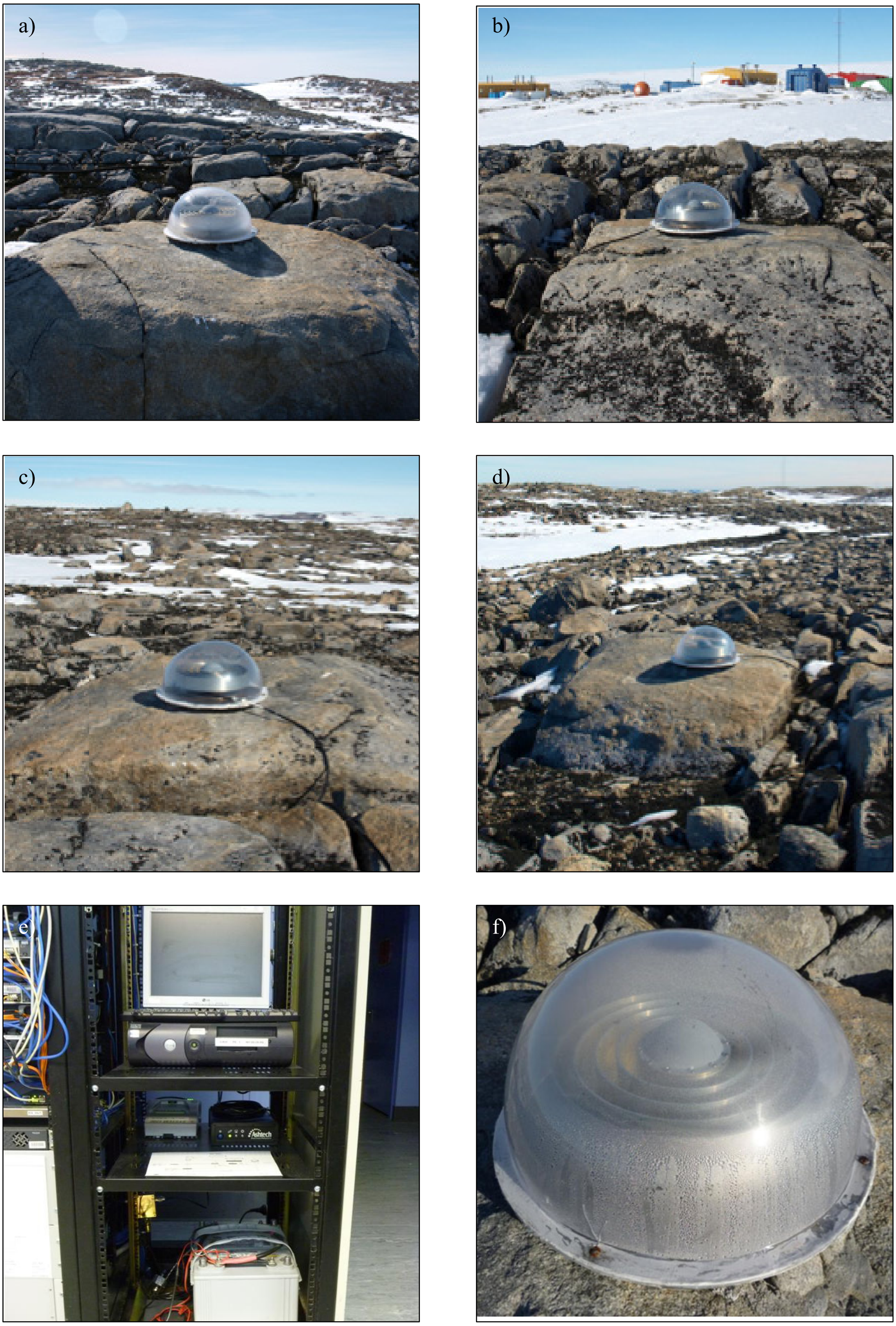


Figure 2.7: *a) the Casey CORS antenna facing north, b) east, c) south, d) west, e) the equipment rack and f) antenna showing condensation and small crack.*

2.4 MACQUARIE ISLAND

In April 2011 Nicholas Brown performed an equipment upgrade and reference mark (RM) survey of the Macquarie Island GNSS site (MAC1) which forms part of the ARGN and IGS. The GNSS equipment is located in the science building and the GNSS antenna is approximately 25m to the north on a large rock (Figure 2.8). The position of MAC1 relative to the reference marks can be seen in Figure 2.9.

Figure 2.8: *Position of MAC1 relative to science building*

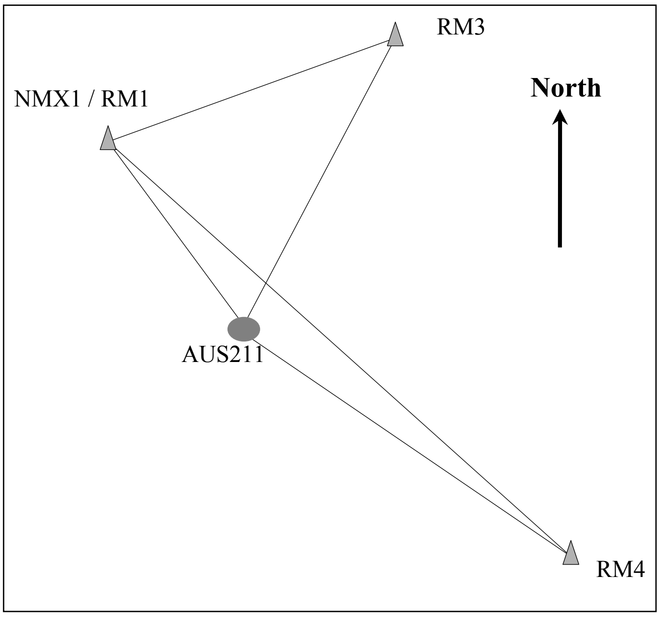


Figure 2.9: *Macquarie Island RM survey network*

2.4.1 Equipment Upgrade

One of the major reasons for visiting Macquarie Island was to upgrade the GNSS equipment. Prior to the upgrade, Geoscience Australia staff noticed problems with the GNSS data. The cause was thought to be issues related to the Trimble NetR5 which was installed in 2009. The rationale for this was that the secondary receiver, an Ashtech UZ12 was not experiencing any problems. The installation in the science building is set up according to Figure 2.10.

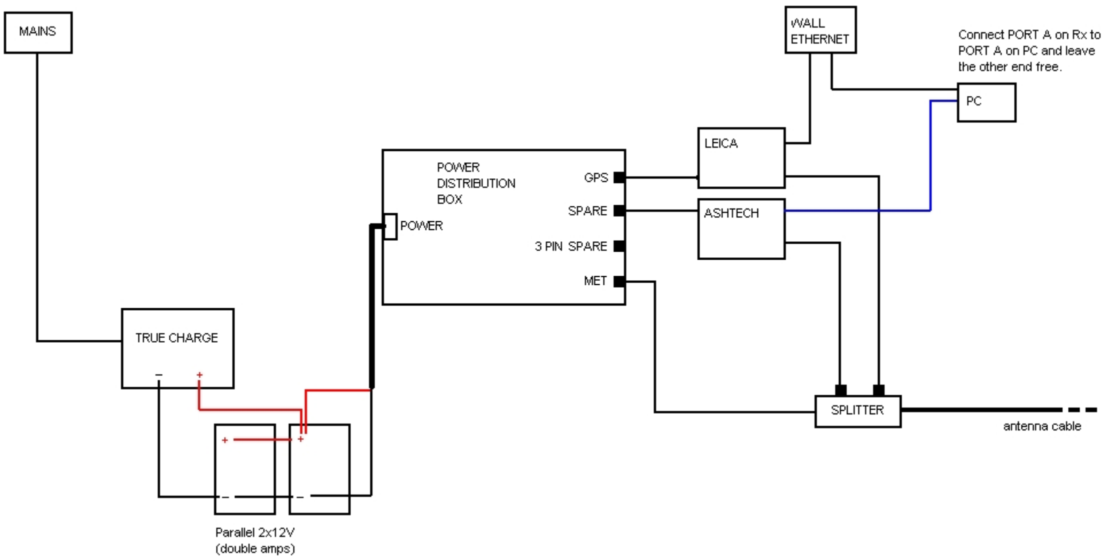


Figure 2.10: *Installation configuration of the Macquarie Island GNSS equipment.*

Receiver
As part of the upgrade, the Trimble NetR5 was removed and replaced with a Leica GRX1200+ GNSS receiver. As shown in the Figure 2.11, the Ashtech receiver was left on site; however, it is no longer switched on. The receiver and PC is plugged into are both off and can be switched on if required.

Antenna
No change was made to the antenna. The antenna is an Allen Osborne Associates (AOA) Dorne and Margolin Type T element (DMT). See Figure 2.12 and Figure 2.13.

True Charge
Xantrex True Charge 2 (20A) was installed and is connected to the 2 x 12V batteries installed in 2009 and the mains power.

Power Distribution Box
The True Charge powers the Power Distribution Box which delivers power to the two GPS receivers and the powered splitter.

Figure 2.11: *Macquarie Island GNSS Equipment*

2.4.2 Local Monitoring Survey

The RM survey was undertaken at the Macquarie Island GNSS site on the 28th April 2011 between AUS211, RM1, RM3 and RM4 as shown in Figure 2.9. No line of sight is available between RM3 and RM4 and therefore no data was observed between these marks.

The GNSS antenna mount at Macquarie Island is a special case and the surveyor must be very careful when performing the RM survey. The following steps were performed to remove the antenna, gain access the AUS211 spigot and ensure the antenna could be replaced with no change:

1. Remove dome
2. Place prism on antenna and measure the height difference between the top of antenna and BM HT2 (base of pillar)
3. Unscrew the nuts which hold the antenna in place while making sure the bolts do not move
4. Remove antenna
5. Perform survey
6. Replace antenna
7. Screw nuts back in place
8. Place prism on antenna and measure the height difference between the top of antenna and BM HT2 (base of pillar). Check that the difference is negligible when compared to previous values.
9. Replace dome.

Figure 2.12: *Base of AOA antenna (MAC1) after RM survey*

Figure 2.13: *Macquarie Island ARGN GNSS antenna, dome and bracing mount*

Checking Antenna Height

To ensure the antenna was replaced to the same position following the RM survey, the change in height between AAE HT RM2 (base of pillar) and the top of antenna was measured before removing the antenna and again after it was replaced. The change in height was 0.0002m which is judged to be insignificant.

Survey Results

The RM survey data was processed using the survey adjustment software GEOLAB to determine the coordinates of the RM's relative to AUS211 (Table 2.10). Note that the heights are not recorded in this table. The reason for this is because it is believed that the heights have been incorrectly listed in previous Macquarie Island reports. In the past, the height of AAE HT RM1 (BM on top of pillar) has been used as the height of AUS211 in the RM survey adjustment. This is incorrect because the readings are taken from AUS211, not AAE HT RM1. Furthermore, given that RM surveys are aimed at detecting horizontal movement, heights need not be shown here and are discussed in detail in Section 3.5. Table 2.10 and Table 2.11 list the final geodetic and Cartesian coordinates from the 2011 Macquarie Island survey. Comparisons between previous reference mark surveys at Macquarie Islands are shown in Table 2.12.

During the 2009 survey, GA staff were unable to set up the total station on AUS211 to observe to the RM's. This is because the AUS211 spigot sits in a depression within the pillar. On the advice of Ryan Ruddick, a 30.4 mm high shim was taken which can fit in the depression, and then the total station tribrach is screwed onto the shim. This allows the surveyor to directly measure to all three RM's from the pillar and increases the redundancy of the survey.

Table 2.10: *Final geodetic coordinates from the 2011 Macquarie Island reference mark survey. The height of AUS211 was held fixed at epoch ITRF1997.0 to allow for comparison with previous surveys. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ
AUS211	-54° 29' 58.31811"	0.0	158° 56' 09.00137"	0.0
NMX/RM1	-54° 29' 57.28898"	0.7	158° 56' 08.35536"	0.4
RM3	-54° 29' 56.61145"	0.7	158° 56' 10.53013"	0.4
RM4	-54° 29' 59.42705"	0.8	158° 56' 10.73670"	0.9

Table 2.11: *Final Cartesian coordinates from the 2011 Macquarie Island reference mark survey. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
AUS211	-3464049.1315	0.0	1334176.8676	0.0	-5169240.3217	0.0
NMX/RM1	-3464067.1169	0. 6	1334196.2534	0.4	-5169218.8212	0.5
RM3	-3464095.1684	0. 7	1334165.1155	0.2	-5169203.7543	0.5
RM4	-3464030.4946	0. 7	1334136.2233	1.0	-5169254.5077	0.6

Table 2.12: *Comparison between the previous Macquarie Island reference mark surveys.*

YEAR	AUS211 TO ...	Δ EAST	Δ NORTH	Δ UP
2006	AUS211-RM1	-11.6262	31.8220	-3.7187
2009	AUS211-RM1	-11.6256	31.8233	-3.7113
2011	AUS211-RM1	-11.6262	31.8216	-3.7113
2006	AUS211-RM3	27.5141	52.7738	-7.2826
2009	AUS211-RM3	27.5142	52.7732	-7.2752
2011	AUS211-RM3	27.5130	52.7710	-7.2751
2006	AUS211-RM4	31.2292	-34.2882	-7.0405
2009	AUS211-RM4	31.2300	-34.2884	-7.0332
2011	AUS211-RM4	31.2301	-34.2891	-7.0335

3. Tide Gauges

The AAD and the National Tidal Centre (NTC) operate a network of tide gauges across the AAT, including each of the main research stations (Figure 3.2). To geodetically control this network and facilitate the distinction between relative and absolute sea level change, GA have established permanent GNSS antennas at each of these sites and undertake routine precise level connections between the antennas, gauges and a series of well-defined benchmarks.

During the 2010/11 summer, precise levelling was conducted at the Davis, Mawson and Macquarie Island stations using the Electronic Distance Measurement (EDM) height traversing technique (Johnston and Verrall 2002). Height difference observations were made using a Leica TCA2003 Total Station to a prism mounted on a fixed height stainless steel prism pole (approximately 1.5m in height) and to a fixed height stainless steel stub (approximately 0.2m in height). Atmospheric conditions (temperature, pressure, and relative humidity) were recorded and entered into the instrument every 30 minutes. Levelling loops covering all monuments in the survey network were completed in both directions. Each instrument set-up involved reading three rounds of face left and face right observations to a single prism set-up over two marks. The levelling observations were adjusted using least squares to derive adjusted height differences between all marks.

To ensure the tide gauges are working correctly, calibrations were undertaken at Davis and Mawson using a GPS antenna setup on the sea ice directly above the tide gauge (Figure 3.1). Observations were made at 1 second and referenced to a second receiver located on a nearby tide gauge benchmark (TGBM). Observations were made over a 24 hour period and compared with the tide gauge observations, which were downloaded after the survey. A similar method was also used to establish a temporary GPS based tide gauge at Beaver Lake.

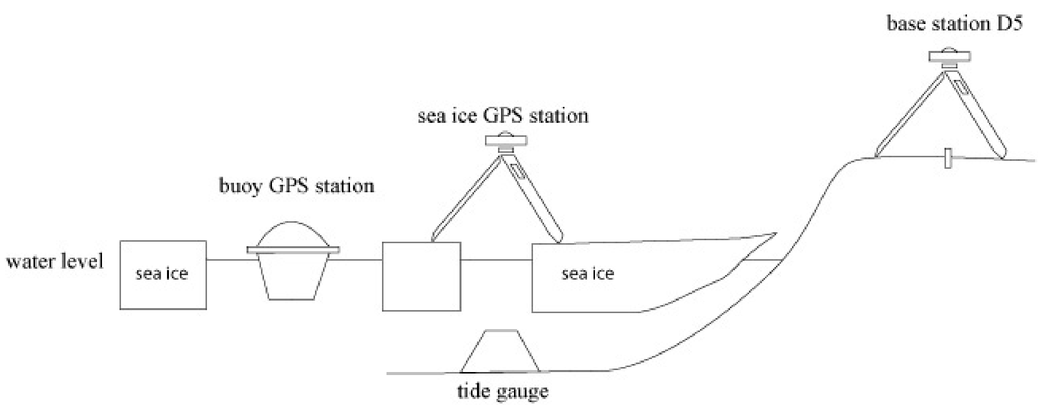


Figure 3.1: *Schematic diagram of tide gauge calibration procedure.*

The tide gauge at Nella Fjord in the Larsemann Hills was also removed during the summer.

Figure 3.2: *Map showing the location of tide gauges in the Southern Ocean.*

3.1 DAVIS STATION

There are two bottom-mounted pressure tide gauges at Davis Station, an inner and an outer gauge (Figure 3.4). These are located by lining up a series of barrels and antenna on the shoreline. The inner gauge is located at a depth of approximately 6 m. The inner gauge was covered in a substantial amount of weed and required cleaning. Download of the data was attempted, but was unsuccessful due to the weed covering. The outer gauge was not inspected during this visit.

3.1.1 Orthometric Levelling Results

On 28th November 2010 a precise level connection was made between AUS099 (DAV1) and the TGBM's NMV/S/4 and AUS186. The survey was conducted in light winds with the 1983 Mean Sea Level (MSL) height of NMV/S/4 held fixed as a reference. Along with the TGBM's, connections were made to a number of other marks around the station (Figure 3.4).

The final reduced levels and comparisons with previous surveys are shown in Table 3.1. The 2010 survey compares well with previous levels with differences compared to 2009 being no greater than 1 mm. This indicates that there has not been any local movement between the GPS antenna and the TGBM's.

3.1.2 GPS Connection and Calibration

Between the 26th November and 29th November a GPS antenna was setup on the sea ice over the inner tide gauge and also on the two TGBM's AUS186 and NMV/S/4. Data was recorded at a rate of 1 Hz for a daily tidal cycle (~ 24 hours). Due to a significant amount of weed growing over the gauge download of data after the survey was not possible. As such a comparison between with the GPS observations cannot be made until the gauge is cleaned appropriately and the data downloaded. The GPS data was processed using a kinematic method in the Bernese GPS processing software version 5.2. The resulting time-series is shown in Figure 3.3 compared with the predicted tidal signature (BOM 2010).

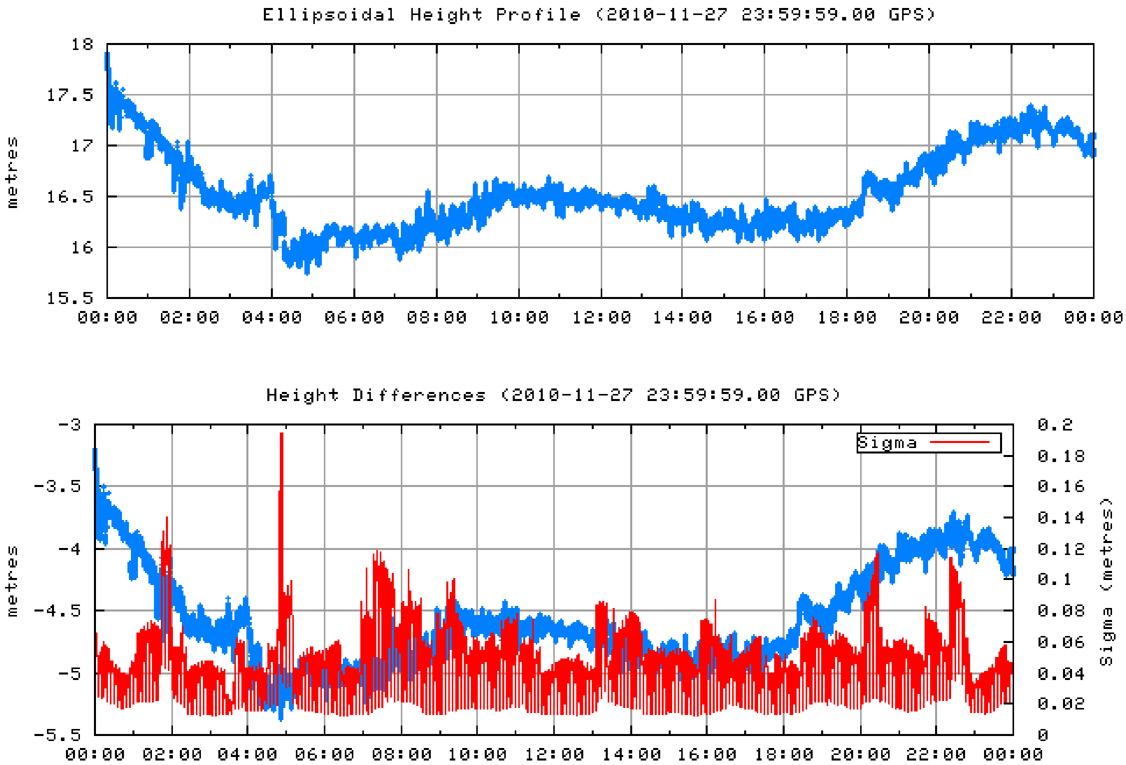


Figure 3.3: *GPS time-series showing the tidal signature above the inner tide gauge at Davis for 27 November 2010. Also shown are the predicted tidal values for the same day from the Bureau of Meteorology.*

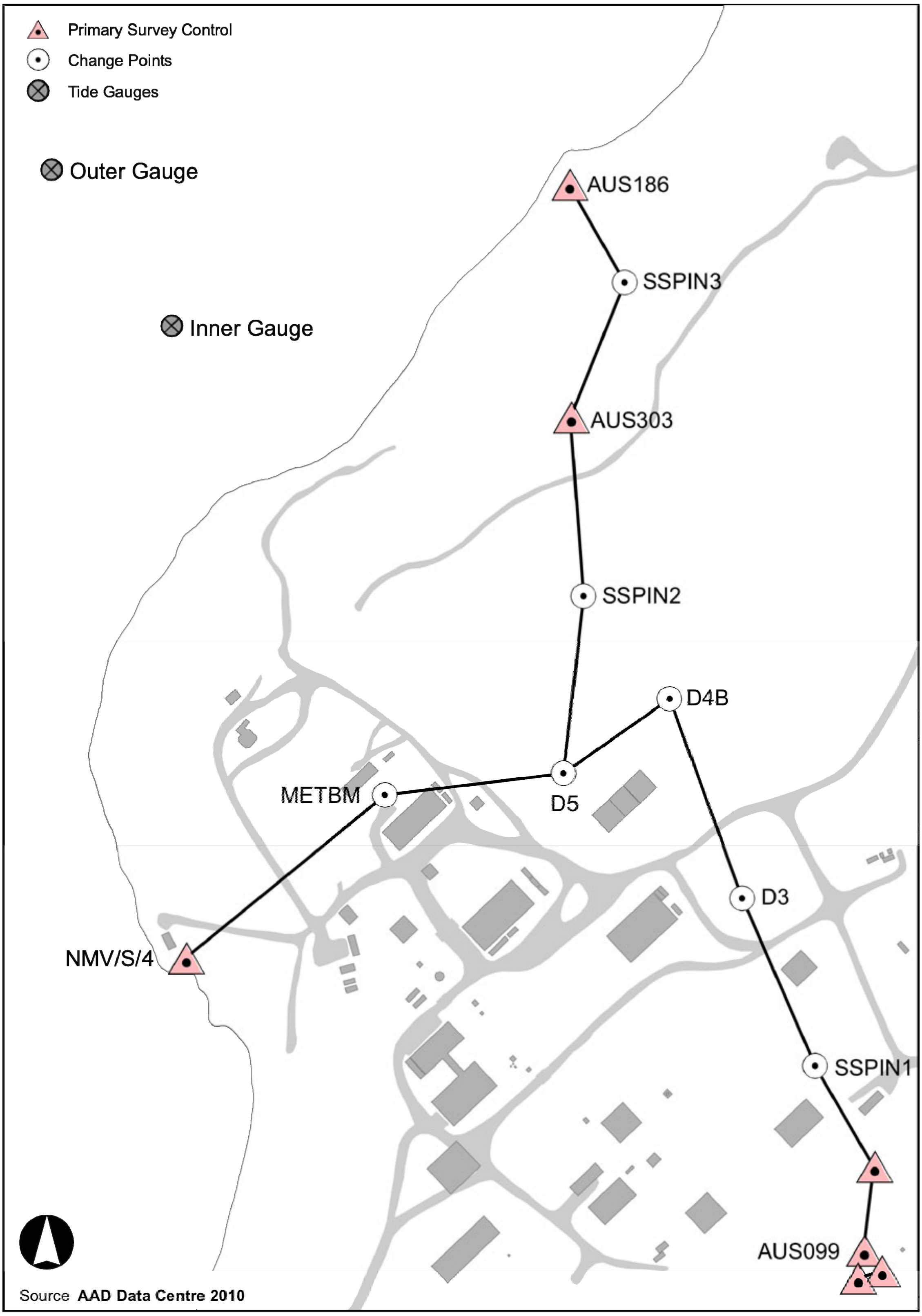


Figure 3.4: *The level traverse from the CORS (AUS099) to the two TGBM (AUS186 and NMV/S/4). Primary survey control is indicated by red triangles, circles indicate change points on secondary control.*

Table 3.1: *Geodetic connections to tide gauge benchmarks at Davis. Reduced levels in metres based on the 1983 MSL height of NMV/S/4.*

MARK	1994	1995/96	1996/97	1998/99	1999/2000	2001	2004/05	2006/07	2008/09	2010/11	COMMENT
AUS099	27.874		27.869		27.861	27.8686	27.8637	27.8628	27.8629	27.8626	ARGN GPS mark
NMV/S/5	27.855		27.854								Directly below AUS099
AUS099 RM1			25.542			25.5415	25.5370	25.5363	25.5358	25.5354	ARGN reference mark
AUS099 RM2			27.425			27.4245	27.4202	27.4191	27.4187	27.4182	ARGN reference mark
AUS099 RM3			26.921			26.9206	26.9163	26.9155	26.9150	26.9143	ARGN reference mark
BMR Gravity			27.592								-
METBM	18.404		18.399			18.4013	18.3957	18.3956	18.3954	18.3963	Near Met Building
HBM2			4.110	4.110	4.106						
HBM1			2.867	2.866	2.863						
NMV/S/4	2.179		2.179	2.179		2.1790	2.1790	2.1790	2.1790	2.1790	Tide Gauge Benchmark
D3				23.087	23.080	23.0843	23.0810	23.0803	23.0798	23.0804	-
D4				18.926	18.923			Disturbed	Disturbed	Disturbed	-
D4B										18.5292	-
D5						19.9195	19.9161	19.9161	19.9154	19.9161	-
AUS303				15.494	15.493	15.4995	15.4953	15.4952	15.4943	15.4954	-
AUS302				1.660	1.670						
AUS186	4.713	4.713	4.732	4.706	4.713	4.7202	4.7151	4.7155	4.7145	4.7153	Tide Gauge Benchmark
AUS184	2.022		2.041	2.014	2.023						
SSPIN1										22.4372	ARGN reference mark
SSPIN2										15.0123	-
SSPIN3										8.4064	-

3.2 MAWSON STATION

There are two tide gauges at Mawson a bottom-mounted pressure gauge (TG020) and a shore-mounted gauge (Figure 3.6). The gauge TG020 is located by lining up a series on antennas on the shore. The shore-mounted gauge is near the magnetic variometer building inside the Magnetic Quiet Zone (MQZ).

3.2.1 Orthometric Levelling Results

On the 12th December 2010 a precise level connection was made between AUS064 (MAW1) and the TGBM's AUS258, AUS267 and AUS268. The survey was conducted in nil-wind conditions with the MSL height of ISTS051 (9.792 m) being used as a reference. Along with the TGBM's connections were also made to AUS251, AUS301 and ISTS051 RM2 (Figure 3.6). Due to heavy snow cover the benchmarks NMV/S/1 and AUS300 could not be observed.

The final reduced levels and comparisons with previous surveys are shown in table 3.2. The 2010 survey compares well with previous levels with differences compared to 2006 being no greater than 1 mm. This indicates that there has been no local movement between the GPS antenna and the TGBM's.

3.2.2 GPS Connection and Calibration

Between the 12th and 13th of December 2010 GPS antennae were setup on the ice over TG020 and on the TGBM AUS258. Data was recorded at a rate of 1 Hz for a daily tidal cycle (~ 24 hours). After the survey the data was downloaded from the tide gauge. The GPS data was processed using a kinematic method in the Bernese GPS processing software version 5.2 (Figure 3.5). The resulting time-series is shown in Figure 3.5 compared with the predicted tidal signature (BOM 2010) and the actual tidal observations.

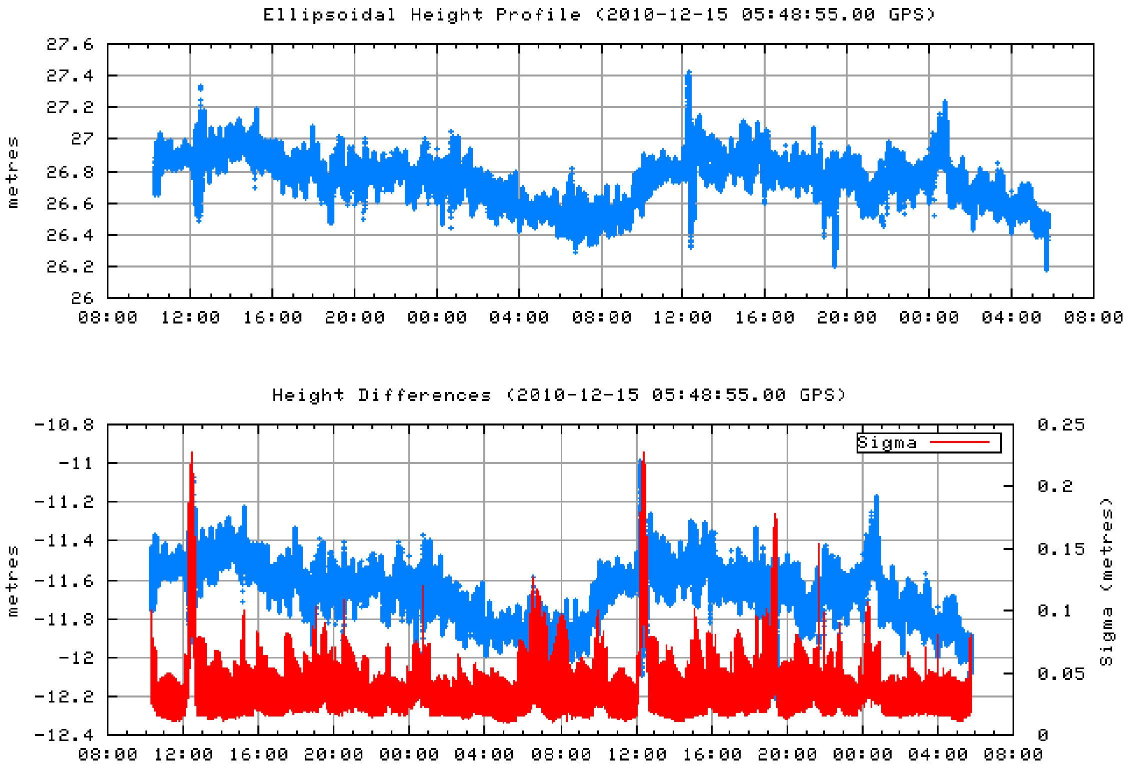
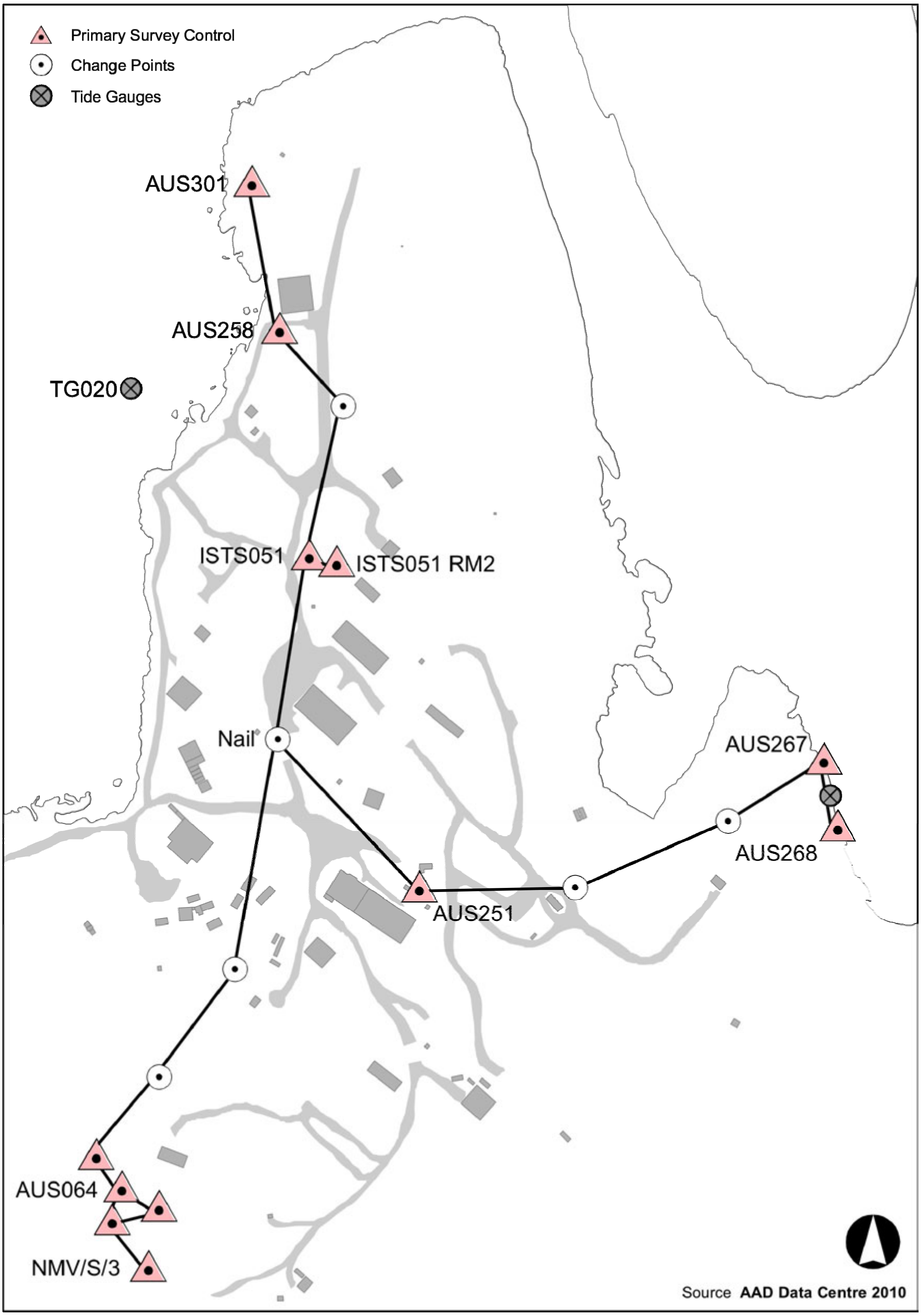


Figure 3.5: *GPS time-series showing the tidal signature above the bottom-mounted pressure tide gauge (TG020) at Mawson for 13-15th December 2010. Also shown are the predicted tidal values for the same day from the Bureau of Meteorology.*



Figures 3.6: *The level traverse from the CORS (AUS099) to the two TGBM (AUS186 and NMV/S/4). Primary survey control is indicated by red triangles, circles indicate change points on secondary control.*

Table 3.2: *Geodetic connections to tide gauge benchmarks at Mawson. Reduced levels in metres based on the MSL height of ISTS51.*

MARK	1995/96	1996/97	1997/98	1998/99	2000/01	2006/07	2010/11	COMMENT
ISTS051	9.7920	9.7920			9.7920	9.7920	9.7920	Datum for comparison
ISTS051 RM2	11.6860	11.6840		11.6770		11.6833	11.6835	-
ISTS051 RM4								-
AUS064	32.4490	32.4490	32.4490		32.4458	32.4441	32.4447	ARGN GPS mark
AUS064 RM1		30.0840		30.0580	30.0792	30.0786	30.0790	ARGN reference mark
AUS064 RM2	31.9590	31.9600	31.9560	31.9560	31.9557	31.9547	31.9548	ARGN reference mark
AUS064 RM3		28.9950	28.9930	28.9900	28.9905	28.9897	28.9902	ARGN reference mark
AUS300			2.1480	2.1220	2.1328	2.1312		North of fuel farm
AUS301			1.8500		1.8351	1.8342	1.8341	North of aircraft hanger
AUS321								-
NMV/S/11								-
BM1								-
NMV/S/3								-
AUS258	1.4130	1.4140	1.4270	1.4000	1.4108	1.4098	1.4094	Tide Gauge Benchmark
AUS251						18.1385	18.1391	BM next to smoke hut
AUS267						2.8755	2.8768	Tide Gauge Benchmark
AUS268						3.5365	3.5378	Tide Gauge Benchmark
NMV/S/1						15.5673		BM near ANARESAT

Notes: 1 based on a MSL height of 9.792 metres at ISTS051. This value was adopted from the ISTS051 May 1981 Station Summary.
2, 3 Class LC* optical leveling, using fiberglass staves. All values corrected for thermal expansion/contraction of the staves (King 2000).
4 Class LC* optical levelling, using Aluminum staves. All values corrected for thermal expansion/contraction of the staves (King 2000). Although included in the summary for completeness, these results may be dubious.
5 Class LC* optical levelling. All values corrected for thermal expansion/contraction of the staves (King 2000). Although included in the summary for completeness, these results may be dubious.
6 Class L2A* levelling, using the "Leap-Frog" EDM Height Traversing. Due to limited time at Mawson Station, only the section between AUS258 and ISTS051 was observed in both directions, with the remaining sections only leveled one way. However, the comparison with previous levelling was acceptable and the superior technique used means that this 200/2001 levelling is the most reliable (see section 3 of AUSLIG Technical Report 5 for more details).
7 The GPS antenna attached to AU064 was leveled to, but it is not clear which part of the antenna was used. Assuming that the top of the ground plane was leveled, the height shown was obtained by reducing the measured height by 38 mm to bring it to the base of the antenna (the antenna reference point - ARP), plus a further 31⁄2 mm for the height of this antenna above the AUS064 station mark (see the site log sheet for details).
8 AUS064 RM2 was used as the common point to compare the 1997/98 & 1998/99 results with the other years, as ISTS051 was not connected during these surveys.

3.3 LARSEMANN HILLS TIDE GAUGE

In January 2000 a tide gauge was installed by the AAD mapping group at Nella Fjord in the Larsemann Hills. Since then the tide gauge has run out of batteries and has now been superseded by a tide gauge at Chinese station, Zhong Shan. During the summer we were tasked with the removal of the Nella Fjord tide gauge.

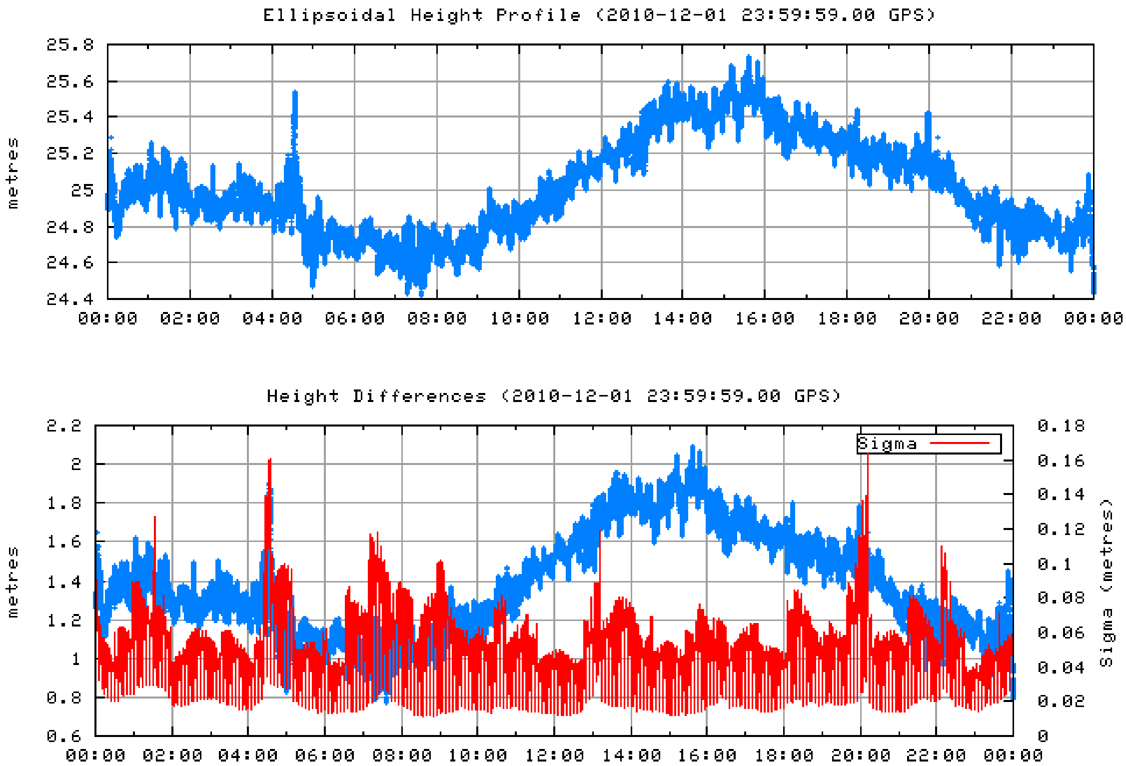
On 27 November 2010 we visited the Larsemann Hills to remove the tide gauge with helicopter support from Davis. At Nella Fjord a Chinese National Antarctic Research Expedition (CHINARE) geodetic surveyor, Jifeng Haung, assisted us with the removal. The tide gauge was easily located using the offsets from AUS335; the fast ice had rafted up over the area and required a jiffy drill with four metres of extensions. Once the hole was drilled, the tide gauge was removes using a tide gauge "grabber" and under water camera, attached to 7 metres of cane poles. The tide gauge was not downloaded on site but Returned To Australia (RTA) to the AAD mapping group.

In 2008/09 (Ruddick, Woods and Brown 2009) a precise level connection was made between the TGBM's at Nella Fjord and Zhong Shan station survey network. This connection along with Chinese connection to the Zhong Shan tide gauge could be used to redefine the vertical datum across the Larsemann Hills.

3.4 BEAVER LAKE

Beaver Lake is located at Latitude: -70° 48' 11.65", Longitude: 68° 10' 44.64" and has been used as a prominent field research station in the past. Located at the site is a number of field huts (apples) and it typically hosts a significant amount of aviation fuel due to its proximity to the lower reaches of the Prince Charles Mountains, as such accessibility to the site is frequent by both fixed wing and helicopter.

During the 2010/11 summer GA was tasked by the AAD mapping group to setup a temporary GPS tide gauge on the lake ice. The aim of the survey was to measure the tidal signature over a 24-hour period (Figure 3.7). A GPS receiver was setup on the ice with a reference receiver on AUS2021, it was intended to also establish a reference receiver on AUS2022 (TGBM) but this mark was buried by ice. Due to logistics, it was not possible to return to the site immediately within a 24 hour period and the receivers were left running for a period of 6 weeks with data available over an 18 day period.



Figures 3.7: *GPS time-series showing the tidal signature at Beaver Lake over a 24 hour period.*

3.5 MACQUARIE ISLAND

Precise orthometric height differences were observed from the tide gauges in Garden Cove (AQUATRAK and DRUCK) to the Macquarie Island ARGN station (AUS211) and its reference marks in late April 2011. The level run made direct connections to survey monuments observed in previous TGBM level surveys conducted on the island (Figure 3.8) including, SPM10708, SPM10709, AUS091, AUS092, AUS228, AAE BM1 RM1 and AAE BM1 RM2 and GBAY2. GBAY one could not be observed because the mark was unstable and was disturbed when the GPS antenna used in the tide gauge calibration was removed. The entire spigot came off with the antenna. Anna Hill (UTAS) received assistance from some of the station trades people to reinstall the mark in the same location. Since the mark position has changed, it has been renamed GBAY2.

The orthometric heights were derived with respect to the Macquarie Island MSL height determined for benchmark AAE BM1 RM2 (2.598m). Each survey mark was observed at least twice as the level run went from the ARGN station (AUS211) down to the tide gauges and back up to AUS211. An analysis has not been made in this report to distinguish any absolute sea level rise or crustal movement.

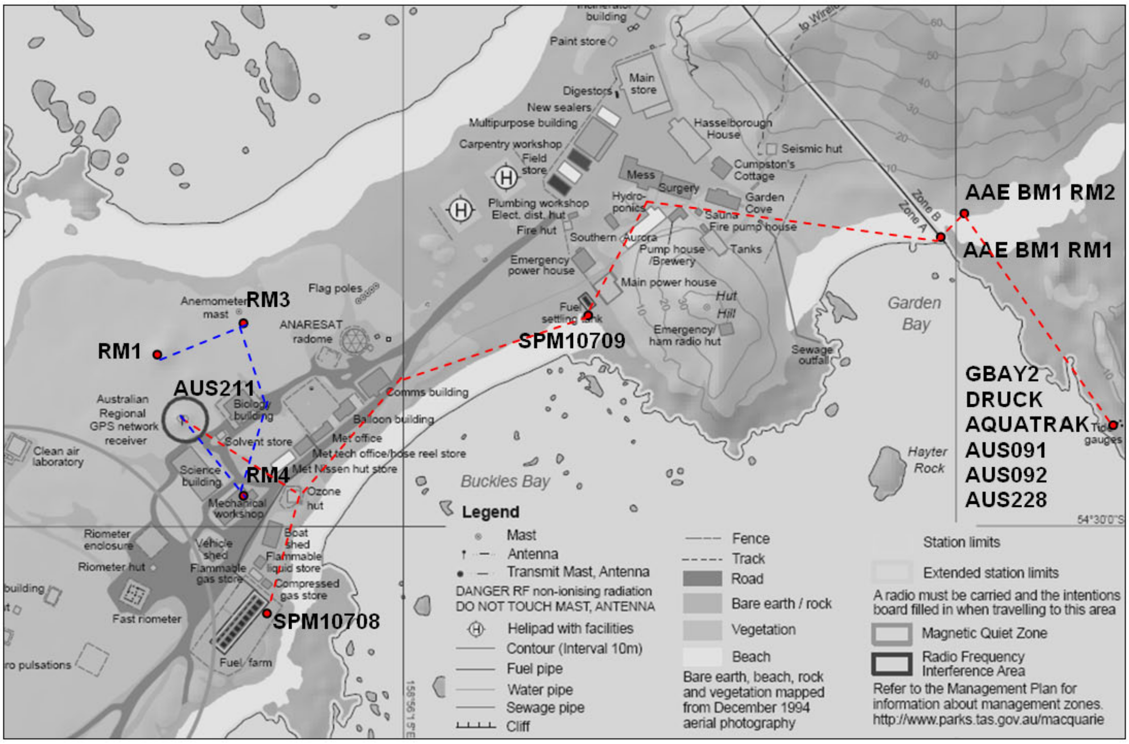


***Figure 3.8:** Macquarie Island Levelling Route.*

MARK	1994	1996	1996	1997/98	1999/00	2002	2006	2009	2011	COMMENT
AUS211 HT RM1	-	-	12.88	-	-	-	12.88	12.88	12.883	Top of bolt on top of ARGN pillar
AUS211 HT RM2	11.68	11.68	11.68	11.681	-	11.68	11.68	11.68	12.683	Top of bolt at base of ARGN pillar
NM/X/1 RM1	9.162	9.162	9.161	9.161	-	9.162	9.163	9.163	9.165	Ground mark on mound north of ARGN pillar
AUS211 RM4	-	-	-	-	-	5.84	5.841	5.841	5.843	Ground mark at Mechanical Workshop
AUS211 RM3	-	-	-	-	-	5.598	5.599	5.6	5.601	Ground mark at Anemometer mast
AUS156	5.722	5.723	5.723	5.725	5.723	-	-	5.723	-	Top of bolt at base of Anemometer mast
SP10708	-	-	-	-	-	-	7.214	7.214	7.215	East Cnr of Fuel Farm
SP10709	-	-	-	-	-	-	4.969	4.97	4.971	East Cnr of Fuel Settling Tank
AAE BM1 RM1	1.903	1.903	1.903	1.903	1.904	1.904	1.903	1.903	1.903	On top of rock at east end of beach in Garden Bay
AAE BM1 RM2	2.598	2.598	2.598	2.598	-	2.599	2.597	2.598	2.598	On rocky mound at east end of beach in Garden Bay
AUS228	3.297	3.296	3.297	3.297	3.297	-	3.296	3.296	3.296	Near Tide Gauges
AQUATRAK RM	3.212	3.212	3.212	-	-	-	-	3.212	3.212	Tide Gauge RM
AQUATRAK RIM	3.228	3.228	3.228	3.229	3.229	3.227	3.228	3.228	-	Top of brass rim of Tide Gauge
DRUCK RM	-	3.335	3.336	-	-	-	-	3.334	*	Tide Gauge RM
DRUCK RIM	-	3.351	3.352	3.352	3.353	3.35	3.351	3.351	-	Top of brass rim of Tide Gauge
AUS091	3.332	3.332	3.332	3.332	3.332	3.331	3.331	3.331	3.331	Near Tide Gauges
AUS092	3.495	3.495	3.495	3.495	3.495	3.494	3.495	3.494	3.494	Near Tide Gauges
GBAY2**	-	-	-	-	-	-	-	-	6.619**	Base of threaded spigot near Tide Gauges in Green Bay

Table 3.3: Comparison of the 2011 RL's compared to previous surveys based on the AAE BM1 RM2 of 2.598m (installed in 1992).

* The incorrect DRUCK RM point was observed. Nick Brown was advised that the reference mark was the bolt set up on in Figure 3.9 (circled in red). The true reference marks are the punch marks in the RIM and another punch mark in the base of the plate. Future advice is that these should be clearly marked on the gauge in the future.

** New mark after GBAY was destroyed

Figure 3.9: *The* ***incorrect*** *DRUCK reference point.*

4. Australian Antarctic Geodetic Network

The AAGN consists of a series of survey marks placed on solid rock outcrops throughout the AAT. The majority of these marks were established using terrestrial surveying techniques from the 1960's onwards. Over the past 20 years, GNSS observations have been made on selected marks to strengthen the network, as satellite positioning methods can be used over much longer distances with a far greater accuracy without the need for inter-visibility.

The current comprehensive AAGN provides a realisation of latest ITRF coordinates for over 460 geodetic grade survey marks, providing an extensive coverage across areas of the AAT that contain significant bedrock features. This network can facilitate geodynamic studies and act as a fundamental geospatial reference for other sciences across the greater continent. Figure 4.1 and Figure 4.2 show the locations of the AAGN marks during the 2010/11 GNSS campaign.

Tables 4.1-4.10 list the GNSS observations made on AAGN marks during the 2010/11 season. Data shown below has been processed via Auspos Version 2.00 (shown below with results presented in ITRF 2005 in both Geographic and Cartesian formats). Data has also been processed amongst an exclusive Bernese GNSS campaign that will integrate measurements within the greater AAGN adjustment. At the time of writing this report, the adjustment has been integrated within Dynanet, a software package developed within the Victorian state government. This adjustment is an ongoing process and is being continually refined with results included as part of the ongoing NGRS project and database. Original field and Rinex data can be located under the internal GA directory; N:\geodesy_data\gnss\data\campaign\antarctica

Table 4.1: *Marks and days for which data was observed at Vestfold Hill.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
NMVS8	Deep Lake	10333	10337	Ash UZCGRS	AT504
NMVS9	Deep Lake	10333	10337	Thales ICGRS	AT504
273e	Tarbuck Crag (Ecce)	10333	10337	Ash UZCGRS	AT504SS
N273	Tarbuck Crag (main)	10338	10339	Ash UZCGRS	AT504SS
NMVS57	Lake Laternula	11024	11027	Ash ICGRS	AT504
NMVS58	Clear Lake	11024	11026	ASH UZ-12	AT504
NMVS60	Cemetery Lake	11024	11027	ASH UZ-12	AT504
NMVS72	Lake Druhzby	11025	11033	Leica GRX1200	AT504
NMVS262	Sorsdall Knoll	11027	11033	Ash UZ-12	AT504
NMVS74	Oblong Lake	11027	11033	Ash UZ-12	AT504
NMVS258	Lichon Valley	11034	11038	Ash UZ-12	AT504
NMVS63	Lake Zvedza	11034	11036	Ash UZ-12	AT504
NMVS69	Lake Jabs	11034	11038	Ash UZ-12	AT504
NMVS85	Long Fjord	11035	11038	Leica GRX1200	AT504

Table 4.2: *Marks and days for which data was observed at Davis Station.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
A186	Tide Gauge BM	10328	10331	Leica GRX1200pro	LeiAT504
NMVS4	Tide Gauge BM	10328	10331	Leica GRX1200pro	LeiAT504
DTG1	Davis Tide Gauge	10330	10331	Leica GRX1200pro	LeiAT504
D4B	Davis Station Mark	11027	11031	Ash UZ-12	Lei AT504GG

Table 4.3: *Marks and days for which data was observed at Mawson Station.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
A258	Tide Gauge BM	10347	10349	Leica GRX1200pro	AT504
MTG1	Mawson Tide Gauge	10347	10349	Ash UZ-12	AT504
AUS267	New Mawson BM	10354	10355	Leica GRX1200pro	AT504
AUS268	New Mawson BM	10354	10356	Ash UZ-12	AT504
A252	Fang Saddle	10365	10365	Leica GRX1200pro	AT504

Table 4.4: *Marks and days for which data was observed at Bunger Hills.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
BHIL	Bunger Hills CORS	11019	11021	Leica GRX1200Pro	Ashtech w/dome
RM01	RM1	11019	11020	ASH UZ-12	AT504
RM02	RM2	11020	11020	ASH UZ-12	AT504
RM03	RM3	11020	11021	ASH UZ-12	AT504
N238	Bunger E/D Camp	11019	11020	Leica GRX1200 Pro	AT504
N237	Dobrowolski Camp	11020	11020	Leica GRX1200 Pro	AT504
N238 RM1	Bunger E/D Camp	11021	11021	Leica GRX1200 Pro	AT504

Table 4.5: *Marks and days for which data was observed at Beaver Lake.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
AUS2021	Beaver Lake BM	10334	11	Leica GRX1200Pro	Lei AT504
BL01	Beaver Lake	10334	11	Leica GRX1200	Lei AT504 GG

Table 4.6: *Marks and days for which data was observed at Larsemann Hills.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
NMS135	Blundell Peak	11041	11043	ASH UZ-12	Lei AT504
3 Man	Three Man Peak	11041	11043	Leica GRX1200	Lei AT504

Table 4.7: *Marks and days for which data was observed at Grove Mountains.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
A351	CORS Station	11014	11017	Leica GRX1200Pro	Ashtech w/dome
GRM1	RM1	11014	11014	Leica GRX1200Pro	Lei AT504
GRM2	RM2	11014	11015	Leica GRX1200Pro	Lei AT504
GRM3	RM3	11015	11016	Leica GRX1200Pro	Lei AT504

Table 4.8: *Marks and days for which data was observed at Wilson Bluff.*

Site	Description	GPS Start	GPS End	Receiver Type	Antennae Type
A368	Wilson Bluff	11012	11013	Leica GRX1200Pro	Ashtech w/dome
WBFO	Dresden RM	11012	11013	Leica GRX1200Pro	Lei AT504

Table 4.9: *Final geodetic coordinates from 2010/11 GPS campaigns. GRS80 ellipsoid aligned to ITRF2005 at 1 January 2005. Final estimates of precision are shown as 1σ in mm.*

Site	Latitude	Longitude	Ellipsoidal Height (m)	Height above MSL (m) (Davis 1983 datum)
NMVS8	-68 33 22.94334	78 11 16.29784	-32.971	-50.313
NMVS9	-68 33 46.61611	78 11 15.30428	-31.782	-49.116
273e	-68 34 38.52780	78 11 54.99623	157.676	140.357
N273	-68 34 38.54970	78 11 54.72070	157.59	140.271
NMVS57	-68 38 55.56708	77 58 54.03152	19.037	1.882
NMVS58	-68 38 32.84763	77 59 49.67580	11.432	-5.738
NMVS60	-68 37 25.26908	77 58 28.00700	20.31	3.119
NMVS72	-68 35 52.47783	78 18 48.95216	26.358	9.036
NMVS262	-68 38 58.70824	78 13 00.15050	97.846	80.607
NMVS74	-68 37 30.09899	78 14 13.59291	15.299	-1.974
NMVS258	-68 27 59.42845	78 24 31.49565	153.751	136.273
NMVS63	-68 31 32.65460	78 28 12.86644	33.921	16.497
NMVS69	-68 33 20.01395	78 16 19.93375	-17.365	-34.724
NMVS85	-68 29 50.13635	78 16 29.27080	39.384	21.955
A186	-68 34 20.60052	77 58 05.62821	21.256	3.987
NMVS4	-68 34 33.92398	77 57 48.96697	18.702	1.44
D4B_	-68 34 29.25318	77 58 11.28017	35.097	17.831
A258	-67 36 00.54591	62 52 22.69359	28.075	-0.571
AUS267	-67 36 08.98601	62 52 49.95457	29.547	0.905
AUS268	-67 36 09.44959	62 52 50.51059	30.212	1.57
A252	-67 47 32.32881	62 34 37.57070	862.84	833.959
A368	-74 17 26.07816	66 47 32.03258	1235.797	1227.177
WBFO	-74 17 28.43685	66 47 32.62993	1240.407	1231.787
A351	-72 54 29.17667	74 54 36.42955	1907.467	1894.663
GRM1	-72 54 28.61504	74 54 35.40383	1903.81	1891.006
GRM2	-72 54 29.77262	74 54 36.28533	1904.974	1892.171
GRM3	-72 54 29.21184	74 54 34.75173	1903.287	1890.484
BHIL	-66 15 04.92403	100 35 54.89047	18.006	20.714
RM01	-66 15 04.69433	100 35 55.16378	17.15	19.858
RM02	-66 15 05.44149	100 35 55.41304	17.933	20.642
RM03				
N238	-66 14 59.78775	100 36 13.23686	5.269	7.978
N237	-66 16 26.61742	100 44 58.53316	34.592	37.381
N238 RM1				
AUS2021	-70 48 11.65976	68 10 44.64606	37.148	19.073
NMS135	-69 25 33.67905	76 06 14.77860	N/A	N/A
Three Man Peak	-69 22 49.31953	76 17 41.30398	N/A	N/A

Table 4.10: *Final Cartesian coordinates from the 2010/11 GPS campaigns. GRS80 ellipsoid aligned to ITRF2005 at 1 January 2005. Final estimates of precision are shown as 1σ in mm.*

Site	X	Y	Z
NMVS8	478706.03	2289013.614	-5914029.764
NMVS9	478577.386	2288343.47	-5914298.981
273e	477844.964	2287037.664	-5915063.012
N273	477847.883	2287036.377	-5915063.179
NMVS57	484946.056	2277909.251	-5917838.227
NMVS58	484467.292	2278678.575	-5917574.81
NMVS60	485776.425	2280396.919	-5916820.189
NMVS72	472812.319	2285856.151	-5915777.269
NMVS262	475585.137	2279818.727	-5917947.062
NMVS74	475288.483	2282461.689	-5916870.068
NMVS258	471765.657	2300046.051	-5910531.598
NMVS63	468059.506	2294485.217	-5912841.888
NMVS69	475354.259	2289804.125	-5914011.107
NMVS85	476484.6	2295771.204	-5911683.391
A186	487134.403	2285554.81	-5914733.113
NMVS4	487238.688	2285138.7	-5914881.537
D4B_	487020.812	2285329.015	-5914843.935
A258	1111413.4	2169367.987	-5874268.764
AUS267	1111016.729	2169300.183	-5874369.762
AUS268	1111004.944	2169291.584	-5874375.848
A252	1113613.94	2146279.346	-5883175.489
A368	682780.468	1592449.829	-6118988.512
WBFO	682748.602	1592388.242	-6119012.754
A351	489658.74	1816031.161	-6076059.187
GRM1	489671.824	1816043.76	-6076050.573
GRM2	489655.22	1816013.056	-6076062.234
GRM3	489672.921	1816024.985	-6076055.512
BHIL	-473772.994	2531930.486	-5815308.594
RM01	-473777.484	2531935.92	-5815304.945
RM02	-473776.705	2531914.835	-5815314.982
RM03			
N238	-474024.05	2532026.432	-5815232.861
N237	-480013.829	2528403.786	-5816342.41
N238 RM1			
AUS2021	781892.106	1952800.429	-6001133.935
NMS135			
Three Man Peak			

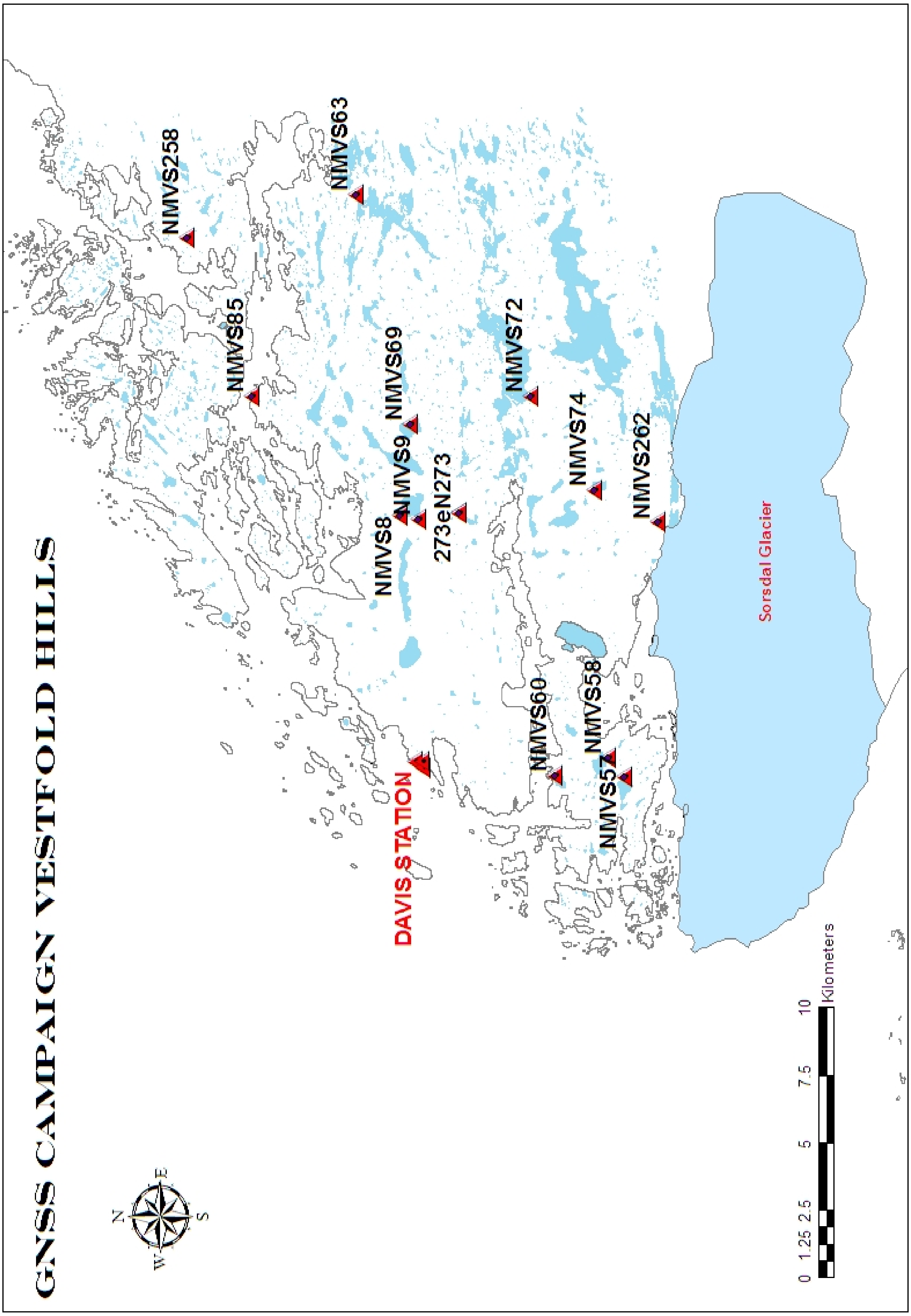


Figure 4.1: *Location of AAGN marks during 2010/11 GNSS campaign in the Vestfold Hills.*

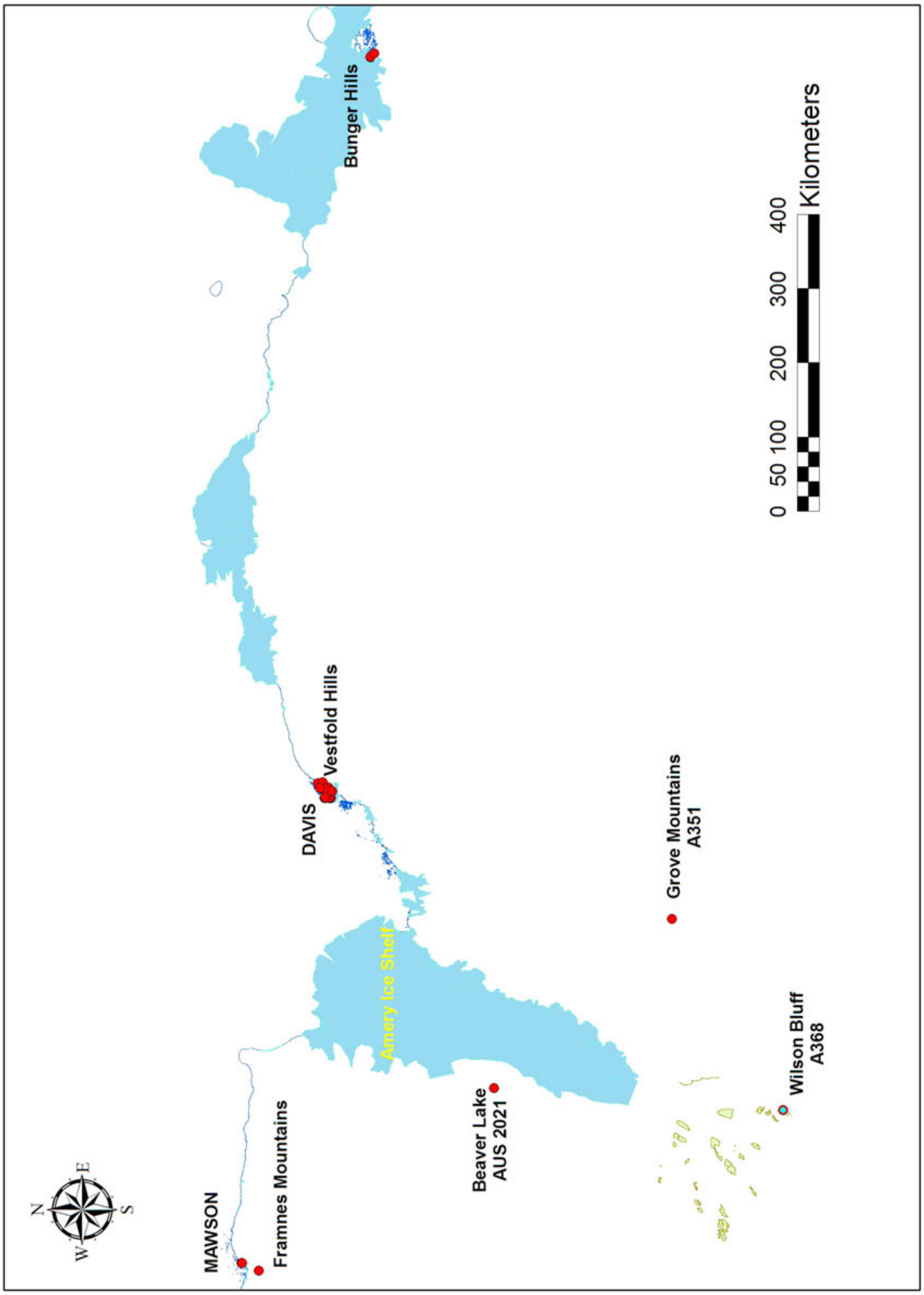


***Figure 4.2**: Locations of Antarctic GNSS campaign 2010/11*

Figure 4.3: *AUS252 being observed within the Framnes Mountains (near Fang Peak).*

5. Deep Field Campaign

Continuous monitoring of the Antarctic tectonic plate is largely facilitated by three permanent GNSS stations included to the ARGN located at the Australian Antarctic Stations of: Casey, Davis and Mawson. The data collected from these stations has been used to compute temporal movement vectors of the Antarctic continent. The sites, however, are restricted to the coast and do not reliably represent neo-tectonic motion within the continental interior (Brolsma and Corvino 2007, updated 2008). Obtaining reliable inland measurements is a difficult process given the limitations in access and the severity of weather conditions. The large proportion of Geodetic marks in inland areas has been limited to restricted epoch GPS observations acquired at a few remote AAGN and Australia National University (ANU) study sites during summer Australian National Antarctic Research Expeditions (ANARE). However, with the introduction of permanent deep field sites to the Grove Mountains, Wilson Bluff, Bunger Hills and Mt Creswell (Figure 5.1), Geoscience Australia has established a series of suitable geodetic marks that will allow for a more complete geodynamic analysis of the continental plate. The CORS observations at each site provide base level historic data from which long-term calculations of Antarctica's continental motion can be made (Brolsma and Corvino 2007, updated 2008).

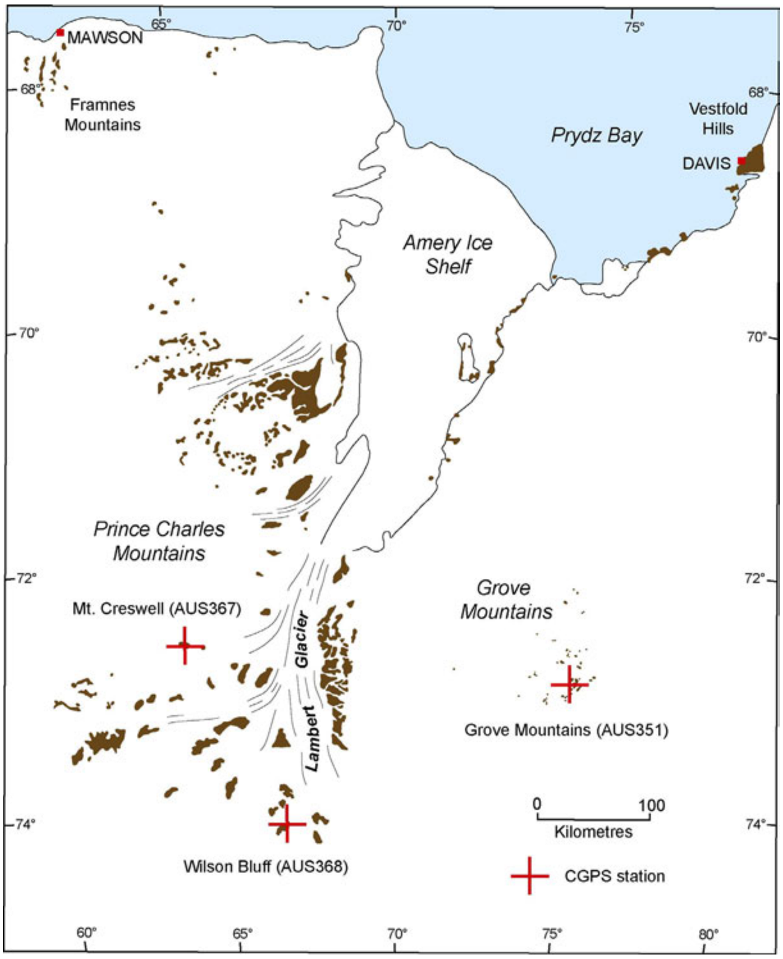


Figure 5.1: *Inland CORS operated by Geoscience Australia*

GA operates four CORS sites in remote areas of East Antarctica. The sites are located at the Grove Mountains, Wilson Bluff, Bunger Hills and Mount Creswell (Figure 5.1). The data collected at these sites is combined with the other GPS campaign data to improve precision and strengthen the geodetic network. The data from these sites also contribute to research on the physical Earth processes, such as tectonic motion and the response of the Earth's crust to ice-loading or unloading.

5.1 REMOTE SITE DESIGN

Continuous operation of GNSS sites in Antarctica is difficult, particularly in the winter months when there is little or no sunlight available for solar energy. Sites need to be well designed to withstand the strong winds and overcome the extreme cold. Previously, remote sites were powered during winter using *Air Industrial* wind turbines. These worked occasionally, but generally the wind turbines failed and were destroyed. This season sites were refurbished and installed at the Grove Mountains, Bunger Hills and Wilson Bluff with an emphasis on simplification to reduce prominent system failures which have been a common occurrence since the CORS inception.

5.1.1 Structural System

During the winter months the remote sites experience strong winds, which have at times blown over or snapped the structures that house the equipment boxes and support the solar panels. To overcome this, a new structure was designed and built by *Baxter Engineering* in Canberra 2008. The structure was designed with a stable footprint of 1.6 x 1.6m and enclosed on the windward side (south) by aluminium panels angled at 60 degrees the leeward side (north) holds three solar panels also at 60 degrees to pick up sunlight low on the horizon. The base is slightly elevated to reduce snow build-up. Mounts on either side of the structure allow for the addition of an iridium antenna or vertical axis wind turbine (5/8" spigot), however these features have been removed in the 2010/11 season due to simplification requirements. A large insulated space-case contains all other equipment, including the batteries and rests on a mesh grid within the frame (Figure 5.2). The structure weighs 55kg and contains solely 13mm nuts and bolts.

Figure 5.2: *Solar panel frame structure, as installed at the Grove Mountains (December 2009).*

5.1.2 Power System

A *Plasmatronics* PL20 regulator controls the power, provided by three 60W solar panels and a 12V 296Ahr battery bank. The regulator is programmed (Figure 5.3) to restrict the flow of power to the battery bank during the intense solar periods of the summer and monitor the batteries during the winter months, switching off the load when the voltage drops to 11.1V. The load is disconnected preserving charge in the batteries until the solar system charges the battery voltage to 12.6V. This protects the batteries from being drained completely; leaving some charge so that they can recover when there is sufficient sunlight after winter. The system is designed to support wind turbines, such as *Forgen* 500 vertical axis wind turbines, however, none were installed in the 2008/09 season and this continued into the 2010/11 season. However there is potential scope to reintroduce turbines in the near future.

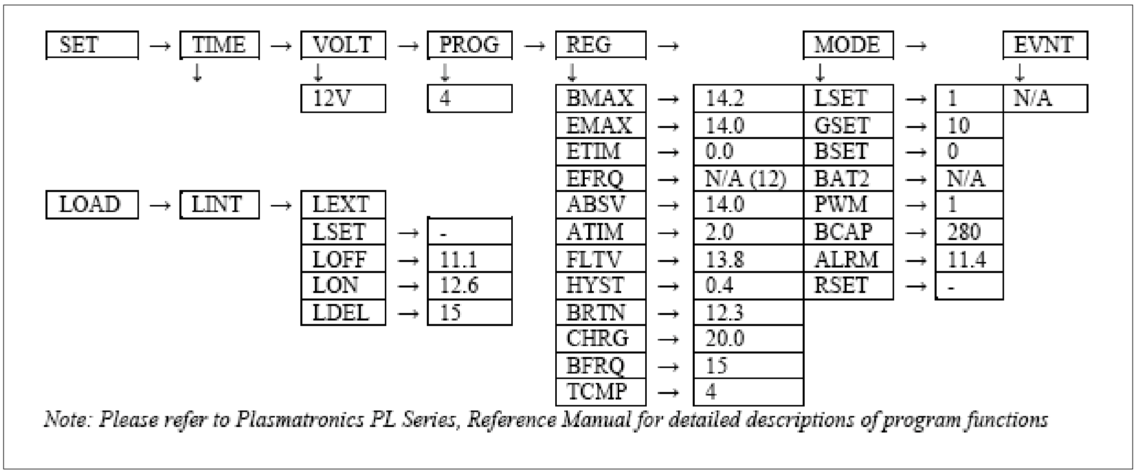


***Figure 5.3**: Configuration of Plasmatronics PL20 regulator.*

5.2 WILSON BLUFF

Wilson Bluff is located in the southern Prince Charles Mountains at the southern end of the Lambert Glacier. The survey control point AUS368 was installed in 2002/03 during the Prince Charles Mountains Expedition of Germany-Australia (PCMEGA) campaign (Johnston, Manning, Dawson et al. 2003) and in 2003/04 the CORS equipment was installed at the site. Since then the site was been visited twice in 2006/07 (Brown and Woods 2009) and 2008/09 (Ruddick, Woods and Brown 2009). In 2008/09 the wind turbine was removed and the installation simplified.

The CORS monument is located on a small rise within an undulating lateral moraine, mid-way along the northern face of Wilson Bluff (Figure 5.4). The marker is defined by the intersection of a stainless steel plate with a stainless steel 5/8" vertical spigot, anchored to an in-situ rock (Brolsma and Corvino 2007, updated 2008) via three levelling screws. The Antenna sits on a 0.0305m stainless steel shim and is orientated north. There are two additional survey control points in the vicinity; a marker (WBF0) established by the Dresden University of Technology during the PCMEGA campaign (Johnston, Manning, Dawson et al. 2003) located approximately 100 m south of AUS368, and a trigonometrical marker (NMS281) located on the eastern summit. The marker WBF0 consists of a vertical 5/8" spigot drilled into rock and acts as a reference mark for AUS368.

Figure 5.4: *The CORS at Wilson Bluff is located on a rock outcrop beside the campsite.*

5.2.1 Site Assessment

During the 2010/11 season the CORS site was visited for maintenance and data download between 11 and 13 January 2011. On arrival the system was non-operational and the batteries drained, but the solar panels and frame were in perfect condition. On further inspection it was discovered that the Plasmatronics PL20 solar regulator had failed during the 2010 winter. A new regulator was installed, along with four new batteries restoring the site to full operational capacity.

The setup now consists of a Leica GRX1200 Pro (Firmware 4.12/2.122) receiver connected to an ASH701945E_M antenna covered by an SCIS style radome by a 10 m length of RJ58 coaxial cable with a short 0.3 m extension at the receiver end (Figure 5.5). Four 12 V 74 Ahr GelTech batteries provide power to the equipment. The batteries are charged by four 3 Amp 12 V solar panels (2 x VLX53 and 2 x SX50U) connected to a Plasmatronics PL20 solar regulator, which is setup to shut down the load if the battery voltage drops below 11.5 V. A 4 Gb SanDisk Ultra II CF card is used to store the data and allows for up to 4 years of data recorded at 30-second epochs.

Figure 5.5: *a) the Wilson Bluff CORS antenna facing north, b) east, c) south, d) west, e) inside the equipment box and f) the solar panel frame.*

5.2.2 Local Monitoring Survey

There has been some doubt to the local stability of the CORS monument at Wilson Bluff (Figure 5.6), due to the environment being a moraine field. In 2004 observations were made on rock type and orientation and the monument was considered to be in-situ (Brolsma and Corvino 2007, updated 2008). To monitor the stability of the site GPS data is routinely observed on the nearby "Dresden" mark WBF0.

During the visit a local monitoring survey was undertaken using a GPS survey method. 24 hours of observations were made on WBF0. Independent baselines were formed holding the CORS (A368) fixed to its ITRF2005@2000.0 coordinates. The computed results are shown in Tables 5.1-5.3.

Table 5.1: *Final geodetic coordinates from the 2011 Wilson Bluff local monitoring survey. GRS80 ellipsoid aligned to ITRF2005 at 1 January 2000. Heights are ellipsoidal. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ	HEIGHT (M)	σ
AUS368	-74° 17' 26.0782	0.002	66° 47' 32.0358	0.002	1235.797	0.003
WBF0	-74 17 28.43685	0.002	66 47 32.62993	0.002	1240.407	0.002

Table 5.2: *Final Cartesian coordinates from the 2011 Wilson Bluff local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
AUS368	682780.468	0.002	1592449.829	0.002	-6118988.512	0.003
WBF0	682748.602	0.002	1592388.242	0.002	-6119012.754	0.002

Table 5.3: *Comparison between the previous Wilson Bluff local monitoring surveys.*

Year	AUS368 to …	Δ east	Δ north	Δ up	range
2001	WBF0	n/a	n/a	n/a	n/a
2006	WBF0	n/a	n/a	n/a	n/a
2010	WBF0	5.0181	-73.1412	4.6106	73.4580
Std Dev		0.002	0.002	0.002	0.002

Figure 5.6: *From left to right. The GPS antenna set up on WBF0 and A368.*

5.3 GROVE MOUNTAINS

The Grove Mountains are a group of mountains and nunataks in Princess Elizabeth Land, approximately 500 km southwest of Davis station and 160 km east of the Mawson escarpment. The survey control point AUS351 was installed in 2000/01 by surveyors from GA (Johnston and Digney 2001) and in 2003/04 (Brolsma and Corvino 2007, updated 2008) the CORS equipment was installed at the site. Since then the site has been visited three times in 2004/05 (Naebkhil and Moore 2005), 2006/07 (Brown and Woods 2009) and 2008/09 (Ruddick, Woods and Brown 2009). In 2008/09 the installation was simplified and a new solar panel frame was installed. There was also the intention to install a Forgen 1000 vertical bladed wind turbine, but this was damaged during transport.

The CORS monument is located on a flat ledge at the northern end of a small nunatak to the southwest of Mount Harding (Figure 5.7). The marker is defined by the intersection of a 150 mm stainless steel plate with a stainless steel 5/8" vertical spigot, anchored to bedrock via a small concrete pillar. The Antenna sits on a 0.0305m stainless steel shim and is orientated north. There are three reference marks situated in close proximity to the GPS antenna. There are also a number survey control points established by Chinese Antarctic Research Expedition (CHINARE) during their visits to the Grove Mountains.

Figure 5.7: *The CORS at the Grove Mountains is located on the nunatak behind the campsite.*

5.3.1 Site Assessment

During the 2010/11 season the CORS site was visited for maintenance and data download between 13 and 17 January 2011. On arrival the site was discovered to have malfunctioned in April 2009, shortly after being established in December 2008. The problem was attributed to the power system, the Plasmatronics PL20 regulator was showing signs of failure and one of the solar panels behaving erratically. The solar panels and frame were still upright and in perfect condition.

The setup now consists of a Leica GRX1200 Pro (Firmware 4.12/2.122) receiver connected to an ASH701945E_M antenna covered by an SCIS style radome by a 10 m length of RJ58 coaxial cable with a short 0.3 m extension at the receiver end. Four 12 V 74 Ahr GelTech batteries provide power to the equipment. The batteries are charged by four 3 Amp 12 V solar panels (2 x VLX53 and 2 x SX50U) connected to a Plasmatronics PL20 solar regulator, which is setup to shut down the load if the battery voltage drops below 11.5 V. A 4 Gb SanDisk Ultra II CF card is used to store the data and allows for up to 4 years of data recorded at 30-second epochs. Figure 5.8 shows a detailed diagram on how the setup is connected.

Figure 5.8: *a) the Grove Mountains CORS antenna facing north, b) east, c) south, d) west, e) inside the equipment box and f) the solar panel frame.*

5.3.2 Local Monitoring Survey

During the visit a local monitoring survey was undertaken using a GPS survey method. A minimum of 6 hours data were observed at each of the three local reference marks. Independent baselines were formed by holding the CORS (A351) fixed to its ITRF2005@2000.0 coordinates. The computed results are shown in Tables 5.4-5.6.

Table 5.4: *Final geodetic coordinates from the 2011 Grove Mountains local monitoring survey (AUSPOS derived). GRS80 ellipsoid aligned to ITRF2005 at 1 January 2000. Heights are ellipsoidal. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ	HEIGHT (M)	σ
AUS351	-72° 54 29.1767	0.001	74° 54 36.4296	0.001	1907.467	0.001
AUS351-RM1	-72° 54 28.6150	0.002	74° 54 35.40383	0.002	1903.810	0.003
AUS351-RM2	-72° 54 29.7726	0.002	74° 54 36.2853	0.002	1904.974	0.003
AUS351-RM3	-72° 54 29.2118	0.002	74° 54 34.7517	0.002	1903.287	0.004

Table 5.5: *Final Cartesian coordinates from the 2011 Grove Mountains local monitoring survey. GRS80 ellipsoid aligned to ITRF2005 at 1 January 2000. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
AUS351	489658.740	0.001	1816031.161	0.001	-6076059.187	0.001
AUS351-RM1	489671.8240	0.002	1816043.7600	0.002	-6076050.5730	0.003
AUS351-RM2	489655.2200	0.002	1816013.0560	0.002	-6076062.2340	0.003
AUS351-RM3	489672.9210	0.002	1816024.9850	0.002	-6076055.5120	0.004

Table 5.6: *Comparison between the previous Grove Mountains local monitoring surveys.*

Year	AUS361 to …	Δ east	Δ north	Δ up	range
2001	AUS361-RM1	n/a	n/a	n/a	n/a
2006	AUS361-RM1	n/a	n/a	n/a	n/a
2010	AUS361-RM1	-9.3529	17.4148	-3.6572	20.1029
Std Dev		0.002	0.002	0.002	0.002
2001	AUS361-RM2	n/a	n/a	n/a	n/a
2006	AUS361-RM2	n/a	n/a	n/a	n/a
2010	AUS361-RM2	-1.3147	-18.4801	-2.4946	18.6940
Std Dev		0.002	0.002	0.002	0.002
2001	AUS361-RM3	n/a	n/a	n/a	n/a
2006	AUS361-RM3	n/a	n/a	n/a	n/a
2010	AUS361-RM3	-15.2998	-1.0908	-4.1802	15.8981
Std Dev		0.002	0.002	0.002	0.002

5.4 BUNGER HILLS

Bunger Hills is a coastal range located along the Knox Coast in Wilkes Land. The AAD maintain a summer station, Edgeworth David (Figure 5.9), in the western section of the Bunger Hills consisting of 2 melon huts and 2 apple huts. The survey control point and CORS station was established in 2006/07 (Brown and Woods 2009) and collected data continuously until the 2008 winter when the receiver failed. AAD pilots visited the site in 2008/09 from Casey to remove the damaged equipment (Ruddick, Woods and Brown 2009).

The CORS monument is located on a small hill approximately 275 m southwest of the Edgeworth David camp. The marker is defined by the intersection of a stainless steel plate with a stainless steel 5/8” vertical spigot, anchored to bedrock via three levelling screws. The antenna sits on a 0.0305m stainless steel shim and is orientated north. Surrounding the marker are three reference marks, which consist of an un-levelled stainless steel spigot drilled and set into rock. There are a number of other survey control marks scattered around the western section of the Bunger Hills: NMS238 is located in-front go the Edgeworth David camp; NMS237 is located at the nearby abandoned Polish station, Drobrowolski; NMS240 is located on an island along the eastern coastline and NMS239 along the south-western edge beside the plateau.

During the 2010/11 season the CORS site was visited between 19 and 21 January 2011. Air support was provided for a return trip out of Davis station using the Twin Otter aircraft. The sea ice beside Edgeworth David camp provides a relatively safe landing spot with plenty of fuel.

Figure 5.9: *The CORS at the Bunger Hills is located on a hill next to the Edgeworth David camp.*

5.4.1 Site Assessment

The majority of equipment was removed during the 2008/09 season, only the solar panel frame, two solar panels and antenna remained. The solar panels were replaced, due to corrosion on the cables, and an additional two panels added. A new insulated equipment box was installed along with the original (repaired) Leica GRX1200 Pro receiver, Plasmatronics PL20 regulator, 4 GelTech 12 V 74 Ahr batteries and a new 10 m antenna cable. The new site is an identical setup to those at the Grove Mountains and Wilson Bluff.

The setup now consists of a Leica GRX1200 Pro (Firmware 4.12/2.122) receiver connected to an LEIAT504 antenna covered by an SCIS style radome by a 10 m length of RJ58 coaxial cable with a short 0.3 m extension at the receiver end. Four 12 V 74 Ahr GelTech batteries provide power to the equipment. The batteries are charged by four 3 Amp 12 V solar panels (4 x SX50U) connected to a Plasmatronics PL20 solar regulator, which is setup to shut down the load if the battery voltage drops below 11.5 V. A 4 Gb SanDisk Ultra II CF card is used to store the data and allows for up to 4 years of data recorded at 30-second epochs. Photographs of the station are shown in Figure 5.10.

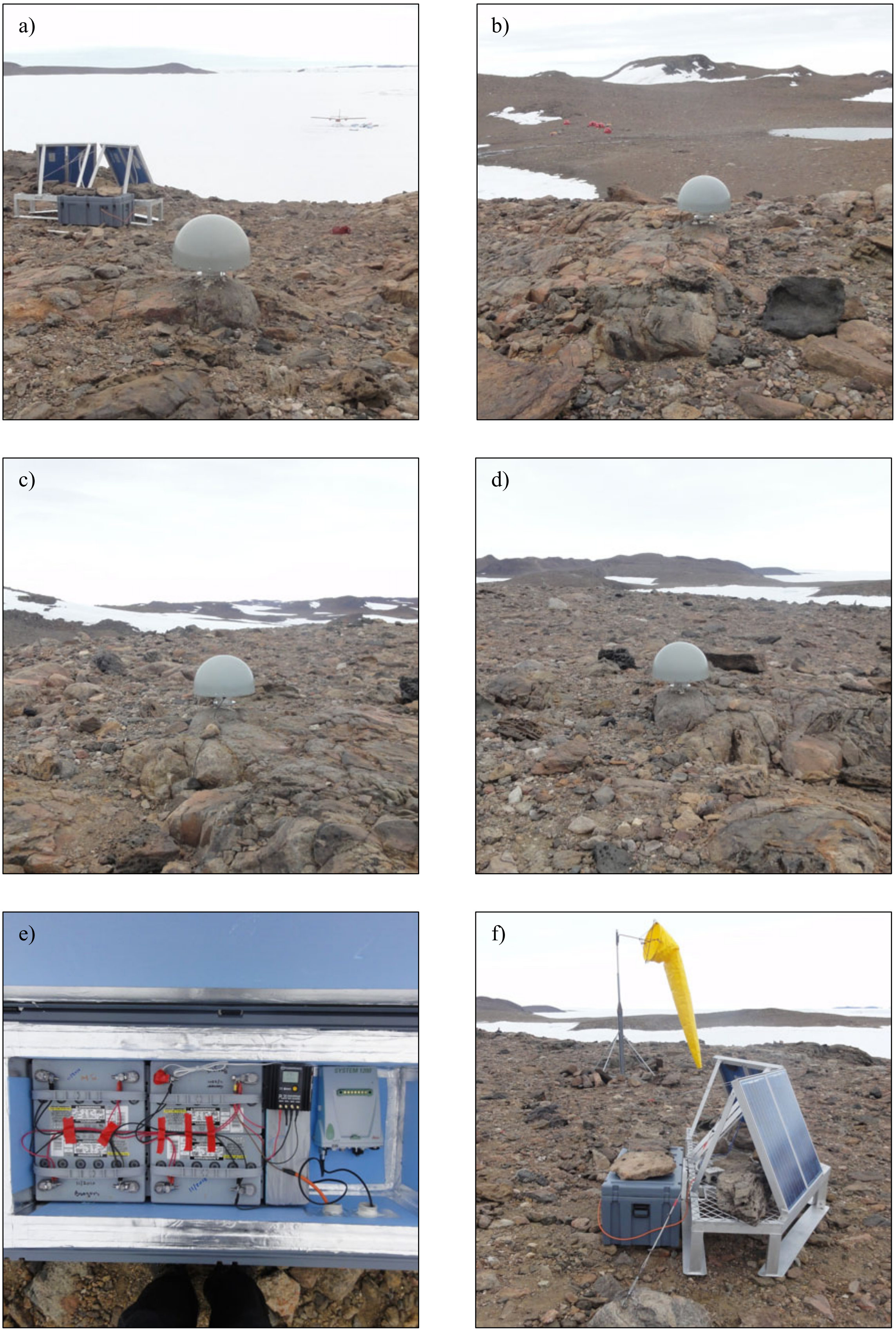


Figure 5.10: *a) the Bunger Hills CORS antenna facing north, b) east, c) south, d) west, e) inside the equipment box and f) the solar panel frame.*

5.4.2 Local Monitoring Survey

Despite reference marks being installed a local monitoring survey has never been conducted at the CORS site. During this visit GPS data were recorded for a minimum of 6 hours at each of the three reference marks in turn and in conjunction with data being recorded at the CORS site. Due to the reference mark spigots not being level a tribrach was used mount the antenna. The computed results are shown in Tables 5.7-5.9.

Table 5.7: *Final geodetic coordinates from the 2011 Bunger Hills local monitoring survey (AUSPOS derived). GRS80 ellipsoid aligned to ITRF2005 at 1 January 2000. Heights are ellipsoidal. Final estimates of precision are shown as 1σ in mm.*

SITE	LATITUDE	σ	LONGITUDE	σ	HEIGHT (M)	σ
BHIL	-66 15 04.924	0.002	100 35 54.8904	0.002	18.006	0.003
BHIL-RM1	-66 15 04.69433	0.002	100 35 55.1637	0.002	17.150	0.003
BHIL-RM2	-66 15 05.44149	0.002	100 35 55.4130	0.002	17.933	0.003
BHIL-RM3	n/a		n/a		n/a	

Table 5.8: *Final Cartesian coordinates from the 2011 Bunger Hills local monitoring survey. GRS80 ellipsoid aligned to ITRF2000 at 1 January 2000. Final estimates of precision are shown as 1σ in mm.*

SITE	X	σ	Y	σ	Z	σ
BHIL	-473772.994	0.002	2531930.486	0.002	-5815308.594	0.003
BHIL-RM1	-473777.484	0.002	2531935.920	0.002	-5815304.945	0.003
BHIL-RM2	-473776.705	0.002	2531914.835	0.002	-5815314.982	0.003
BHIL-RM3	n/a		n/a		n/a	

Table 5.9: *Comparison between the previous Bunger Hills local monitoring surveys.*

Year	BHIL to …	Δ east	Δ north	Δ up	range
2001	BHIL-RM1	n/a	n/a	n/a	n/a
2006	BHIL-RM1	n/a	n/a	n/a	n/a
2010	BHIL-RM1	3.4139	7.1144	-0.8564	7.9375
Std Dev		0.002	0.002	0.002	0.002
2009	BHIL-RM2	n/a	n/a	n/a	n/a
2004	BHIL-RM2	n/a	n/a	n/a	n/a
2002	BHIL-RM2	6.5263	-16.0291	-0.0736	17.3070
Std Dev		0.002	0.002	0.002	0.002
2009	BHIL-RM3	n/a	n/a	n/a	n/a
2004	BHIL-RM3	n/a	n/a	n/a	n/a
2002	BHIL-RM3	n/a	n/a	n/a	n/a
Std Dev		0.002	0.002	0.002	0.002

5.5 MT CRESWELL

Figures 5.11: *Mt Creswell as approached from the North via helicopter. The site is located approximately 100m from a large rock cairn near the shear cliff in the centre south region of the mountain.*

The Mt Creswell CORS station was initially established at site AUS367 (Latitude: 72° 44' 13.0273" S, Longitude: 64° 15' 03.567" E) on the 17th of December 2003 as part of the PCMEGA campaign (Figure 5.11). The GPS monument is a stainless steel plate, with 5/8" spigot, drilled into an outcropping granite dyke 100m north of the survey cairn on the top of Mt. Creswell (Figure 5.12).

Mt. Creswell is known to be notorious for its incessant katabatic winds and blowing snowdrift which make operations at the site substantially difficult and leaves equipment susceptible to damage. Accordingly the original apparatus was aligned roughly east-west along the trend of the outcrop to counter the prevailing southerly winds (Figure 5.12). This was to prevent any one piece of equipment from being buried by snowdrift accumulating in the lee of another. The wind turbine was located 10m to the west of the GPS antenna and away from any turbulence generated by the other equipment.

5.5.1 Site Assessment

The site was revisited on the 9th of February 2011 to retrieve data and possibly dismantle according to a condition report. The mission was tasked as a day trip (approximately 12 hours) out of Davis via two Squirrel Helicopters taking advantage of fuel dumps at Fisher Massif, Beaver Lake and Samson Island. Unfortunately, upon arrival at the Mt. Creswell location the site was found to be severely damaged and the majority of equipment lost to the frequent blizzards encountered in the area. A helicopter reconnaissance around the immediate area was unable to locate any further parts to the setup.

The solar panel frame, antenna cable, GPS receiver, and computer were unable to be located. The battery box was still on site, but badly damaged due to exploding batteries. The wind turbine frame was still standing, however this was somewhat damaged and non functional due to damage on the turbine blades.

The GPS monument itself, including 1 × Ashtech choke ring GPS antenna (model 701945-02E with dome) was in good repair and salvageable. Thus it was decided to remove the installation from the survey monument (including 30.5mm shim). Figure 5.12 illustrates the remaining setup of the monument itself, the shim was only partially removed due to severe cold bonding the metal together.

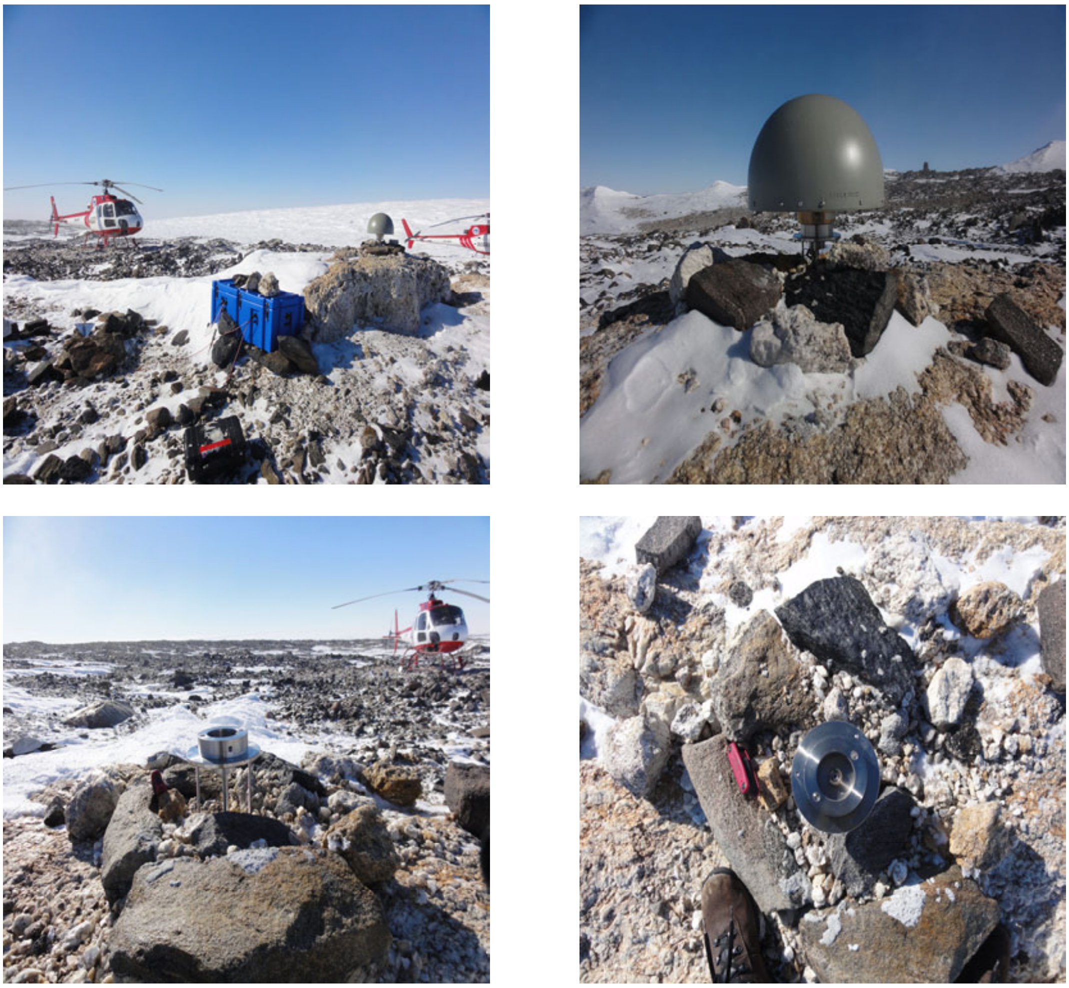


Figure 5.12: *Deconstruction of the Mt Creswell CORS. Note Shim was only partially removed due to extreme cold.*

6. Lake Levelling

In support of the long running AAD lake levelling program relative height differences were measured between water levels and nearby benchmarks of 25 lakes scattered throughout the Vestfold Hills (Figure 6.1). Two-way level runs were undertaken at each lake to determine the height difference using a Topcon Digital Level and calibrated bar-code staff. The lakes were visited with helicopter support during January and February 2011. The average temperatures during the 2010/11 summer have been colder than usual; as a result a number of the lakes surveyed still had significant coverage of ice on the surface which could have biased the results. The lake levels are shown in Table 6.2 and compared with the values from the 2007 and 2009 surveys. Compared with the previous two surveys the majority of lakes are showing a decrease in the water level. The average change across all lakes compared with the 2009 survey was -0.116 m. The largest decrease was at Watts Lake (-0.532m), while only two lakes, Lake Pauk and Lake Zvebda showed increases. These lakes are the closet to the plateau and would be most affected by melt water run-off; Lake Pauk was also mostly frozen during the survey. During the survey readings were also made where applicable to permanent level staffs.

The level at Deep Lake has been observed every month since the 1970's. The level is read using a graduated staff situated in a bay at the north-western corner of the lake (Figure 6.1). To verify the calibration of the staff the level was read at the same time as the height difference from the benchmark, NMV/S/8 was calculated (Table 6.1). The stave has 10 mm graduations, hence the levels are generally observed to the nearest 5 mm. Table 6.1 shows the comparison of the calibration values for the 2011 survey with those of 2007 and 2009. During this time the staff does not appear to have moved locally and remains calibrated,

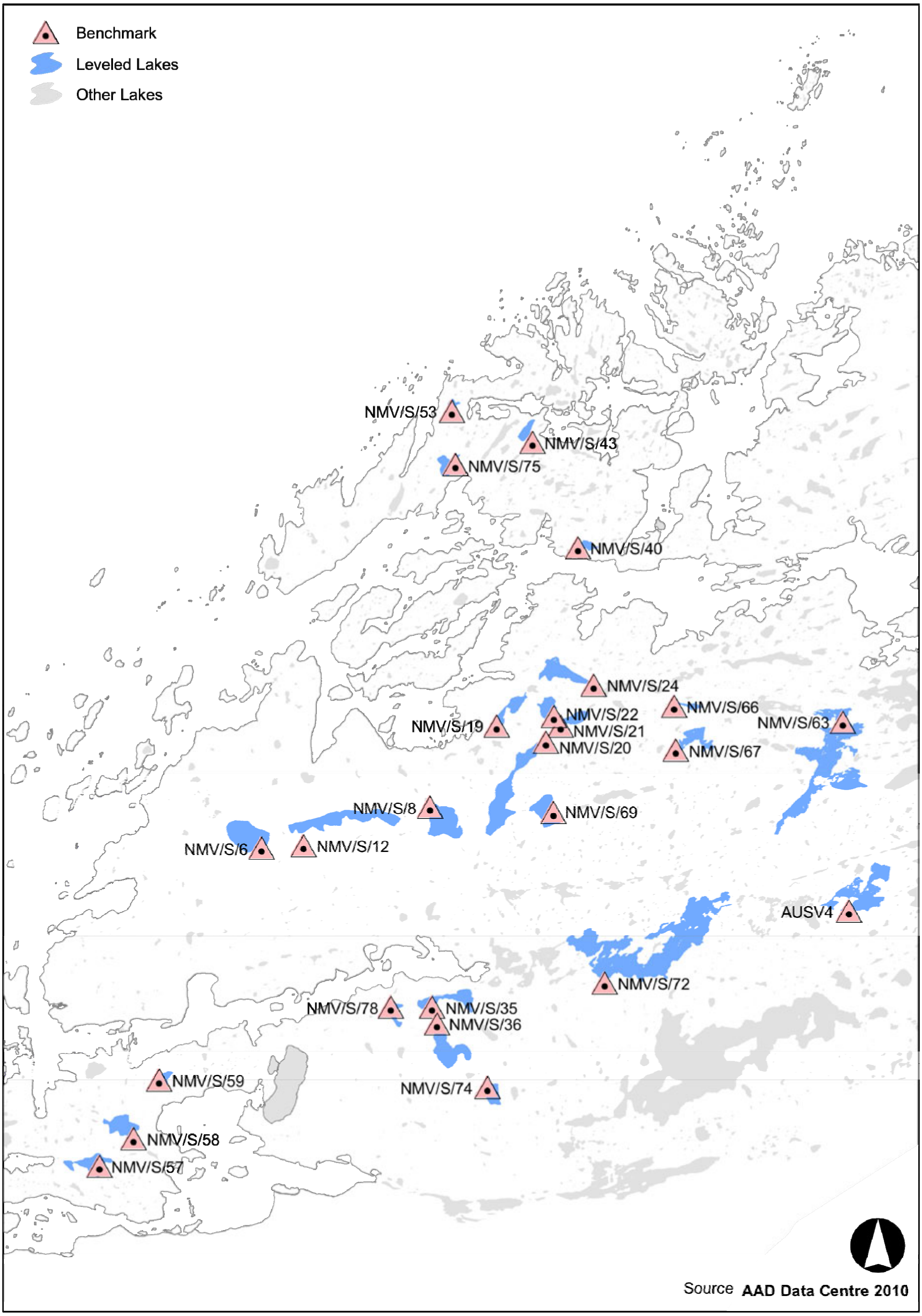
Table 6.1: *Level staff calibration value at Deep Lake for 2007, 2009 and 2011. Units are in metres.*

LAKE NAME	BENCHMARK	DATE	LAKE LEVEL	STAFF LEVEL	DIFFERENCE
Deep Lake	NMV/S/8	1-Mar-07	-0.925	0.730	-1.655
Deep Lake	NMV/S/8	9-Feb-09	-1.104	0.548	-1.652
Deep Lake	NMV/S/8	25-Nov-10	-1.242	0.415	-1.657
Deep Lake	NMV/S/8	29-Jan-11	-1.235	0.425	-1.660

Figures 6.1: *a) level staff at Deep Lake, b) calculating the height difference between the benchmark and lake level at Pendant Lake.*

Table 6.2: *Vestfold Hills Lake levelling results. Benchmark heights are given with respect to Davis MSL 1983. Units are in metres.*

			LAKE LEVELS					
LAKE NAME	**BENCHMARK**	**BM HEIGHT**	**2007**	**DATE**	**2009**	**DATE**	**2011**	**DATE**
Ace Lake	NMVS75	10.817	-1.719	2-Mar-07	-1.784	2-Feb-09	-1.817	28-Jan-11
Clear Lake	NMVS58	-4.838	-3.660	2-Mar-07	-3.828	15-Feb-09	-3.952	24-Jan-11
Club Lake	NMVS20	-34.305	-3.659	1-Mar-07	-3.813	10-Feb-09	-3.914	29-Jan-11
Deep Lake NW	NMVS8	-49.656	-0.925	1-Mar-07	-1.104	9-Feb-09	-1.235	15-Feb-11
Ekho Lake	NMVS24	0.423	-2.035	1-Mar-07	-2.212	10-Feb-09	-2.285	29-Jan-11
Lake Abraxas	NMVS40	16.970	-4.282	2-Mar-07	-4.522	3-Feb-09	-4.605	28-Jan-11
Lake Anderson	NMVS78	6.078	-2.679	2-Mar-07	-2.853	17-Feb-09	-2.940	2-Feb-11
Lake Braunsteffer	NMVS67	36.595	-2.229	3-Mar-07	-2.385	11-Feb-09	-2.462	3-Feb-11
Lake Dingle	NMVS06	3.765	-13.093	1-Mar-07	-13.218	9-Feb-09	-13.405	15-Feb-11
Lake Druzhby	NMVS72	9.755	-1.814	3-Mar-07	-1.596	18-Feb-09	-1.718	24-Jan-11
Lake Jabs	NMVS69	-34.087	-3.087	1-Mar-07	-3.105	10-Feb-09	-3.262	3-Feb-11
Lake McCallum	NMVS59	1.664	-3.646	2-Mar-07	-3.795	15-Feb-09	-3.867	24-Jan-11
Lake McNeil	NMVS66	30.083	-3.546	1-Mar-07	-3.959	11-Feb-09	-4.018	29-Jan-11
Lake Stinear SW	NMVS15	2.654	-16.705	1-Mar-07	-16.881	9-Feb-09	-16.991	15-Feb-11
Lake Zvezda	NMVS63	17.150	-1.270	3-Mar-07	-1.265	15-Feb-09	-1.234	3-Feb-11
Laternula Lake	NMVS57	2.755					-5.223	24-Jan-11
Lebed' Lake	NMVS36	16.791	-3.519	2-Mar-07	-3.627	17-Feb-09	-3.757	2-Feb-11
Oblong Lake	NMVS74	-1.196	-2.313	2-Mar-07	-2.355	18-Feb-09	-2.608	2-Feb-11
Organic Lake	NMVS53	5.761	-3.928	2-Mar-07	-3.842	2-Feb-09	-3.996	28-Jan-11
Oval Lake	NMVS21	-26.106	-2.756	1-Mar-07	-2.944	10-Feb-09	-3.115	29-Jan-11
Pauk Lake	AUSV4	N/A	-3.746	3-Mar-07	-3.581	15-Feb-09	-3.529	24-Jan-11
Pendant Lake	NMVS43	5.792	-2.689	2-Mar-07	-2.637	2-Feb-09	-2.673	28-Jan-11
Shield Lake	NMVS22	-4.374	-2.865	1-Mar-07	-3.001	10-Feb-09	-3.053	29-Jan-11
Triple Lake	NMVS19	-8.142					-4.285	29-Jan-11
Watts Lake	NMVS35	4.395	-10.547	2-Mar-07	-10.808	17-Feb-09	-11.340	2-Feb-11



Figures 6.2: *Lakes that were levelled in the Vestfold hills*

7. Australian Antarctic Division Projects

7.1 DAVIS STATION

Geoscience Australia maintains high order survey control network throughout Davis station. This control set was most recently comprehensively surveyed (both horizontally and vertically) during the 2008/09 season to provide latest accurate ITRF coordinates. This was supported by linking terrestrial surveys to the reference mark survey of the ARGN Davis site (AUS099).

Additional GNSS surveys have also been carried out on various marks around station and integrated with terrestrial survey data. During 2010/11 several days of GPS data was collected over four days to complement previous GNSS data over other station control points. The derived ITRF coordinates from the GNSS surveys have subsequently been adjusted alongside the terrestrial data to produce a best fit survey network. Final coordinates have been provided to the AAD mapping group to upgrade records of station spatial infrastructure

Height has been established via the precise levelling tasks performed early season and aligned to MSL values.

7.1.1 Detail and Engineering Surveys

Engineering surveys were conducted on a number of areas around station during the 10/11 season. This included the wharf, water tank holding area, mechanics workshop, new field store, new living quarters, Australian Geological Survey Office (AGSO) building (pineapple) and pumphouse foundations. The purposes of these surveys was to provide the onsite construction/plant manager (Mark Pekin) with appropriate information for the shift of a number of plant and building facilities and to also provide up to date mapping information for the update of AAD records.

Detail and construction was enabled via the Davis Station Survey control network re-established this season (Figure 7.1). Control was derived from the ITRF2000 coordinate values from the 2008/09 Antarctic Geodesy Report. UTM values (Zone 43) where derived from Redfern's formula via the Geoscience Australia Geodesy Calculation homepage:
http://www.ga.gov.au/earth-monitoring/geodesy/geodetic-techniques/calculation-methods.html
Corresponding values are listed in Table 7.1 and Table 7.2.

Table 7.1: *ITRF 2000 @ 2000 Coordinates for Davis Station Control network.*

Mark	Latitude	Longitude	E. Height	MSL
AUS099	-68° 34' 38.36207"	77° 58' 21.40903"	44.4160	27.8629
RM1	-68° 34' 36.94421"	77° 58' 21.69995"	42.0891	25.5358
RM2	-68° 34' 38.69743"	77° 58' 22.27437"	43.9720	27.4187
RM3	-68° 34' 38.63382"	77° 58' 21.17215"	43.4683	26.9150
D16	-68° 34' 34.59611"	77° 58' 24.26627"	40.0034	23.4501
D3	-68° 34' 32.54282"	77° 58' 15.07076"	39.6331	23.0798
D4B	-68° 34' 29.25151"	77° 58' 11.28110"	35.0815	18.5282
AUS303	-68° 34' 24.64743"	77° 58' 06.16749"	32.0475	15.4943
D5	-68° 34' 30.59139"	77° 58' 06.56102"	36.4687	19.9154
D9	-68° 34' 34.43692"	77° 57' 59.12868"	31.5934	15.0400
CON18	-68° 34' 38.95082"	77° 58' 00.74882"	32.1806	15.6272
D2	-68° 34' 35.56651"	77° 58' 11.06226"	40.3710	23.8177

Table 7.2: *UTM Zone 43 Coordinates for Control used in Engineering surveys.*

Survey Mark	Easting	Northing	Height
D9	620880.859	2389974.814	31.5934
CON18	620892.447	2389834.264	32.1806
D2	621014.162	2389933.348	40.3710
D3	621064.025	2390024.715	39.6331
RM3	621123.935	2389832.916	43.4683
RM2	621136.308	2389830.345	43.9720
D4B	621026.074	2390128.623	35.0815

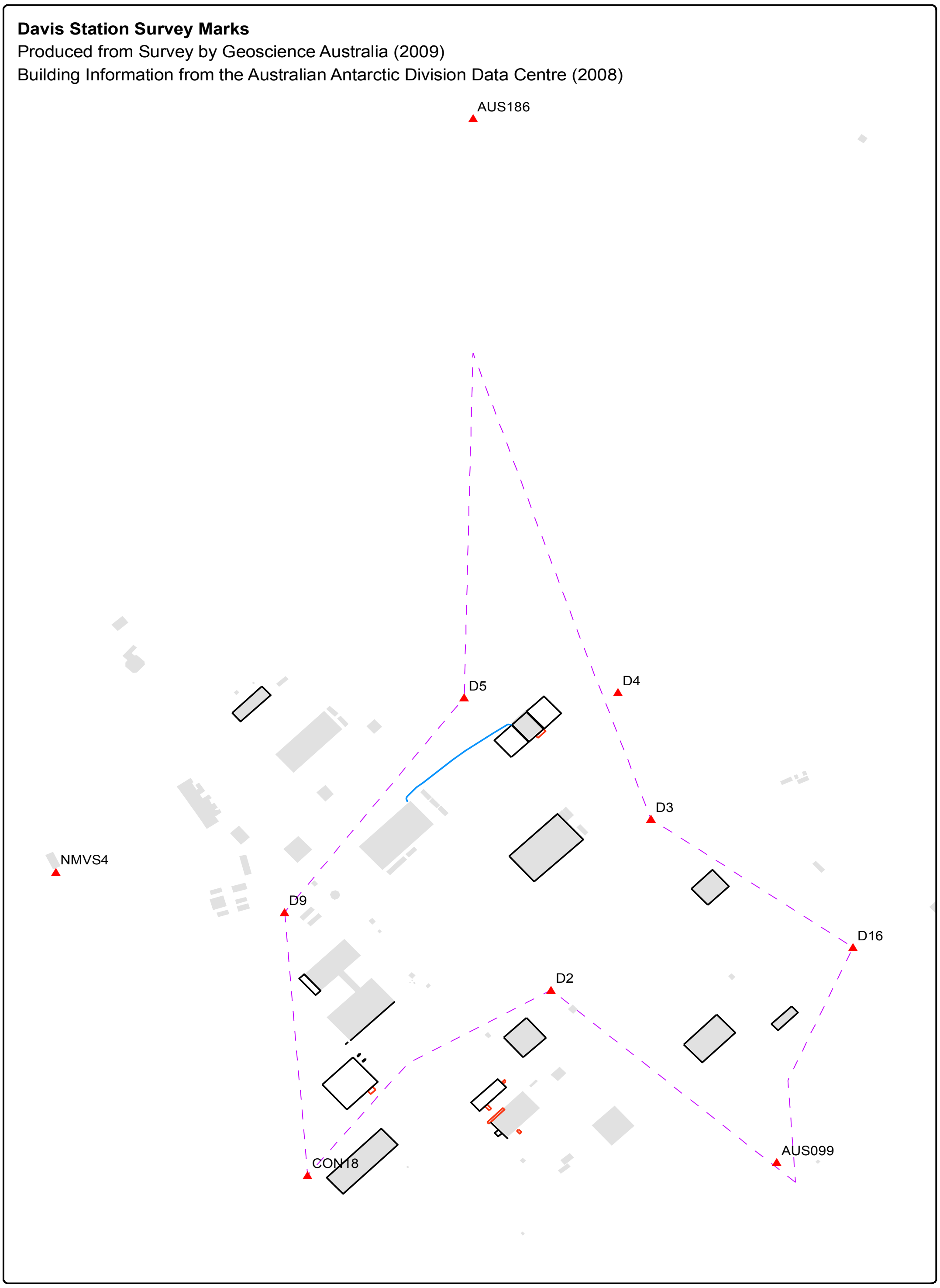


Figure 7.1: *Davis Control network diagram 2010.*

7.1.2 'Pineapple' Foundations

Works relating to the movement of the 'Pineapple' or new AGSO supply building included the location of underground service pipes within a trench from the EVS shed (Figure 7.2a). The foundation blocks of the pineapple were also surveyed. Each circular concrete block was (615mm diameter) and embedded into the crushed rock below (Figure 7.2b)

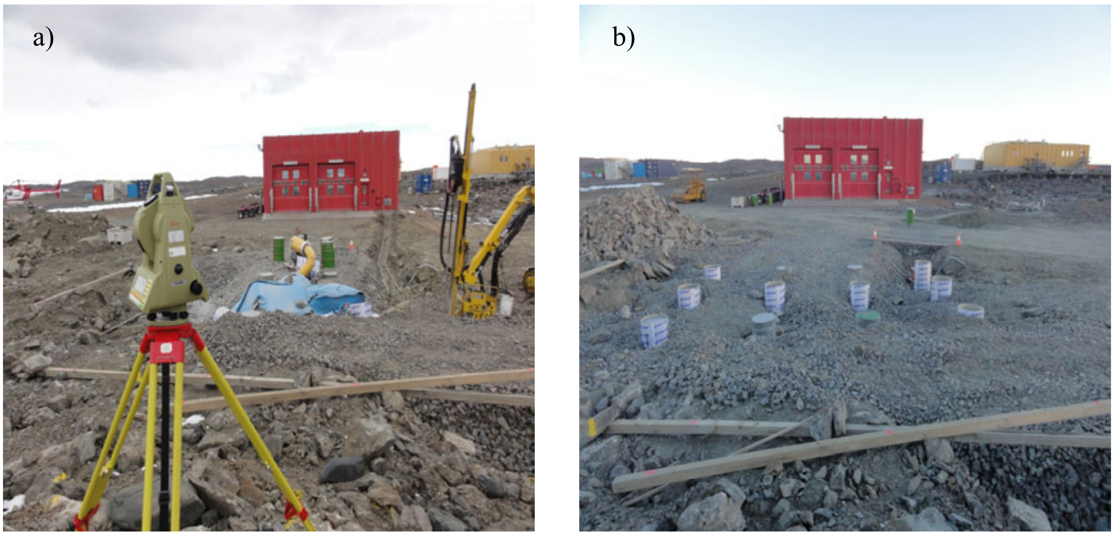


Figure 7.2: *a) underground Service Pipes running from EVS and b) foundation pillars*

This survey also located the horizontal and vertical position of the recently installed gravity mark within the EVS shed (installed 2008/09).

7.1.3 Water Tank Holding Area

A topographical survey was completed to ascertain the size and grade of the area immediately adjacent to the existing water tanks and between the running pipes, TAD and Hothouse.

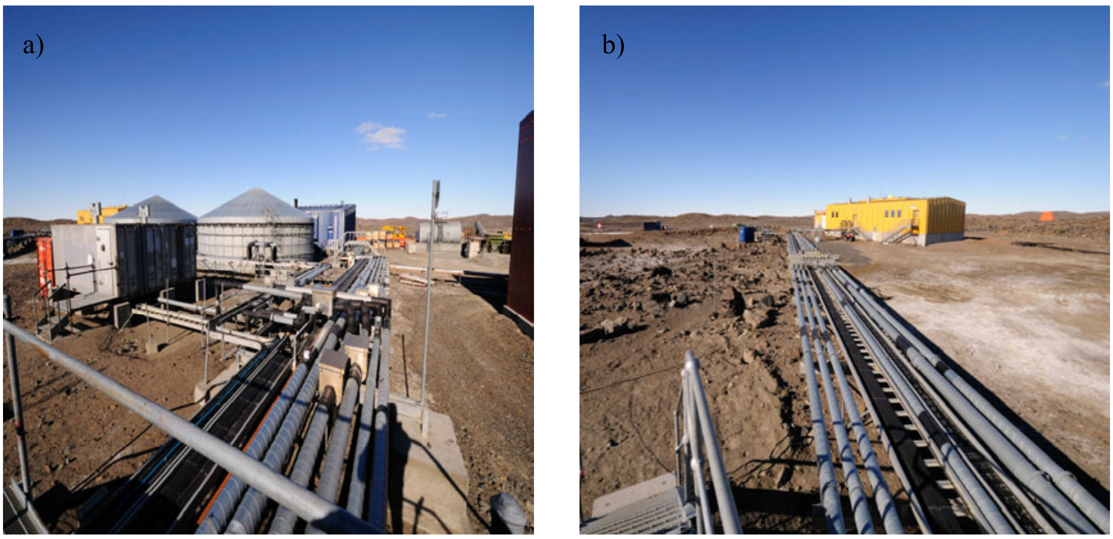


Figure 7.3: *Back view of Water Holding Tanks*

Plans were drawn up with 0.1m contours to indicate grade. Water tanks had an approximate diameter of 17m (Figure 7.3).

7.1.4 Wharf and Boat Ramp

Detail and topography around the existing boat ramp and concrete foundations was surveyed to determine the possibility of extending the existing structure. 0.25m contours where provided in a topographic plan of the area.

7.1.5 Pumphouse Extension and Foundations

Works on the pumphouse extension foundations were surveyed (Figure 7.4). At the time of survey, concrete base blocks had been laid, their relevant size (820mm) and level have been indicated on the reduced survey data.

Figure 7.4: *Pumphouse extension foundations*

7.1.6 New Living Quarters

The new Living Quarters (LQ) has been an ongoing project and was still under construction at the end of summer (Figure 7.5). The walkway connecting new LQ to old LQ had been completed along with the entirety of the building outside structure (including veranda). These features have all been surveyed along with independent floor levels (3 x floor levels).

Figure 7.5: *New Living Quarters as of 20/2/2011*

7.1.7 Workshop Extension

Detail and topography were surveyed in the area adjacent to existing mechanics workshop for the possibility of extension.

7.1.8 New Field Store

The foundations for the new field store had just been completed at the time of survey and work was being performed on construction of the building (Figure 7.6).

All surveys have been reduced using ITRF 2000 coordinates and plans drawn up in *.dwg format. The onsite construction manager received completed copies of plans.

7.2 MAWSON STATION

As part of the regular station updates for the AAD a detail survey was completed on the 22nd of December to incorporate new building works amongst the greater station area.

The location of several small buildings was updated from initial estimates provided on the previous station detail map (2008/09). These buildings included the Field Store, Riggers Hut, Service Huts and Emergency Food supplies container (Figure 7.6 and Figure 7.7).

Horizontal control was established via a minimally constrained adjusted network using the AUS64 reference marks (RM2 and RM3). Subsequent heights were derived from the levelling activities associated with the tide gauge levelling. ISTS51 and ISTS_RM2 were used as primary control with ITRF2000 coordinates transformed to WGS84 (UTM41) for alignment with existing detail plans. The heights are reduced levels determined with respect to the MSL of ISTS051 (9.792m). The computed results are listed in Table 7.3 and Table 7.4.

Table 7.3: *Geocentric Cartesian coordinates (ITRF 2000) for Mawson Horizontal Control.*

Name	X	Y	Z
RM2	1111262.367	2168911.568	-5874497.628
RM3	1111308.469	2168919.068	-5874483.008
NAIL	1111309.710	2169164.386	-5874375.965
AUS251	1111200.924	2169135.801	-5874411.991
ISTS51	1111342.232	2169267.329	-5874328.166
ISTS51_RM2	1111326.035	2169272.004	-5874331.541

Table 7.4: *UTM zone 41 coordinates for Mawson Horizontal Control.*

Name	East	North	Reduced Level
RM2	494525.467	2501182.223	31.9548
RM3	494487.807	2501213.310	28.9902
NAIL	494598.016	2501456.609	13.4241
AUS251	494681.937	2501373.706	18.1391
ISTS51	494615.763	2501573.229	9.7920
ISTS51_RM2	494632.313	2501568.998	11.6835

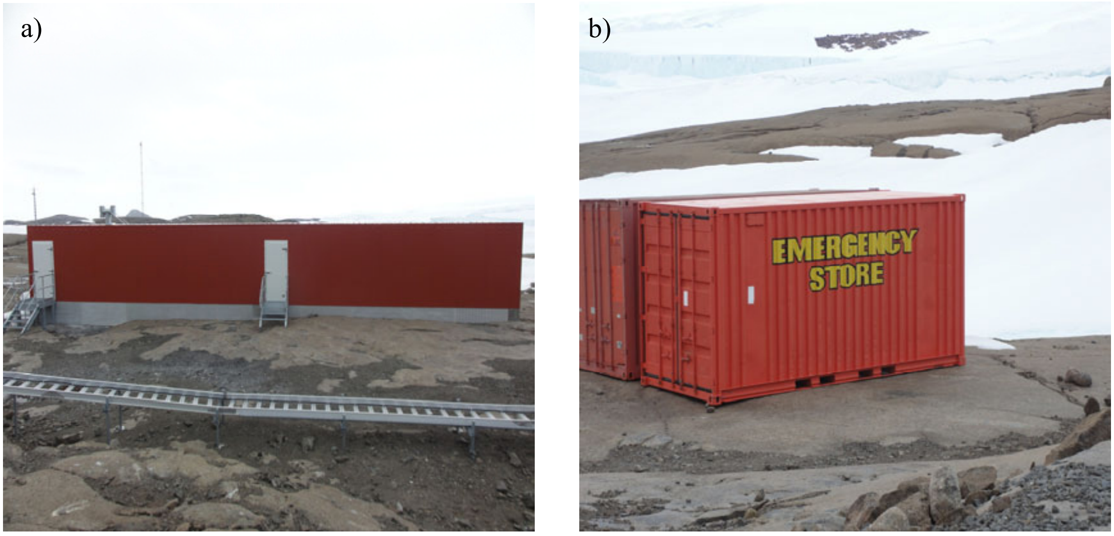


Figure 7.6: *a) Field store and b) Emergency store container.*


Figure 7.7: *Site Service huts located near water holding tanks.*

Further to the detail works a small construction set-out was performed to align a new antenna associated with the physics department to true north. The antenna is located on the lower escarpment underneath the meteorological building and is due for construction in 2011/12. The set out located 9 anchor points rotated around a centre aligned to true magnetic north. This was performed on the 24th of December 2010.

Control used in this layout was again the ISTS marks located opposite the meteorological building. Control also incorporated the horizontal alignment to the Beche' island trig mark for further reference.

7.3 SUPPORT TO OTHER PROGRAMS

As well as supporting the AAD in numerous infrastructure and engineering tasks, GA has been able to lend spatial support to a number of independently tasked scientific programs. This is an important facet and key objective of both the ongoing GA project and also the agencies commitment to GIANT. It is envisioned that the geodetic infrastructure already established within the AAT will further compliment future programs.

During the 2010/11 season support was provided to Jan Lisser and Kym Newberry of the University of Tasmania (UTAS) within their sea ice measurement research project. The use of high rate (1 second) data from permanent geodetic installations to supply kinematic positioning was essential to the success of the project. Further spatial support was supplied via the GA survey team with a high order survey conducted to the outfit of instruments to the support helicopter.

High rate GNSS data at Casey was also used to aid in the calibration of the new series Cryosat Earth Monitoring Satellites. Data from the Casey CORS site was tasked to obtain precise static positioning of essential ground truthing on specific Cryosat passes.

GNSS data from field campaigns and permanent installations has been routinely distributed to a number of projects, including Newcastle University, UK, with which analysis on the contemporary motion of the Antarctic plate has been performed. Matt King from Newcastle University has acknowledged the use of GA's geodetic infrastructure on his recent Antarctic GPS velocity field paper which is due for release in July 2011.

8. Recommendations

Under the 2011/12 – 2020/21 AAD strategic plan the role of Geodesy has a large ongoing contribution. Specifically, Geodesy features amongst three out of the four identified feature groups of the plan, including Climate processes and Change, Continental Ecosystems and Frontier Science, where it can feature in both primary and support roles.

Continuation of the program will aim to extend established geodetic infrastructure and also improve the continuity and quality of existing fundamental sites and the integration of their data sets amongst the greater scientific community. These continual refinements have flow on benefits including the support of numerous scientific projects requiring precise spatial support and of course improving our continual understanding of crustal deformation throughout the continent.

GA's involvement within SCAR and more specifically GIANT has also been a focus for a long time and it is envisioned that this will continue into the next decade. The challenge of the program is to incorporate a key set of objectives that can be met by the contributing parties. The 2011 GIANT meeting will focus on addressing a simplified program with a key aim to be able to deliver data portals to all freely available data, making this accessible to the greater SCAR community.

8.1 MODERNISATION

GNSS modernisation of CORS sites is an objective being met through the installation of GNSS receivers capable of tracking the new Galileo satellites recently launched by the European space agency. In the coming years it is envisioned that all permanent installations will have full GNSS capabilities which will hopefully translate into an improvement in position resolution.

With communications technologies also improving, permanent installations will always remain a target for improvement. The current setups have been trialled successfully over a number of years, however it is envisioned that further safeguards can be introduced into the system to reduce network outages and lost or delayed data.

8.2 NETWORK DENSIFICATION

Future expeditions will aim to establish further CORS installations to densify the high order network and enhance understanding of Antarctic geodynamics. A possibility remains in 2011/12 to establish a Commonwealth Bay site, dependant on available budget.

With a focus on improving the quality of observations within the AAGN, a key component of future GNSS campaigns will focus on the areas of the West Prince Charles Mountains. The area, West of Beaver Lake, has not been accessed for a number of years, but contains many Australian National Mapping Geodetic marks that have been originally observed via traditional methods and thus are key candidates for GNSS observations (and improved position resolution). Such campaigns would act to significantly strengthen the precision and accuracy of the overall AAGN adjustment which is heavily weighted in the immediate Davis/Vestfold hills area and Southern PCM's. Access and Logistics to these areas is the main deterrent, although there has been an effort made in recent years to improve the Traverse capabilities of the AAD. With Helicopter and Fixed win support continuing, GA may have the opportunity to access these areas in upcoming campaigns.

8.3 NETWORK PROCESSING

The collation and adjustment of the existing AAGN is also a focus of the program, with results to be incorporated amongst the NGRS project and recently updated database. There has been a distinct transition of data from original adjustment package Newgan to Dynanet over the past 4 years. It is an aim to continue the process of data formatting and adjustment within the Dynanet package and regularly produce updated results related to latest ITRF datum.

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