GOVERNMENT OF SAMOA

SAMOA SECOND INFRASTRUCTURE AND ASSET MANAGEMENT PROJECT (SIAM II)

COMPONENT 5.01: LAND ADMINISTRATION & SURVEY

SAMOAN GEODETIC NETWORK
INITIAL REVIEW &
OPTIONS for UPGRADE

TECHNICAL ASSISTANCE REPORT NO. 6

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2.1	7 June 05	Final report submitted to MNREM.	A Dyson

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ABBREVIATIONS & ACRONYMS

AusAID	Australian Agency for International Development
AUSLIG	Australian Surveying and Land Information Group
BM	Bench Mark
CGPS	Continuous Global Positioning System
GoS	Government of Samoa
GPS	Global Positioning System
ITRF	International Terrestrial Reference Framework
LIC	Land Information Centre, New South Wales, Australia
LPI	Land & Property Information Division, New South Wales Department of Lands
MNREM	Ministry of Natural Resources, Environment & Meteorology
MSL	Mean Sea Level
MWTI	Ministry of Works, Transport and Infrastructure
NTF	National Tidal Facility (Australia)
PCGIAP	Permanent Committee on GIS Infrastructure for Asia and the Pacific Region
SGRS	Samoan Geodetic Reference System
SIAM-2	Second Infrastructure Asset Management Project
SIG	Samoa Integrated Grid (formerly WSIG)
SLC	Samoa Land Corporation
SPSLCMP	South Pacific Sea Level & Climate Monitoring Project
UTM	Universal Transverse Mercator
WGS 72	World Geodetic System 1972
WGS 84	World Geodetic System 1984
WSIG	Western Samoa Integrated Grid

1. INTRODUCTION

1.1 Summary

This report has been prepared as part of the Government of Samoa (GoS) Second Infrastructure Asset Management Program (SIAM-2), Component 5.01 - Sustainable Management, Land Administration and Survey (the Project).

Within the project, Component 1 – Survey & Geographic Information will provide Samoa with a survey and geographic information system which supports the management of the environment, national emergencies and sustainable management of land and natural resources.

The Geodetic Survey sub-component will provide a single strengthened and unified geodetic reference framework capable of supporting land information integration with particular application to cadastral boundaries.

This report provides a review of the existing Samoan Geodetic Network.

Options and recommendations are provided for the upgrading of the Geodetic Network to support the country's future needs and the requirements of the Project.

Further recommendations relate to adoption of a new geodetic datum and map grid for Samoa.

This report was prepared by Mr Andrew Dyson, Geodetic Adviser, with the assistance of staff of Ministry of Natural Resources, Environment & Meteorology. In particular, the assistance of: Mr Safuta Toelau Iulio, Assistant CEO Technical Services; Mr Ueligitone Seiuli, Principal Surveyor; and Mr Leoo Polutea, Principal Mapping Officer.

National Survey Adviser, Mr Seve Keilani Soloi provided invaluable support with the research for preparation of this report.

1.2 Purpose of a National Geodetic Network

A national geodetic network provides the fundamental support for land surveying, mapping, engineering and related applications and is the basis for the integration of all such activities. It is the basic reference framework for all surveying, mapping and land related information. A geodetic network controls the position, extent and orientation of surveys. To provide this support a geodetic network must be both accurate and homogeneous.

Vertical control related to mean sea level (MSL) is essential for engineering and construction activities and is particularly important for, water supply, drainage, flood control and coast protection measures.

A network must be of sufficient quality to ensure that mapping, cadastral and general surveys are based on a homogeneous coordinate system. Without such a system, development takes place in a disjointed and unrelated manner which ultimately leads to unnecessary expense when neighbouring surveys meet. The advantages of a suitable geodetic network are:

- The accuracy of surveys is controlled and maintained and the propagation of errors is reduced. (An adequate network allows surveyors to work from the whole to the part, a standard survey practice, not from the part to the whole.)
- A network enables uniform scale and orientation to be maintained over surveys.

- As surveys are connected to the network, they are directly interrelated to each other.
- All future surveys connected to the network can be integrated into one system, avoiding duplication and wasted effort.
- Cadastral surveys are also related to mapping and other geographical land information through proper connection to a geodetic network.
- Adequate vertical control will ensure that engineering works can be designed and built with confidence.

1.3 Needs of SIAM-2 for a National Geodetic Network

Orderly social and economic development relies upon a sound land administration system. Without the security of tenure and boundaries that results from a sound land administration system, citizens and developers are reluctant to invest in appropriate development. Development, resource management and land administration relate to land tenure and all depend upon reliable surveying and mapping.

A major component of the project is the development of a strategy for the integration of land information. A sound geodetic network provides the ability to spatially locate all surveying, mapping and the cadastre enabling the integration and linking of data from diverse sources.

An accurate and homogeneous geodetic network is essential to support the land information integration requirements of the project. Such a network will ensure that the position, extent and orientation of surveys and mapping are controlled thereby preventing the creation of gaps or overlaps.

2. EXISTING GEODETIC NETWORK

2.1 Horizontal Network

Information about the horizontal network comes primarily from a report by David Silcock, Project Surveyor, Department of Lands & Surveys (1988 -1990)[1]

The existing horizontal network was established between 1983 and 1990 as part of a Mapping Project with the assistance of the Australian Agency for International Development (AusAID). In order to provide sufficient mapping control it was necessary to establish a geodetic network throughout the country.

The control was restricted to coastal traverses around each of the two main islands with connections across the strait between the islands and limited traversing in the interiors. Many stations were pillars set on rocks along the coast line or on offshore rocky outcrops. Most stations in the interior are on inaccessible mountaintops.

Six absolute position fixes by Doppler Satellite techniques were derived by the Royal Australian Survey Corps in 1982. These positions were in terms of the WGS 72 ellipsoid.

Two GPS baselines, between three key stations, were observed in 1988 as part of a survey to determine crustal movements in the South West Pacific.

[1] MNREM File 4/5/18: Geodetic & Photogrammetric Control Surveys in Western Samoa (1983-90), David Silcock, Project Surveyor

Adjustment of the geodetic network was carried out by the Australian Surveying & Land Information Group (AUSLIG), the Australian Government authority responsible for the Australian Geodetic Network at that time. The geodetic functions of AUSLIG are now the responsibility of Geoscience Australia.

The Doppler coordinates of the station Observatory Doppler (011) were held fixed and the adjustment was carried out on the WGS 72 ellipsoid.

The Primary Network consisted of 101 geodetic stations. Plan 5325 shows the network stations.

The geodetic datum is referred to as WGS 72 but in fact it was a local determination of WGS 72 based on a Doppler point position survey. The defining parameters for the existing geodetic datum are:

Datum:	WGS 72 (local determination)	
Ellipsoid:	WGS 72	
	Major semi-axis	6378135.0000
	Minor semi-axis	6356750.5200
	Flattening	1/298.26
Origin:	Observatory Doppler (011)	
	Latitude	13 48 52.98 (S)
	Longitude	171 46 51.33 (W)
	Height (MSL)	0.91

The Map Projection adopted by Samoa is a Transverse Mercator Projection with a 2 degree zone width referred to as the Western Samoa Integrated Grid. The defining parameters are:

Name:	Western Samoa Integrated Grid (WSIG)
Longitude of Origin:	Central meridian = 172 degrees West
Latitude of Origin:	Equator
False Easting:	700,000 metres
False Northing:	7,000,000 metres
Central Scale Factor:	1.0000
Zone width:	2 degrees.

2.1.1 Precision:

The network was established to support mapping. The report from Mr Jim Steed who was responsible for adjusting the network does not indicate the precision of the network. This information would have been available from the adjustment.

A letter from Mr Fiu Mataese Elisara Laula, Director of Lands & Environment suggests that the network was carried out to New Zealand third order standards.[2]

[2] Letter from Fiu Mataese Elisara Laulu, 6th December 1990 in MNREM File 4/5/29

A letter from Mr Godfrey Day, Integration Surveyor, Department of Lands & Surveys (1991-1994?) to Mr Leoo Polutea, reports that Mr David Silcock had suggested that the precision of the network probably fell between third and second order precision.[3]

2.1.2 Records:

Mr Silcock's report indicates that the data was stored on a computer in the Mapping Section and that the original results from AUSLIG were on two floppy disks (360kb 5¼" disk). Mr Leoo Polutea, Principal Mapping Officer, has reported that the computer in question was replaced after the hard disk was corrupted in 1995 and that the files could not be retrieved. The floppy disks were disposed of because they were accidentally damaged during the move to their present offices and the data could not be accessed.

The only records remaining are hard copy listings of coordinates.

The other records associated with the network, including the original Survey Record Cards were also stored in Mapping Section and are available. Copies of these records are also held in Surveys Section.

The Geodetic Adviser contacted Mr Geoff Luton of Geoscience Australia to enquire if his agency had maintained any digital or other records related to the Samoan Geodetic Network. In response, Mr Luton advised that he had carried out a meticulous search of their records and had been unable to locate any relevant information.

The Land Information Centre (LIC)of the Australian state of New South Wales was involved in providing assistance for the 1983-90 mapping project. The ACEO Technical Services has suggested that an approach be made to LIC in Bathurst requesting that they search their records for any information that they might have related to the Samoan Geodetic Network. LIC is now a part of the Land & Property Information Division (LPI) of the New South Wales Department of Lands.

It is recommended that MNREM contact LPI and request a search of their records for any records related to the Samoan Geodetic Network.

2.1.3 Status:

As indicated above, many stations were pillars set on rocks along the coast line or on offshore rocky outcrops. A number of these marks are believed to have been destroyed by storm and wave action and some of those that remain are inaccessible without a boat or can only be occupied at low tide. Other stations are on inland mountain tops and are virtually inaccessible without helicopter transport.

Preliminary reconnaissance activities on Upolu have confirmed that a number of the marks have been destroyed. Not all marks were inspected but of those selected for inspection, eight had been destroyed.

So far no reconnaissance has been conducted on Savai'i, but advice has been obtained from Mr Leoo Polutea indicating which stations were recovered in 1999 during survey activities for the mapping project conducted by Airesearch Mapping Pty Ltd for MNREM. At that time approximately 30% of stations were missing.

The precision of the network is regarded as inadequate to support a modern land information system.

[3] Facsimile message from Godfrey Day, 22nd May 1998 in MNREM File 4/5/18

2.1.4 Datum Issues:

The existing horizontal datum is based on the WGS 72 ellipsoid, from a relatively low accuracy Doppler satellite survey by the Australian Army Survey Corps in the 1980s. It is a local determination of the datum. It is neither maintained nor supported and is not compatible with WGS 84, the GPS satellite datum. Global transformation parameters between WGS 72 and WGS 84 may not be applicable in Samoa because the local determination of WGS 72 is unlikely to agree with true WGS 72 because of the low accuracy of the Doppler survey. This opinion is based on advice to the Geodetic Adviser from Mr Jim Steed of Geoscience Australia in January 2005.

Maritime boundaries in Samoa are to be defined in terms of WGS 84, the accepted international datum for such boundaries.[4]

The point positioning accuracy from GPS has improved such that it is often at the 2-5 metre level and with the current modernisation programme is expected to be at the 2 metre level over the next 10 years. Point positions from GPS are in the WGS 84 coordinate system.

The proposed European Galileo satellite system promises metre level positioning in the next five years.

This means that users of relatively inexpensive GPS hand held receivers can obtain coordinates at the sub five metre level on WGS 84, without reference to a local geodetic datum. The trend to satellite based high accuracy differential GPS correction systems means that positions at the 10cm accuracy level can be obtained in the International Terrestrial Reference Frame (ITRF). ITRF is very closely aligned to WGS 84 and for all intents and purposes it can be considered to be one and the same coordinate system.

Such users often have little or no understanding of datums and the geodetic issues surrounding the use of different datums and the need to transform coordinates from one system to another, to ensure compatibility of data. This situation has the potential to create confusion with many users collecting data in WGS 84 from GPS and a local coordinate system that is not compatible. Anecdotal evidence suggests that such problems have already arisen in Samoa.

2.2 Vertical Network

Mr Silcock's report indicates that vertical control for the horizontal network was provided by trigonometrical heighting between 1983-1985. Between 1986-1988, an adjustment of the trig. heighting network was carried out using the existing sea level determination and four additional short period tidal observations.

Quite considerable spirit levelling has been conducted throughout Samoa at various times. A search of records and some preliminary reconnaissance activities indicate that the existing situation is as follows:

2.2.1 Upolu:

An undated report by Sumeo Matamu[5] gives some details on the vertical datum and levelling for Samoa. The report indicates that the existing vertical datum for Samoa is Mean Sea Level (MSL) based on hourly readings at the Mulinuu Tide Gauge between 1951 & 1969. It is often referred to as MSL (51-69).

[4] Maritime Zones Amendment Act 2004

[5] MNREM Survey Section Folder "Bench Mark Cards – Level Data" Vertical Datum in Western Samoa, Sumeo Matamu, undated.

Tidal observations have also been conducted at Fagaloa Bay on the north eastern coast and at Salani on the south eastern coast.

From a search of the levelling records, the advisers have deduced that spirit levelling has been conducted as follows:

1971, levelling completed in the Apia area as shown on Plans 3137 & 3157[6]. The accuracy of most levelling is quoted as second order (±0.03 √D – Check if metric or imperial) Suspect this is the same as .02√k as quoted elsewhere)

1981, levelling going east from Apia to Utamau'u on the northern coast.

1982, levelling was continued east from Utamau'u and then south to Vaipu.

1982, 2nd order levelling going north from the tide gauge at Salani to Vaipu. A closure was made to the Fagaloa Bay tide gauge using vertical angles with a misclosure of 0.4m.

1983, a loop of levelling was undertaken in the north east of Upolu for a hydro electricity project. It went from Falevao to Saluafata, connecting to the Utamau'u to Vaipu loop.

1983, levelling was conducted going west from the tide gauge at Salani to Si'umu at the junction with the Cross Island Road and continued from Si'umu to Saanapu on the South Coast Road.

1984, a loop of levelling from Tuaefu, in the south west of Apia, going west along the Alafa'alava Road to Aleisa West, then north to Tufulele and east along the West Coast Road to Vaiusu in western Apia. Lands & Surveys Tracing Tracing 902 indicates a misclosure of 0.6m at BM XXV!

1989, levelling from Aleisa West along the Alafa'alava Road, then south on the Cross Island Road to Saanapu effectively completing a loop around Upolu. A search of records has not revealed the resulting closure.

Preliminary reconnaissance activities have located eight bench marks (BMs) from the 1989 levelling.

2.2.2 Savai'i:

Mr Matamu's report indicates that for Savai'i, tidal observations were conducted at Asau Harbour towards the western end of the north coast and at Salailua Village on the south western coast. Reports are to be found in MNREM File 4/5/17. A further sea level determination was made at Salelologa Wharf in June 1979 and a report is also filed in MNREM File 4/5/17.

Levelling has been conducted between Asau and Salailua. The two BMs at Salailua were unavailable but the levelling was closed on an extension to the concrete slab that BM2 was sited on. The overall misclosure was 0.075m which was adjusted through the levelling (MNREM File 4/5/25). Assuming the levelled distance to be approximately 40km, this misclosure is equal to the allowable misclosure for Australian Third Order Levelling (±0.012 √k, where k is the distance in kilometres).

Mr Matamu indicated that levelling was also conducted from Salailua to Salelologa in the late 1980s. New BMs were established but he was unable to locate any records. Lands & Surveys Tracing 970 has been located showing reduced levels for this level run. The misclosure was 0.030m. BM cards have been located in the folder in Survey Section with other BM information.

[6] Letter from Acting Director of Lands to Director of Works, 10th March 1971 in MNREM File 4/5/25 (Original supposedly in 4/5/17)

3. SUBSEQUENT GEODETIC ACTIVITIES

3.1 Horizontal Control

As part of a project studying the motion of the Pacific Tectonic Plate a number of Continuous GPS (CGPS) stations have been established throughout the Pacific region by geophysical researchers including John Beavan, Institute of Geological & Nuclear Sciences, Lower Hutt, New Zealand and Mike Bevis, Ohio State University, USA. One such CGPS station has been established at Faleolo Airport and has been running since 1996. Data from this site is downloaded by Mr Safuta Toelau Iulio, Assistant CEO.

In mid 2001, another CGPS station was established at the old Fagali'i Airport by Geoscience Australia to monitor vertical crustal motion as part of AusAID funded South Pacific Sea Level & Climate Monitoring Project (SPSLCMP). In addition to monitoring vertical movement, the data is also used to measure horizontal crustal motion. Data from this site is usually downloaded automatically. If any problems are experienced with this process, Mr Ueligitone Seiuli, Principal Surveyor, is responsible for downloading the data which is written to a disk and forwarded to Geoscience Australia.

Control surveys were carried out for Ministry of Works Transport & Infrastructure (MWTI) by New Zealand based BECA Consultants in 1993 and 2004.

The 1993 survey was for reconstruction of roads damaged by cyclones Ofa and Val in the eastern part of Upolu. The two sections of road were from Saluafata to Falevao and from Lotofaga to Lalomanu.

The 2004 survey was for the upgrading of the road from Apia to the Faleolo Airport.

The report on the 1993 GPS activities indicates that constraining the GPS survey by the existing horizontal control downgraded the quality of the results. If baseline processing results are available and the control points are still in the ground it may be possible to incorporate this data into the proposed new network.

To date the report for the 2004 survey has not been acquired. Mr Vailini Raratoga, MWTI Chief Surveyor has been approached for a copy of the report. It is important that a copy of the report and details of marking and data are acquired to determine if it can contribute useful data to the upgrade of the geodetic network.

A report on survey and mapping activities conducted by Airesearch Mapping Pty Ltd during 1999 for SIAM reveals that significant discrepancies were encountered at 33 existing horizontal and vertical control stations[7]. These discrepancies were up to 61.6m in eastings and up to 144.5m in northings. It is quite possible that some of the large differences were due to mis-identification of control points but the general level of differences suggests serious problems with the horizontal network.

3.2 Vertical Control

A SEAFRAME tide gauge was established in Apia as part of the SPSLCMP in February 1993. Data from the gauge is downloaded automatically to the National Tidal Facility (NTF) in Australia. An array of deep bench marks has been established around Apia to monitor movement of the tide

[7] Airesearch Mapping Report on Survey Control, Lee Smith, 18th January 2000

gauge. This array has been levelled eight times by Mr Steven Turner, formerly of the NTF. The latest levelling was in September 2004.

Levelling was also undertaken as part of the control surveys for MWTI in 1993 and 2004.

The report on the 1993 survey found discrepancies between three of the BMs on the Le Mafa Pass Road. No attempt was made to resolve the anomalies.

As indicated above, the report for the 2004 survey for reconstruction of the West Coast Road has not been acquired. Two way 3rd order levelling was conducted from Apia to Mulifanua Wharf. Anecdotal information suggests that it revealed serious discrepancies in the heights of the existing bench marks between Apia and Tufulele. It is important that a copy of the report and details of marking and data are acquired to determine the extent of the differences and if the survey can contribute useful data to the upgrade of the geodetic network.

As indicated above, the Airesearch Mapping report on survey and mapping activities reveals that there were significant discrepancies in heights for horizontal control stations. These discrepancies were up to 5.5m. The magnitude of the height differences suggests significant problems with the heights of the horizontal network. It is believed that all heights on these points were derived from trigonometrical heighting.

4. CADASTRAL SURVEYING

4.1 Lemuta Cadastral System

The following is taken from a report prepared by R J Newland in 1988.[8]

Cadastral surveying is based on a plane coordinate system known as the Lemuta Cadastral Datum. It is apparently based on control traverses commenced in 1927 and completed between 1953-56. The traverse followed the perimeter roads of Upolu and Savai'i with a triangulation connection between them. Check bearings were by solar and stellar observations.

In 1954 the mean latitude at Lemuta from 1911 and 1954 astronomic observations was corrected by half the difference between the astronomic and traverse derived latitude at Poutasi on the southern side of Upolu. A value of S13 48 56.5 was adopted. There is no indication of the Longitude of Lemuta.

Mr Godfrey Day has confirmed that Lemuta is a plane datum and accordingly it is not based on any ellipsoid. He has acknowledged that this creates problems the further one moves from the origin and indicated that there is "a Lemuta to WGS 72 transformation programme which is based on a few comparisons of Lemuta coordinates with geodetic coordinates but is not that accurate in Apia getting worse as you head east and west (it is a plane transformation)."

The Terms of Reference for Component C5 notes that "from anecdotal information that there may be differences in the Lemuta datum [sic] over different parts of the islands".

5. UPGRADE REQUIREMENTS

The existing geodetic datum is not compatible with the GPS system and must be upgraded and properly defined to ensure that all GPS users can take full advantage of this powerful technology

[8] Integrated Grid for Western Samoa, R J Newland, 5th October 1988

without the confusion of different datums. At the same time it would be appropriate to move from the existing map grid to a universally accepted map grid.

The existing horizontal network is not adequate to support the basic spatial framework nor the sustained management and development of Samoa's environment and natural resources because many monuments have been destroyed and the precision is very low. It is proposed to upgrade the existing geodetic network to a world standard, high precision network that will support the surveying, mapping and land information needs of Samoa into the future. The network will be capable of supporting the integration of all land information.

Further assessment is needed of the existing vertical network when more information becomes available. But the evidence so far suggests that it does not provide reliable vertical information, in particular around sensitive coastal areas.

Transformation parameters must be developed to enable transformation of data from the existing WGS 72 datum and if possible the Lemuta Datum.

5.1 Horizontal Datum

In 1999, the Permanent Committee on GIS Infrastructure for Asia and the Pacific Region (PCGIAP) adopted a resolution to adopt ITRF as the datum for the Asia Pacific region. In doing so it recognised the need to adopt a uniform geodetic control system across the region.

Nations throughout the region have been moving in this direction, and the Kingdom of Tonga is expected to adopt ITRF in the near future.

International maritime boundaries are defined on WGS 84 which is effectively the same as ITRF.

The adoption of ITRF would mean that coordinates obtained from the GPS system would be consistent at the decimetre level with the datum.

It would be appropriate to take the opportunity provided by this project to adopt the International Terrestrial Reference Frame as the geodetic datum for Samoa to ensure the maximum level of compatibility with the GPS satellite system for all users regardless of their understanding of datums.

ITRF coordinates are available for the CGPS station at Fagali'i airport. Geoscience Australia can provide the latest coordinates for the installation.

It is recommended that Samoa adopt ITRF as its horizontal geodetic datum.

GPS observations from the Fagali'i CGPS indicate that due to tectonic plate movement Samoa is moving about 0.07m/year in a west-north westerly direction [9]. Over 20 years this will amount to about 1.4m. To minimise the impact over this time it is suggested that the projected movement over the next ten years be incorporated into the coordinates of stations in the geodetic network.

It is recommended that in defining the new Samoan Geodetic Reference System (SGRS), ten years of projected tectonic plate movement be incorporated into the coordinates.

[9] South Pacific Sea Level & Climate Monitoring (SPSLCMP) GPS Coordinate Time Series, Geoscience Australia, 2nd March 2004

5.2 Map Projection

The current Samoa Integrated Grid (SIG), formerly known as the Western Samoa Integrated Grid (WSIG) has a central meridian of 172 degrees west, a Central Scale Factor of 1.0000 and zone width of two degrees.

The adoption of the Universal Transverse Mercator Projection (UTM) would mean a central meridian of 171 degrees west, a Central Scale Factor of 0.9996 and zone width of six degrees. This would result in larger scale factor corrections across most of the country than for SIG.

UTM is an internationally accepted application of the Transverse Mercator projection and as such it is programmed into all GPS receivers.

UTM is the accepted projection for International Maritime Boundaries.

If the current SIG system is retained there would be a very significant risk of confusion and mistakes. This would arise because upgrading and reobserving the geodetic network using GPS technology will inevitably change the coordinates at each and every control point except for the origin. A new coordinate set would be produced. However the change in coordinates would be relatively small resulting in two similar sets of coordinates for each existing point.

Unless extreme care was taken in identifying the correct coordinate set for a particular set of coordinates confusion and mistakes would be common. The adoption of a new datum and map projection will ensure that the new grid coordinates are quite different from the old SIG coordinates and it will be obvious to which datum and grid either old or new coordinates are referenced.

The adoption of UTM would meet this need.

It is recommended that Samoa adopt the UTM map projection for all survey, mapping and land information purposes.

5.3 Horizontal Network

To meet the future surveying, mapping and spatial needs of Samoa, it is suggested that a Primary Network at approximately 15km spacing around the coastline of Samoa would be adequate.

To assist in determining the extent of the tertiary network in Apia and the preferred spacing of marks, a field inspection was conducted by the National Survey Adviser and Geodetic Adviser on 23rd March. The Principal Surveyor was unable to participate. To support cadastral and other survey projects in Apia it is suggested a network of third order control points be established at approximately 250m spacing. Where appropriate the spacing between marks may be increased but within the central business district it would be appropriate to reduce this spacing. This would enable surveyors to easily connect to three network marks to effectively control the position, extent and orientation of surveys. Existing cadastral reference marks should be incorporated into the Tertiary Network.

Given the recent development activity in Salelologa on Savai'i the establishment of a Tertiary Network would be appropriate.

It is recommended that a modern GPS based Primary Geodetic Network be established throughout Samoa with stations spaced at approximately 15km.

It is recommended that as a first priority, a Tertiary Geodetic Network be established in Apia with stations spaced at approximately 250m.

It is recommended that subject to the availability of resources and time permitting, a Tertiary Geodetic Network be established in the developed areas of Salelologa and in the areas of Salelologa that have been subdivided for future development with stations spaced at approximately 250m. If it is not possible to complete this activity as part of the project, it could be completed by Survey Section after they have acquired the necessary level of expertise from the project.

5.4 Vertical Datum

MSL is almost universally accepted as a vertical datum. The existing MSL (51-69) was determined 35 years ago, based on observations at the Mulinuu tide gauge. This tide gauge no longer exists. The Geodetic Adviser has anecdotal information from Mr Steven Turner indicating that data from the SEAFRAME tide gauge at Apia Harbour suggests that MSL has changed by 2-3mm/year since the tide gauge was installed in 1993.

The adviser sent a request to the NTC, on 17th March, requesting details of their findings regarding a change in MSL. No response had been received by 23rd March.

It is recommended that the vertical datum remains as MSL but that the results from the SPSLCMP be used to adopt a new value of MSL.

5.5 Vertical Network

The available evidence suggests that there are some serious problems with the existing vertical control and that it does not provide reliable vertical information. Further assessment is needed, to determine the quality of the vertical control and how much of the vertical network remains intact.

It is recommended that a complete search of all available vertical data be made, including all recent level activities. The height differences must be tabulated and mathematical closures determined to establish the quality of the overall vertical network.

It is recommended that a field search be undertaken to determine how many BMs remain, to enable a proper assessment to be made of the need to upgrade and extend the vertical network, taking into account the loop closures and any other information indicating the quality of the network.

It is recommended that to provide adequate vertical control for likely future requirements, the existing vertical networks should be upgraded and extended as necessary to provide a network of spirit levelled heights around the perimeter of, and along the cross island roads on Upolu, and around the perimeter of Savai'i. The extent of the upgrade and additional levelling will depend upon the findings above.

It is recommended that BMs from the BECA survey of 2004 should be incorporated into the national vertical network and consideration also be given to the BMs from the BECA survey of 1993.

It is recommended that wherever practical, stations in the Primary Network should be levelled by connection to the national levelling network to assist in defining the geoid/ellipsoid separation.

It is recommended that the vertical network should be adequately connected to the SPSLCMP tide gauge bench mark array in Apia.

6. CAPACITY OF PUBLIC & PRIVATE SURVEY SECTOR

The capacity of both the public and private sector to upgrade and sustain the geodetic network has been considered.

A national geodetic network is the basic reference framework for all surveying, mapping and land information and is a fundamental component of the national infrastructure. It is not in itself expected to generate revenue or a return on the investment in establishing the network. Rather, the value of a geodetic network is derived from its support for and contribution to other products.

Without a permanently monumented geodetic network, the integration of various layers of spatial information can only be achieved by each organisation providing its own spatial control. This duplication of the measurement process would result in a significant financial cost to the individual organisations and hence the community as a whole. Therefore the avoidance of these costs represents the value of a geodetic network.

Accordingly, establishing and maintaining a national geodetic network should be regarded as the role of government in the same way as the establishment and maintenance of other basic infrastructure such as: roads, bridges, flood control measures, and water supply etc; the provision of schools and hospitals; and other basic government services such as the police and court system.

6.1 MNREM Survey Section

MNREM's Survey Section is the appropriate organisation to bear responsibility for establishing and maintaining the Samoan Geodetic Network. Its activities should reflect this responsibility with an emphasis on the upgrade, management, maintenance and future expansion of the geodetic network. Under the project, Survey Section will acquire high precision GPS equipment suitable for the establishment of the new Samoan Geodetic Network, for ongoing maintenance and any expansion of the network as required in the future.

The project will provide training to ensure that MNREM is able to maximise the benefits of GPS technology and ensure long term sustainability. It is important that the most appropriate staff are selected to participate in the training.

Survey Section is supervised by Mr Ueligitone Seiuli, Principal Surveyor, who is also responsible for maintenance of the CGPS installation at the Fagali'i Airport site in Apia. He has 10 staff under his supervision. One classed as a Staff Surveyor with a Certificate from Honiara Technical Institute. The remaining staff are without any survey qualifications and are classified as Survey Trainees or Assistant Surveyors. These staff have basic survey capabilities developed from experience in the field.

The Staff Surveyor and some of the Survey Trainees, with appropriate on the job training, will become proficient GPS operators and party leaders. A minimum of three GPS party leaders will be required.

Within the Survey Section only the Principal Surveyor is considered to have the basic qualifications and background experience to effectively undertake the training needed to sustain GPS operations in the future. He has been identified as the key counterpart to the Geodetic Adviser and should be involved in all the major activities associated with establishing the new geodetic network. These include GPS planning, data processing and adjustments.

It has been suggested that the Project Component Manager, Mr Vitaoa Pele Fuata'i, will participate in the GPS training. While he is considered a suitable candidate, the adviser is concerned that

Mr Fuata'i is unlikely to be able to devote the quite significant amount of time required for effective training because of his existing workload as Component Manager.

It is recommended that to maximise the benefits and ensure long term sustainability, consideration be given to identifying the most suitable staff from within the whole of MNREM to participate in the GPS operations and training. One possible candidate is Mr Petania Tuala from Mapping Section.

6.2 Other Public Agencies

Survey staff from Samoa Land Corporation and the Ministry of Works, Transport & Infrastructure have indicated an interest and willingness in involvement in the GPS activities.

It is recommended that staff from these agencies be invited to participate in the GPS training and observation stages of the project.

A suitable candidate for training has been identified from outside MNREM. Mrs Eseta Maualaivao, Chief Surveyor, Samoa Land Corporation is a recent graduate (1999-2001) of the University of Otago, School of Surveying and has had exposure to good quality GPS training. She would be eminently suited to training in GPS planning, data processing and adjustments. However, at the moment she has a heavy workload and would not be available for the amount of intensive on-the-job training that would be required to develop her expertise to an appropriate level.

6.3 Private Sector

The private sector as the provider of surveying services to the community, is a major user of the national geodetic network. Only one surveyor from the private sector, Mr Keilani Soloi, has had any significant exposure to and experience in the use of GPS technology. He is the National Survey Adviser for the project and is playing a significant role in the upgrade of the geodetic network. In this role he will undergo training in GPS planning, data processing and adjustments so that he can assist MNREM survey staff and assist the Geodetic Adviser with training activities.

Most of the remaining surveyors have indicated an interest in being involved in training during the GPS observation activities. It is not expected that they will play a significant role in the project because of their existing business commitments but they will be invited to participate and gain some GPS experience.

7. MNREM SURVEY SECTION PARTICIPATION

MNREM Survey Staff are needed to participate in all activities associated with the upgrade of the Samoan Geodetic Network.

It is recommended that MNREM identify suitable staff to participate in the following activities and the associated training.

7.1 Primary Network

- Reconnaissance
- Monumentation
- Levelling

- Observations
- Baseline Processing
- Network Adjustment
- Transformation Parameter Determination
- Record Management

7.2 Tertiary Network

- Office Search & Grouping of all Survey Plans in the area.
- Reconnaissance
- Monumentation
- Levelling
- Observations
- Baseline Processing
- Network Adjustment
- Transformation Parameter Determination
- Record Management

7.3 Vertical Network

- Office Search of all Levelling Data
- Compilation of all existing levelling and calculation of loop closures
- Reconnaissance to determine what BMs exist
- Reconnaissance for new BMs
- Monumentation
- Levelling
- Reductions
- Record Management