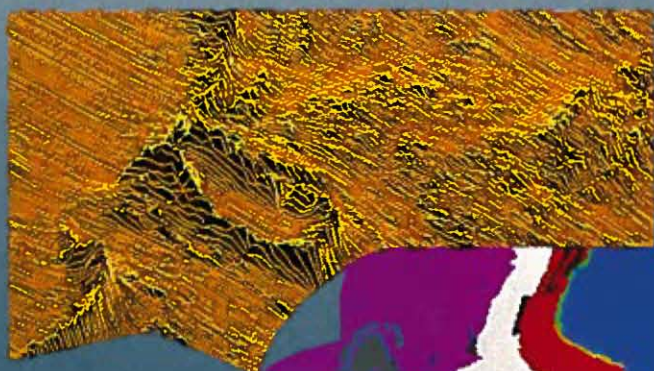




Government of South Australia



Land Information Management

South Australia

AUG 25 2 49 PM '93

**1993 GUAM GEODETIC
NETWORK PROJECT**

PHASE I

FINAL REPORT

South Australian Department of Environment and Land Management

August 1993

Bureau of Planning

Table of Contents

<u>SECTION 1</u>	<u>INTRODUCTION</u>	1
<u>SECTION 2</u>	<u>PROJECT OVERVIEW</u>	2
2.1	Objectives	2
2.2	Method of Survey	2
2.3	Project Management	2
2.4	Project Phases	2
2.5	Project Logo	2
<u>SECTION 3</u>	<u>NETWORK AND MONUMENTATION</u>	3
3.1	Primary Network	3
3.2	Specifications for the 1993 Guam Geodetic Network	4
3.3	U.S. National Geodetic Survey (NGS) Specifications	4
3.4	Role to be Played by NGS in the Final Adjustment of the 1993 Guam Geodetic Network	5
3.5	Numbering System for Network Marks	5
3.6	Naming of Stations	5
3.7	Datum Monument	5
3.8	Form of Monumentation	6
3.9	Monitoring of Monumentation Standards	7
3.10	Construction of Primary Monuments	7
3.11	Construction of Secondary and Tertiary Monuments	7
3.12	Form of Witnessing	9
3.13	Spacing of Tertiary Network Marks	9
3.14	Estimate of Number of Secondary and Tertiary Marks	10
3.15	Desirability of Placing Network Marks in Easements and Rights of Ways	10
3.16	Connection to Existing 1963 GGTN Marks	11
3.17	Connection of Department of Public Works Road Centre-Line Monuments	12
3.18	Connection to Existing Survey (Non-Network) Marks	12
3.19	Location of Underground Services	12
<u>SECTION 4</u>	<u>FIELD OPERATIONS</u>	13
4.2	Percentage of Network to be Controlled with Kinematic GPS	13
4.3	Acquisition of Total Station	13
4.4	Possibility of Atmospheric Problems for Kinematic GPS	13
4.5	Vehicle Requirements	14
4.6	Fitting Out of GPS Vehicles	14
4.7	Safety Issues	15
4.8	Working Hours	15
4.9	Format for Location Cards	16

4.10	Format for Field Pages	16
SECTION 5	<u>PERSONNEL AND TRAINING</u>	17
5.1	Key Personnel	17
5.2	Personnel Required for Project Operations	17
5.3	Training Considerations	18
5.4	Need for Expertise in Final Geodetic Adjustments	19
5.5	Type of Geodetic Adjustment Training Required	20
5.6	Suitability of Personnel	20
5.7	Publicity and Education	20
SECTION 6	<u>COORDINATE SYSTEMS</u>	22
6.1	Geodetic Datum	22
6.1.1	Definition of the Existing Guam Datum	22
6.1.2	Discussion - Geodetic Datum	22
6.1.3	Legal Implications of Datum Changes	24
6.1.4	Recommendations - Geodetic Datum	25
6.2	Map Projection	25
6.2.1	Existing Situation	25
6.2.2	Discussion - Map Projection	26
6.2.3	Recommendations - Map Projection	27
6.3	Absolute Position Information from the Philippine Sea Plate Survey ..	28
SECTION 7	<u>ASSESSMENT OF EXISTING SURVEY NETWORKS</u>	29
7.1	Horizontal Control - The 1963 Triangulation Network	29
7.1.1	Background	29
7.1.2	Data Set	29
7.1.3	Assignment of Observation Accuracies	30
7.1.4	Method of Network Assessment	30
7.1.5	Results - Phase 1	30
7.1.6	Results - Phase 2	31
7.1.7	Conclusions and Recommendations	31
7.2	Vertical Control - The 1963 Levelling Network	32
7.2.1	The Vertical Datum	32
7.2.2	The Primary Levelling Network	32
7.2.3	Conclusions and Recommendations	33
SECTION 8	<u>TRANSFORMATION REQUIREMENTS STUDY</u>	35
8.1	Introduction	35
8.2	Transformation Investigation - Geodetic Datums	35
8.3	Transformation Investigation - Map Grids	36
8.4	Results	36
8.4.1	Datum Transformation	36
8.4.2	Grid Transformation	38

8.5	Conclusions and Recommendations	39
SECTION 9	<u>ESTABLISHMENT OF VERTICAL CONTROL</u>	41
9.1	Introduction	41
9.2	A Geoid Map for Guam	41
9.3	Geoid Mapping Investigation	42
9.4	Conclusion and Recommendations	43
SECTION 10	<u>DESIGN FOR THE GUAM SURVEY MARK SYSTEM</u>	45
10.1	Background	45
10.2	System Components	46
10.2.1	Overview	46
10.2.2	Survey Mark Data Base	46
10.2.3	Survey Mark Index	47
10.2.4	Location Cards	47
10.2.5	Method of Operation	48
10.3	Design Considerations	48
10.3.1	Data Model	48
10.3.2	Data Dictionary	49
10.3.3	Data Flow Diagram	49
10.3.4	Proposed Screen Layouts	49
10.3.5	Interfaces Between Sub-Systems	50
10.3.6	Volume and Frequency of Use	50
10.4	Hardware and Software	50
10.5	System Development Plan	51
10.5.1	Stages of Development	51
10.5.2	Detailed System Design	52
10.5.3	Development	53
10.5.4	Testing	53
10.5.5	Implementation	53
10.6	Data File and Location Card Creation	54
10.7	Survey Mark Index Creation	54
10.7.1	Base Mapping Information	54
10.7.2	Coordinate System Considerations	55
10.8	Records Maintenance	55
10.9	Organisational Issues	56
10.9.1	Development and Implementation	56
10.9.2	Maintenance	57
10.10	Associated Issues	58
10.10.1	Feasibility of Incorporating GSMS into GIS	58
10.10.2	Inclusion of Non-Network Marks in GSMS	58
10.10.3	Production of Network Diagrams	59
10.11	Future Development of the GSMS	59

<u>SECTION 11</u>	<u>GUIDELINES FOR THE COLLECTION OF DATA</u>	60
11.1	Introduction	60
11.2	Collection of Digital Cadastral Data by DLM	60
11.2.1	Overview	60
11.2.2	COGO Data Capture	61
11.2.3	Digitised Data in the Planning Layer	62
11.3	Collection of Cadastral Data by Other GovGuam Agencies	63
11.3.1	Introduction	63
11.3.2	Bureau of Planning	63
11.3.3	Guam Power Authority (GPA)	64
11.3.4	Guam Telephone Authority (GTA)	64
11.3.5	Public Utility Agency of Guam (PUAG)	64
11.3.6	Guam Environmental Protection Agency (GEPA)	64
11.3.7	Department of Public Works (DPW)	65
11.3.8	Summary	65
11.4	Transformation of Coordinates	65
11.4.1	Transformation of Existing COGO Files	65
11.4.2	Transformation of Planning Layer	66
11.5	Associated Issues	66
11.5.1	Retention of Source Data	66
11.5.3	Date Stamping	67
11.5.4	Accuracy Codes	67
11.5.5	Custodianship of Cadastral Data	68
<u>APPENDIX 1</u>	<u>SCOPE OF WORK</u>	69
<u>APPENDIX 2</u>	<u>PROPOSED PROJECT LOGO</u>	73
<u>APPENDIX 3</u>	<u>PROPOSED 1993 GGN PRIMARY NETWORK STATIONS</u>	74
<u>APPENDIX 4</u>	<u>PLAQUE DESIGN</u>	75
<u>APPENDIX 5</u>	<u>NETWORK MARK DISTRIBUTION</u>	76
<u>APPENDIX 6</u>	<u>DATUM TRANSFORMATION STATIONS</u>	77
<u>APPENDIX 7</u>	<u>GRID TRANSFORMATION STATIONS</u>	78
<u>APPENDIX 8</u>	<u>MARK DETAIL ATTRIBUTES</u>	79
<u>APPENDIX 9</u>	<u>MARK REFERENCE ATTRIBUTES</u>	83
<u>APPENDIX 10</u>	<u>PROPOSED MARK DETAILS SCREEN DISPLAY</u>	84

<u>APPENDIX 11 - PROPOSED MARK REFERENCE SCREEN LAYOUT</u>	85
<u>APPENDIX 12 - EXAMPLE OF SURVEY MARK INDEX</u>	86
<u>APPENDIX 13 - EXAMPLE OF LOCATION CARD</u>	87
<u>APPENDIX 14 - SMDB ENTITY-RELATIONSHIP DIAGRAM</u>	88
<u>APPENDIX 15 - GSMS DATA FLOW DIAGRAM</u>	89
<u>APPENDIX 16 - ICSM EXTRACT RE CLASS AND ORDER</u>	91

SECTION 1**INTRODUCTION**

This report summarises the outcomes of Phase 1 of the 1993 Guam Geodetic Network Project, undertaken in conjunction with the Government of Guam during the period 14th July - 2nd August 1993.

The scope of work is included as Appendix 1.

The objectives of Phase 1 were to conduct four studies, being:

- . The Preliminary Study,
- . The Transformation Requirements Study,
- . The Broad Systems Design for a Mark Register,
- . The Development of Guidelines for Collection of Data.

The work was undertaken by a team of technical advisers from the South Australian Government's Department of Environment, comprising:

- . Andrew Dyson - Project Leader,
- . Andrew Jones - Geodesist,
- . Craig Macauley - Survey Data Base Expert,
- . David Borchardt - Tertiary Network Expert.

The studies involved intensive consultation with key Government of Guam personnel, and in particular, those of the Department of Land Management (DLM). Consultations were also held with surveyors from the private sector.

All requirements associated with Phase 1 studies have been completed. The associated recommendations are included in the following paragraphs.

SECTION 2**PROJECT OVERVIEW****2.1 Objectives**

The objectives of this project are to:

- . Upgrade the Guam Geodetic Triangulation Network to a modern, accurate, and readily accessible geodetic network,
- . Provide technology transfer to the Guam Department of Land Management regarding the application of GPS technology to land surveys.

2.2 Method of Survey

The 1993 GGN will be established using the satellite based Global Positioning System (GPS) technology. Primary, secondary and tertiary stations will be controlled using a combination of static and kinematic GPS techniques.

2.3 Project Management

The project shall be referred to as the 1993 GUAM GEODETIC NETWORK (1993 GGN).

The Territorial Surveyor for the Government of Guam has been appointed as Project Administrator. The Project Administrator shall both direct and control the project. He shall also certify any and all documents relating to the project.

The South Australian Government's Department of Environment and Land Management shall be responsible for providing technical and administrative assistance to the Territorial Surveyor for the duration of the project.

2.4 Project Phases

The project has been divided into two distinct phases. Phase I of the project (the subject of this report) consists of analytical and preparatory work. Phase II will be concerned with the physical establishment of the network.

2.5 Project Logo

A proposal for the project logo is included as Appendix 2.

SECTION 3**NETWORK AND MONUMENTATION****3.1 Primary Network**

A primary geodetic network, comprising twenty five (25) first order stations, will be established on Guam. Twenty of the stations will be coincident with 1963 GGTN primary marks. The remainder will be stations which have not previously been included in the GGTN.

The preferred sites for the stations are shown on the attached copy of the Guam 1:50,000 map, and are listed in Appendix 3.

During the Phase 1 field check, sixteen of the primary 1963 GGTN stations were visited and confirmed as being suitable for GPS observations. Access difficulties and time constraints precluded visits to:

- | | |
|----------------|--|
| . URUNO 2 1945 | In Andersen Air Force Base |
| . ADOFGAN 1963 | In Apra Harbor Naval Base |
| . TIDAL 4 1949 | In Apra Harbor Naval Base (Tidal Bench Mark) |
| . COCOS 1963 | On Cocos Island |

It is therefore requested that the Department of Land Management determine whether:

- . These marks still exist,
- . Access to the marks can be obtained (through military installations),
- . There is clear visibility to the sky around the stations.

The early determination of this information is particularly necessary in the case of ADOFGAN 1963. If the station is not located, or is considered unsuitable, an alternative site will need to be identified. It is preferable that this be positioned on the western tip of Orote Point. However, if the United States Navy denies access to the area, the proposed site may need to be relocated to the western tip of the Glass Breakwater on the northern side of Apra Harbor.

TIDAL 4 1949 is a tidal bench mark located in the Apra Harbor Naval Base. Although listed as destroyed in 1963 it was apparently recovered by the Pacific Tidal Party during a subsequent project. It is requested that Department of Land Management personnel visit this point and ensure that it still exists. If not located, or if unsuitable for GPS observations, other bench marks in the locality should be recovered.

The proposed new stations are:

. GOVENOR 1993	Datum Station	(New Mark)
. RITIDIAN 1993	In Andersen Air Force Base	(New Mark)
. PATI 1993	In Andersen Air Force Base	(New Mark)
. AAFB 1990	In Andersen Air Force Base	(PSP Mark)
. PAGAT 1993		(New Mark)

Information is required from Dr. John Beavan (Lamont-Doherty Geological Observatory, Columbia University, Palisades, New York) to relocate AAFB 1990. A letter has been sent to Dr. Beavan by the Director, Department of Land Management seeking this information. It is vital that the information be obtained.

A final decision on the suitability and selection of primary stations will be made during the initial stages of Phase II.

3.2 Specifications for the 1993 Guam Geodetic Network

The following relative positioning standards (one sigma confidence level) are proposed for the 1993 Guam Geodetic Network:

First order	10 parts per million
Second order	20 parts per million
Third order	50 parts per million

These specifications will be subject to review in the event of any requirement to comply with NGS specifications.

3.3 U.S. National Geodetic Survey (NGS) Specifications

At the time of writing, it remained uncertain whether the project would be required to conform with US NGS geodetic survey standards and specifications.

The Department of Land Management is seeking to clarify this matter.

When resolved, it is imperative that:

- . The Department of Land Management immediately inform the South Australian Department of Environment and Land Management,
- . A copy of the appropriate standards and specifications be provided as soon as possible.

It is vital that this information be obtained at the earliest possible time. Any NGS requirement could significantly alter the project specifications and proposals for Phase II.

3.4 Role to be Played by NGS in the Final Adjustment of the 1993 Guam Geodetic Network

The role of NGS in the final adjustment of data cannot be determined until the matter of NGS specifications and requirements has been resolved.

3.5 Numbering System for Network Marks

It is essential that a simple numbering system be adopted for the 1993 GGN stations to:

- Avoid confusion and complications,
- Facilitate the establishment of survey mark records.

It is therefore recommended that:

- Every mark in the 1993 GGN be assigned a unique number,
- These numbers be sequential integers, Number 1 being assigned to the new Datum Monument.

3.6 Naming of Stations

The spelling of place names is controlled by Guam Public Law No. 17-65. It will be necessary that the Department of Land Management assess all station names to confirm their suitability and orthography.

3.7 Datum Monument

It is proposed that the Datum Monument be constructed at the rear of the Governor's Office at Adelup Point. The Director, Department of Land Management, is to confirm the selection of this site with the Governor. It is suggested that the datum monument be called GOVERNOR 1993.

It is further proposed that a descriptive plaque be designed and mounted on an appropriate above-ground monument. This plaque will provide information about the project and the 1993 GGN. A suggested design is included in Appendix 4. The design

will be finalised during implementation of the project.

3.8 Form of Monumentation

It is recommended that:

- . All 1993 GGN marks be brass plaques set in concrete and stamped with the mark number,
- . All new marks utilise the newly designed plaque (Vide Appendix 4),
- . Existing marks be reconstructed only if they are considered to be unstable or in some other way defective.

Concrete monuments will be cast in-situ in accordance with the specifications below for each type of mark. If solid rock is encountered, it shall only be necessary to ensure that the concrete is properly anchored to the rock.

Primary and Datum Marks

It is proposed that primary concrete monuments be level with the ground surface, 0.7m deep, 0.3m square cross section at the top and 0.5m square cross section at the base.

A sub-surface mark will be constructed below the main monument separated by 0.1m of sand or soil. This mark will be 0.2m deep and consist of a brass rod set in concrete positioned exactly underneath the main monument.

Three reference marks will be constructed for each primary mark, unless individual situations do not warrant such marks. Reference marks will be brass pins set in concrete blocks 0.3m deep, 0.2m square cross section at the top and 0.3m square cross section at the base.

The Datum Monument will be a suitably marked 0.3m diameter brass plaque, set in a concrete block similar in size to the primary marks. The mark will be circular at the top, with a diameter of 0.4m.

Secondary and Tertiary Marks

It is proposed that secondary and tertiary concrete monuments be either:

- . Level with the ground surface, or,
- . Set below a cast iron cover, the cover being at ground level.

In each case, the concrete block will be 0.3m deep, 0.2m square cross section at the

top and 0.3m square cross section at the base.

In urban areas with concrete sidewalks, it is recommended that marks be set about 0.2m below the ground surface, and fitted with a cast iron cover. It is further recommended that:

- . a concrete cutting saw be acquired to enable holes to be cut in the sidewalk (This will enable a neat finish to be achieved),
- . a DLM employee be assigned permanent responsibility for the care and maintenance of the saw.

3.9 Monitoring of Monumentation Standards

It is imperative that the 1993 GGN monuments be constructed and witnessed in accordance with the specifications established for the project. The structural integrity of the marks is fundamental to every aspect of the project. If the marks are substandard, all subsequent work will be seriously compromised.

It was suggested during discussions that the South Australian Department of Environment and Land Management should provide an expert to supervise and monitor the construction activities. Unfortunately this option is not financially viable. These monitoring activities will therefore be undertaken by the Project Leader and Tertiary Network Expert in conjunction with their other duties.

3.10 Construction of Primary Monuments

It is proposed that all new primary stations and recovery marks be constructed by Departmental personnel.

3.11 Construction of Secondary and Tertiary Monuments

Reconnaissance, monumentation and observation activities for the tertiary network will be split into three stages. The project work plan has been structured such that:

- . Monumentation will begin one week after the reconnaissance for each stage of the tertiary network has commenced,
- . GPS training and observations will commence immediately after the reconnaissance is completed.

It is critical that monument construction proceed unimpeded to avoid retarding the measurement campaigns. Accordingly it is proposed that two construction parties be utilised to undertake the majority of the monumentation.

There appear to be two viable alternatives as regards the composition of the construction parties. They are:

- . That DLM and the private sector provide one party each, or,
- . That DLM provide both parties.

The former option would allow costs to be contained while facilitating active private sector participation in the project. The latter option would permit tighter monitoring of schedules and standards while minimising operating costs.

It is recommended that the latter option be adopted. However, should the former option be chosen, it is recommended that public and private sector employees be assigned to separate parties. Although DLM monitoring of specifications would be easier if each construction party were made up of representatives from each sector, the management advantages of separate teams are greater. By assigning a specific area, with a certain number of monuments to be established, to a particular party, the responsibility for completion will be clearly defined. This will enable the setting of realistic and attainable targets in the contracts which can be readily monitored. Direct responsibility for equipment and materials provided for the monumentation will be placed on the parties themselves. This approach will also make it simpler to utilise the services of those assigned to the observing parties, as and when available.

At the commencement of both the primary and secondary/tertiary construction stages, instruction and on-the-job training will be provided to ensure that the construction teams are fully competent. It is recommended that Department of Land Management assign a member of staff to work closely with the consultants on the monitoring and supervision of monumentation during the early stages. The person may then gradually take on this responsibility during the course of the project.

It is anticipated that personnel assigned to the observing parties will assist with monumentation when ever possible.

3.12 Form of Witnessing

Witnessing is the term used to describe physical structures which are placed to assist in the relocation of marks and the protection of marks from destruction. Two forms of witnessing are proposed:

Urban Areas

It is proposed that marks in urban areas be covered with a cast iron cover bearing the words "SURVEY MARK". The cover will be level with the ground surface. Care will be taken to ensure that the cover is not physically attached to the concrete monument. This will avoid damage to the control mark should the cover be disturbed. It is essential that the covers be placed so as to allow for the drainage of rainwater.

Rural Areas

It is proposed that marks in rural areas be witnessed by galvanised steel star droppers (star shaped posts) placed adjacent to each survey mark. The droppers will be painted bright orange to assist with their identification. An aluminium witness plate will be attached to the dropper indicating that a survey mark is located a specific distance from the dropper. The plate will also direct inquiries to the Department of Land Management (at a particular phone number), and warn of the penalty for disturbing the mark.

3.13 Spacing of Tertiary Network Marks

An objective of the 1993 GGN project is to optimise the distribution of tertiary marks such that:

- . Cadastral surveys can be readily connected to the network without excessive traversing,
- . Intervisibility between adjacent marks is achieved,
- . Unnecessary and excessive placement of tertiary monumentation is avoided, particularly in rural areas.

Accordingly, it is recommended that tertiary network marks be spaced as follows.

Urban Areas The maximum spacing between urban tertiary network marks be 250 metres, intervisibility being maintained between marks wherever practicable.

Rural Areas The spacing between rural tertiary network marks range from 500m to 1000m, intervisibility being achieved wherever practicable (In some areas it may be appropriate to rely on distant primary or secondary control stations to provide reference objects).

3.14 Estimate of Number of Secondary and Tertiary Marks

A preliminary design has been completed for the secondary and tertiary networks.

The design was prepared from an inspection of zoning plans and recently completed aerial photography. Time constraints prevented an extensive field inspection taking place.

From the design, it is estimated that the number of marks to be established and controlled are as follows:

Secondary Marks	200
Tertiary Marks	2000

This revised estimate should be within 10% of the final number of marks placed on Phase II of the project.

It should be noted that the 200 secondary marks include some existing 1963 GGTN primary and secondary stations. A map is attached as Appendix 5 showing the estimated numbers of marks in each municipality.

3.15 Desirability of Placing Network Marks in Easements and Rights of Ways

During consultations with public and private sector surveyors, it became evident that there was wide support for placing the tertiary marks along the sides of roads (near the line of power poles) rather than in the sealed carriageways. The reasons for this were:

- . The fact that approximately 60% of the 1963 GGTN tertiary network marks had been destroyed (These marks were located along the road centre lines and were destroyed as the roads were reconstructed).
- . The increase in traffic since 1963 has made surveying along the centre lines very dangerous, and is now seen as undesirable by both government and private sector surveyors.

It is therefore recommended that all new tertiary network marks be placed within the

right of way but clear of the sealed carriageway.

The Department of Land Management wishes to avoid creating easements for both mark sites and access to marks on private property. It is therefore recommended that, as far as possible, new marks are placed within existing rights of way or easements.

If there is no alternative, and marks must be placed on private property (for example, in strategic locations such as on hilltops), it will be necessary to negotiate a suitable agreement with the relevant land owners. Such negotiations will be undertaken by Department of Land Management personnel.

3.16 Connection to Existing 1963 GGTN Marks

Wherever possible, surviving 1963 GGTN marks will be connected to the 1993 GGN to facilitate:

- . Derivation of the best possible transformation parameters between the existing Guam geodetic datum and the WGS84 datum,
- . Connection of existing surveys to the 1993 GGN.

Marks which are difficult to access will not be connected unless absolutely necessary.

All surviving primary and secondary stations will become either primary or secondary stations in the 1993 GGN. It is estimated that approximately 400 of the 1963 GGTN tertiary marks will be recovered and connected to the new network.

It is essential that all surviving 1963 GGTN marks be located by Department of Land Management personnel before implementation of Phase 2. Where marks are found they should be witnessed with a piece of rebar and marking tape and/or spray paint as appropriate. The locations of recovered marks should be plotted on a suitable map, and, if necessary, sketches made to facilitate recovery during Phase II. The status of these marks should also be marked on the 1963 GGTN plots to be generated from the Department of Land Management Geographic Information System.

It is proposed that a metal detector be purchased so that 1963 GGTN marks which are below resurfaced roads can be relocated.

3.17 Connection of Department of Public Works Road Centre-Line Monuments

Road centre-line monuments, placed by the Department of Public Works, are not recognised by DLM as cadastral reference marks.

It is therefore recommended that they not be incorporated in the 1993 GGN Project.

These marks could be connected to the network at some future time by Department of Land Management staff using the equipment and expertise acquired on this project.

3.18 Connection to Existing Survey (Non-Network) Marks

Non-network marks refer to all monuments which are placed during the course of a cadastral survey.

The Department of Land Management does not consider the connection of these marks to be a high priority task at the present time.

It is therefore recommended that such marks not be incorporated in the 1993 GGN. Connections could be established at a later date (by Departmental personnel using the GPS equipment and expertise acquired on this project) should a need be identified.

3.19 Location of Underground Services

Before marks are placed, it will be necessary to check for the proximity of any underground services at each locality. It will be the responsibility of Department of Land Management to determine whether underground services are likely to be affected by the construction activities. It will be essential for this information to be provided in a timely manner to avoid any delays in the construction of marks.

SECTION 4**FIELD OPERATIONS****4.1 Identification of Priorities**

The programme of works will be determined in discussion with DLM to ensure that priority areas are clearly identified.

4.2 Percentage of Network to be Controlled with Kinematic GPS

A limited field inspection of Guam was undertaken during Phase 1 of the project.

On the basis of this inspection, it is estimated that at least 95% of the tertiary network could be effectively observed using either Kinematic or Rapid Static GPS techniques.

It should be noted that the Rapid Static technique, while not as fast as Kinematic, will allow fast observation of points when it is not possible to maintain lock on sufficient satellites during movement between stations. Rapid Static techniques are only possible using dual frequency P-Code receivers, such as those proposed for this project.

4.3 Acquisition of Total Station

Given:

- . The large proportion of the proposed 1993 GGN which can be surveyed using GPS,
- . The recent acquisition of a new Wild TC2002 Tachymat Total Station (and accessories) by DLM,

it is not recommended that an additional total station be acquired for the project. It is assumed that DLM's Wild TC2002 will be made available for the project when needed.

4.4 Possibility of Atmospheric Problems for Kinematic GPS

Limited field trials of Kinematic GPS have been conducted during Phase 1. The results suggest that Kinematic GPS should not be adversely affected by tropical atmospheric conditions.

4.5 Vehicle Requirements

The vehicle requirements for the project are as follows:

- . Three four-wheel-drive vehicles will be required for the reconnaissance and GPS observation stages. The vehicles should be no smaller than the Nissan Pathfinder used during Phase 1. In addition, they should be fully enclosed to:
 - Enable equipment to be securely stored at all times, and,
 - Protect equipment against adverse weather conditions.
- . Two four-wheel-drive vehicles will be required by the advisers throughout the project. Periodically, it will be possible to release these vehicles for other uses. On other occasions, it may be necessary to exchange a vehicle for a truck or pick-up (for monumentation).
- . A truck or pick-up will be required during the construction components of stages two and three of the tertiary network.

4.6 Fitting Out of GPS Vehicles

A kinematic GPS survey is conducted by locating a static GPS receiver at a known base-station and moving one or more roving receivers between the stations to be fixed. Each roving receiver occupies a mark for a period of about two minutes, this being sufficient to coordinate the point. It is then relocated to the next mark on the survey.

It is critical to the success of the survey that each roving receiver continuously collect data from at least four satellites at all times. This acquisition must continue during movement between stations. Accordingly, the antenna must be mounted on the outside of the vehicle when travelling.

To minimise the chance of signal obstruction by trees, tall buildings or other structures, the antenna must be mounted as high as possible and should be positioned such that the driver is constantly aware of its location. As two of the GPS vehicles will be used for kinematic observations, they must be fitted with an appropriate mount, on the front of the vehicle, to enable the antenna and range-pole assembly to be quickly and securely attached for travel between stations.

In addition:

- . Each of the GPS vehicles will need to be fitted with a roof rack for transport

of long items of equipment,

- . The GPS receivers need to be mounted on top of the dashboard in a central location,

The fitting out of GPS vehicles must be completed before GPS operations commence. DLM will ensure that the necessary equipment is acquired and fitted.

4.7 Safety Issues

The vast majority of GPS kinematic operation will take place along roads. The method of working will necessitate the GPS vehicles constantly stopping and starting, and being driven in a manner which avoids satellite obstructions. It is therefore essential that appropriate safety measures be adopted throughout the project, and that vehicles be equipped with appropriate safety equipment.

A traffic engineer from the Department of Public Works has advised that both kinematic vehicles should be equipped with a flashing orange light and a sign advising that the *"VEHICLE IS CONSTANTLY STOPPING"*. In addition:

- . All personnel will need to be issued with safety vests which must be worn when working on roads,
- . All field parties will need to be equipped with traffic cones and warning signs.

On very busy roads, such as Marine Drive, it will be necessary to structure working hours to avoid the dangers and inconvenience associated with peak periods. It will be particularly important to schedule kinematic GPS observations for the quietest times. This could be on Sunday mornings.

4.8 Working Hours

Although there is a full constellation of satellites available, there may still be a requirement to work beyond normal hours, either in the interests of efficiency, or to utilise the best periods of satellite geometry.

As mentioned above, it may also be necessary to work at weekends to avoid traffic hazards on busy roads. It is assumed that all personnel will be available as and when required at the discretion of the Project Leader.

4.9 Format for Location Cards

Location Cards will be prepared for all secondary and tertiary stations to facilitate their relocation. The cards will include a location diagram showing the position of each mark in relation to street furniture such as fences, power poles and concrete curbs.

The Location Cards will be standard letter size with a heading incorporating the following:

- . The name of the Department (Department of Land Management),
- . The name of the project (1993 Guam Geodetic Network),
- . The Seal of the Territory of Guam,
- . The 1993 Guam Geodetic Network Project logo.

A Station Summary will be prepared for every primary station. Each summary will include the details specified for the Location Cards and additional information such as access and reference mark details.

The location of each 1993 GGN mark will be indicated on a contact print from the 1993 aerial photography by means of a pin-prick and suitable annotation. This shall be known as photo identification. To enable photo identification, a set of contact prints will be required, providing coverage of all areas where new marks will be established and existing stations utilised. A flight diagram should be provided with the photographs to enable the correct print to be readily accessed.

Visibility Plots will be prepared for each primary network station indicating the location of any obstructions to satellite signals.

4.10 Format for Field Pages

All other field pages required on the project will be standard letter size with the same heading as the Location Cards described above.

SECTION 5**PERSONNEL AND TRAINING****5.1 Key Personnel**

Two members of Department of Land Management staff have been identified as key personnel on this project.

They are Mr. R. Cruz and Mr. B. Atalig.

It is recommended that they be trained and involved in all aspects of the project. It is further recommended that they be candidates for training in South Australia at the end of the project.

5.2 Personnel Required for Project Operations

The following personnel will be required for the field aspects of the project:

Primary Network

Reconnaissance	2 DLM staff	(Cruz & Atalig)
Monumentation	6 DLM staff	(Cruz & Atalig & 4 others)
GPS Training	3+ DLM staff 1 CNMI staff	(Cruz & Atalig & others) &
Observations	3 DLM staff 1 CNMI staff	(Cruz & Atalig & 1 other) &

Secondary & Tertiary Network - Stage I

Reconnaissance	2 DLM staff	(Cruz & Atalig)
Monumentation	4 DLM staff 2 DLM staff & 2 private sector	(depends on private sector involvement) or
GPS Training	3+ DLM staff 1 CNMI staff	(Cruz & Atalig & others) &
Observations	2 DLM staff 1 CNMI staff	(Cruz & Atalig) &

Secondary & Tertiary Network - Stage II

Reconnaissance	5 DLM staff 4 DLM staff 1 DPW staff	(Cruz & Atalig & 3 others) or (Cruz & Atalig & 2 others) &
Monumentation	4 DLM staff 2 DLM staff & 2 private sector	(depends on private sector involvement) or
GPS Training	3+ DLM staff 1 DPW 1 CNMI staff	(Cruz & Atalig & others) & &
Observations	3 DLM staff 1 DPW 1 CNMI staff	(Cruz & Atalig & 1 other) & &

Secondary & Tertiary Network - Stage III

Reconnaissance	5 DLM staff 4 DLM staff 1 DPW staff	(Cruz & Atalig & 3 others) or (Cruz & Atalig & 2 others) &
Monumentation	4 DLM staff 2 DLM staff & 2 private sector	(depends on private sector involvement) or
GPS Training	3+ DLM staff 1 DPW 1 CNMI staff	(Cruz & Atalig & others) & &
Observations	3 DLM staff 1 DPW 1 CNMI staff	(Cruz & Atalig & 1 other) & &

It is important that the above be regarded as indicative of staffing requirements. Flexibility must be maintained to meet any changing needs which become apparent during the project.

5.3 Training Considerations

A major objective of the project is the effective transfer of GPS technology to Guamanian personnel, thereby ensuring its future sustainability. It is proposed that extensive training be provided during the project, this taking the form of:

- . Formal instruction, and,
- . Continuing on-the-job training.

In addition, it is proposed that further on-the-job training in network adjustments be provided in South Australia at the end of the project. This training will take place in a non-academic environment.

Training will also be provided in mark maintenance procedures and survey mark database management.

The Director, Department of Land Management, has declared that he would like:

- . a total of four to six of his staff to be trained to use GPS.
- . staff from the Department of Public Works to be involved in the project.

In addition, the Director expressed an interest in involving personnel from the Commonwealth of the Northern Marianas' (CNMI) Department of Natural Resources in the training aspects of the project. Discussions were held with Mr. F. B. Songsong, Surveyor, of the CNMI who indicated that they would like to have one person involved in each of the training and observational stages of Phase II.

The number of public sector and CNMI personnel requiring involvement in the project meets the required staffing levels for each stage. It is not considered feasible to split the project into more components, or to rotate more people through the project, without causing unnecessary disruption. It is therefore suggested that if private sector involvement is desired for training purposes that it be provided on a voluntary basis. It is not possible to justify denying necessary training to GovGuam personnel.

5.4 Need for Expertise in Final Geodetic Adjustments

It is expected that the network of third order marks will continue to expand following completion of the Guam Geodetic Network Project. The growth will be a necessary response to new development initiatives on the island.

The network expansion will be performed by GovGuam personnel. It is necessary that these personnel possess the necessary knowledge to undertake data acquisition, data processing and network adjustment. At present, such expertise does not exist within the Department of Land Management.

It will therefore be necessary to provide a comprehensive training program for at

least two people on all aspects of GPS surveying. This will include training in the implementation of geodetic adjustments.

5.5 Type of Geodetic Adjustment Training Required

The geodetic adjustment training to be provided will include the following topics:

- . An introduction to microcomputers (including directory and file structures);
- . Compilation of adjustment input files;
- . Processing of adjustment input files through adjustment software;
- . Analysis of key statistics;
- . Analysis of observation residuals; and
- . Transfer of adjusted coordinates to the Guam Survey Mark System.

The training will primarily focus on the adjustment of GPS baselines. However, the adjustment of conventional observations will also be addressed.

Most of the training will take place during project operations on Guam. However, it is proposed that two Guamanian staff members receive further training at the South Australian Department of Environment and Land Management. This training will be for a period of three months and will be conducted towards the end, or upon conclusion, of the project.

5.6 Suitability of Personnel

Geodetic adjustments are complex operations. They are normally undertaken by personnel with tertiary qualifications in surveying/geodesy, or with many years experience in surveying.

The Department of Land Management has personnel who satisfy the latter requirement.

5.7 Publicity and Education

The eventual success of the 1993 GGN will depend upon the comprehension by potential users of:

- . the concepts behind the network, and,
- . the benefits to be derived from its utilisation.

It is recommended that appropriate information be disseminated throughout the project. At the conclusion of the project a brochure should be prepared to provide an explanation of the 1993 GGN and the GPS technology used to establish the network. In addition, training sessions should be held to familiarise users with the operation of the network and its associated records systems.

SECTION 6**COORDINATE SYSTEMS****6.1 Geodetic Datum****6.1.1 Definition of the Existing Guam Datum**

The function of a geodetic datum is to define the location and orientation of a spatial referencing system relative to the body of the earth. It is comprised of two components, being:

- a. An origin station at which the deflections of the vertical and geoid-spheroid separation have been defined or determined,

OR

The coordinates of the origin of the datum (X,Y,Z) relative to the earth's centre of mass.

- b. A reference ellipsoid.

The existing Guam datum was defined during the 1963 triangulation using the following parameters:

- a. The astronomic coordinates of an origin station at TOGCHA (USE),
- b. A reference ellipsoid (Clarke 1866).

An azimuth was observed from the origin station to MACAJNA (GG) for the purpose of orienting the geodetic network.

6.1.2 Discussion - Geodetic Datum

The key issue to be resolved when selecting a future geodetic datum for Guam is whether that datum should be local or geocentric. The issue is not clear cut.

Guam's existing geodetic datum has served the island very effectively over a long period of time. Its method of definition has provided some significant operational advantages to local surveying practitioners. Being an astronomically defined local datum, its spheroid is very closely aligned with the geoid. This, in turn, minimises observation corrections attributable to the deflections of the vertical, usually to insignificant levels. The utility of the datum is further enhanced by the limited extent of the island, and the relatively uniform surface of the geoid.

There are obvious advantages in continuing use of the existing datum. The most important of these is the ability to maintain consistency with existing spatial information, most notably mapping and Geographic Information Systems (GIS). However, the following should be noted:

1. There is now a global trend for countries to adopt geocentric datums as the basis for their domestic spatial reference systems.
2. This trend has been brought about by the advent of satellite navigation systems, and the desire for geographic data bases to be directly compatible with those navigation systems.
3. The most popular of the satellite navigation systems is the Global Positioning System (GPS). This utilises the WGS84 geocentric datum.
4. The continental United States has adopted a geocentric coordinate system (NAD83) which is closely aligned with WGS84. Several federal agencies are now insisting that this system be used in all states and territories for work which they commission.
5. The relationship between the Guam land mass and the WGS84 datum has recently been determined as part of the Philippines Sea Plate Survey.
6. The Department of Land Management will acquire three GPS receivers as a result of the geodetic network project. Naturally, these will operate in the WGS84 system by default.
7. The Guam Power Authority (GPA) has recently acquired two GPS receivers for the purpose of accurately positioning power poles. Other public utilities are considering similar undertakings. Officers of the GPA have expressed a preference for working with WGS84 coordinates to avoid the possibility of errors.
8. It is understood that international hydrographic charts are being progressively converted to the WGS84 datum. There is a strong argument for achieving datum consistency between land and sea-based applications.
9. There is a growing market for GPS equipment, particularly for navigation. There is, therefore, a strong argument for adopting a datum which is consistent with that equipment.

Adoption of the WGS84 system would pose some minor disadvantages for local surveyors. The separation between the geoid and the WGS84 spheroid in Guam is approximately 56 metres. This is significant, and would necessitate the application of

geoid-spheroid corrections to all EDM distances. In the majority of cases, however, a standard correction of 9 millimetres per kilometre would provide sufficient accuracy. The maximum error resulting from this approximation would be 0.5 millimetres per kilometre.

It should be noted that the existing Guam Datum can be related to WGS84 through a set of seven transformation parameters. By using these parameters, WGS84 coordinates (acquired through GPS systems) can be readily converted to the existing Guam datum (and vice-versa). In the short term, this appears an attractive compromise, particularly while there are relatively few GPS receivers in Guam.

However, the transformation process is inconvenient to perform on a routine basis, and is a potential source of error. It is particularly inconvenient for navigation users who may not be skilled in the process, and whose errors might have disastrous consequences.

The Department of Land Management has been presented with a unique opportunity to define a datum which will service the needs of Guam into the twenty-first century. This datum must satisfactorily service a military and civilian population which will increasingly utilise GPS receivers for navigation purposes. The adoption of a geocentric datum would simplify procedures for these users by avoiding the need to transform between two coordinate systems. This, in turn, would remove a major potential source of error and confusion.

Given the limited advantages of a local datum and the growing advantages of a geocentric datum, it is recommended that the WGS84 geocentric datum be adopted as the datum for Guam. It is further recommended that the datum be progressively implemented, commencing on 1st July 1994.

The consultant concedes that the conversion of existing spatial products from one datum to another is not a trivial task. It will require the active cooperation of all interested parties, and will need to be structured in a systematic fashion. However, any proposal to delay conversion will only increase the amount of work required at a later date. It is therefore preferable that conversion be initiated during the Guam Geodetic Network Project.

6.1.3 Legal Implications of Datum Changes

The Director, Department of Land Management, has advised that there is a legal mandate for the 1963 GGTM coordinate values and that new legislation would be required before adoption of the new values from the 1993 GGN could be accomplished.

It is proposed that the legal implications of the 1993 GGN be addressed as part of the Legislation Study during Phase II. Draft legislation will be prepared to enable adoption of the new coordinates, together with any new datum, map projection and coordinate system which may be selected for Guam.

6.1.4 Recommendations - Geodetic Datum

It is recommended that:

1. The Department of Land Management adopt the WGS84 geodetic datum as the territorial datum for Guam,
2. The WGS84 coordinates introduced into the country through the Philippine Sea Plate Survey form the basis of the local datum definition,
3. The Guam implementation of WGS84 be permanently defined through the coordinates of a geodetic origin station. This station should be located in a place of national significance, and should be appropriately monumented.
4. Implementation of WGS84 on Guam commence on 1st July 1994,
5. The legal implications of the 1993 GGN be addressed as part of the Legislation Study during Phase II.

6.2 Map Projection

6.2.1 Existing Situation

The existing map grid for Guam is based on a system of plane rectangular coordinates.

The origin of the grid is located at AGANA MONUMENT, and is defined by the coordinates;

East	50,000 Metres
North	50,000 Metres

All grid bearings are referenced to the geographic meridian through AGANA MONUMENT.

6.2.2 Discussion - Map Projection

The existing map grid used on Guam is officially described as a Modified Azimuthal Equidistant projection (U.S. Geological Survey). In practice, it closely approximates a Transverse Mercator projection and functions as a simple plane grid. The projection works very well on Guam due to the limited extent of the island. Its popularity is reflected by the fact that all survey computations are performed using plane grid coordinates, geographical coordinates rarely being used.

The existing Guam map grid appears to suffer from two deficiencies when compared with other projections used in surveying environments. In particular:

1. It is not a conformal projection, and does not, therefore, rigorously preserve angular relationships away from the central meridian. This is not a serious problem on Guam as the angular distortions are insignificant for virtually all applications.
2. It is not widely supported by current surveying computer software. Again, this is not a serious problem. However, it will increasingly become a consideration as the utilisation of GPS on Guam expands.

The Universal Transverse Mercator (UTM) projection is probably the best known of the map projections used in surveying environments. The UTM system is global in its extent, and utilises well defined parameters and formulae. Unfortunately, the scale factors inherent in the UTM system discourage its use for certain applications. Problems can become particularly severe at the edges of zones where scale corrections may reach 700 parts per million (ppm).

To overcome these problems, agencies frequently implement local Transverse Mercator (LTM) projections to satisfy local needs. Such projections share the same mathematics as the UTM system. However, they are defined by a local central meridian, central scale factor and false origin, and are positioned to minimise linear distortions in a particular area of interest. An increasing number of commercial software packages will allow the user to define an LTM projection.

It is possible to define a local transverse mercator projection for Guam based on the following parameters:

1. **A Central Meridian of 144° 45' East Longitude** - This will pass through central Agaña very close to Agaña Monument. Its position will ensure that projection distortions remain insignificant (for land survey applications) across the entire island.

2. **An Origin at the Intersection of 13° 30' North Latitude and 144° 45' East Longitude which is assigned the coordinate 100,000 Metres East and 200,000 Metres North** - This will assign an Easting coordinate of 100,000 to all points on the Central Meridian, placing the easting origin 100 Km to the west. Easting coordinates on Guam will fall into the range 85,000 - 125,000. These values are distinctly different from the existing grid values, and will avoid confusion with the existing grid.

The origin for Northing coordinates will lie on the Central Meridian. Northing coordinates on Guam will fall into the range 165,000 - 215,000. These values are distinctly different from both the existing grid values and the proposed easting values, again avoiding confusion.

3. **A central scale factor of 1.000000** - This will result in the generation of grid scale factors ranging from 1.000000 in Agana to 1.000002 (2 millimetres per kilometre) at Apra Harbour and 1.000006 (6 millimetres per kilometre) at Pt Pati. These factors could be ignored for most practical purposes.

It should be noted that, once implemented, the LTM grid will function in exactly the same fashion as the existing grid. The only difference apparent to most practitioners will be the change in coordinate values, distinguishing the new system from the old. However the projection will be rigorously conformal, and will permit transformations between grid and geographic coordinates.

6.2.3 Recommendations - Map Projection

It is recommended that a local Transverse Mercator projection be adopted for cadastre-related applications in Guam.

The projection should be referred to as the Guam Map Grid.

The parameters of the projection should be as follows:

Central Meridian and Longitude of Origin	144° 45' East Longitude,
Latitude of Origin	13° 30' North Latitude
Easting of Origin	100,000 Metres,
Northing of Origin	200,000 Metres,
Central Scale Factor	1.00000

6.3 Absolute Position Information from the Philippine Sea Plate Survey

Dr. John Beavan (Lamont-Doherty Geological Observatory, Colombia University, Palisades, New York) conducted two Philippine Sea Plate Experiment Surveys during 1991 and 1992.

The surveys determined the position of station AAFB 1990 by analysing data observed at that station and at three CIGNET stations in Hawaii, Japan and Australia.

In his preliminary report he indicated that initial analysis produced coordinates of AAFB 1990 at about the one metre level on the WGS84 ellipsoid.

While not essential, the final analysis of these surveys would be useful in refining the absolute position of Guam. In addition, it would also be useful to obtain his data for the other points of the 1963 GGTN (observed as part of his campaigns) for inclusion in the adjustment of the 1993 GGN.

Accordingly, a letter has been sent to Dr Beavan by the Director, Department of Land Management requesting the final analysis, the observed data and the adjusted data for the surveys. It is recommended that this matter be pursued until a suitable response is received.

It is understood that Dr Beavan will shortly repeat his surveys to determine the effect of the recent earthquake on the Guam land mass. It is recommended that the data and results from this survey be obtained at the earliest possible time.

SECTION 7 ASSESSMENT OF EXISTING SURVEY NETWORKS

7.1 Horizontal Control - The 1963 Triangulation Network

7.1.1 Background

In 1963, the U.S. Coast and Geodetic Survey undertook a triangulation survey of Guam.

The survey incorporated a total of 159 stations, comprising 29 primary stations, 87 supplementary stations, 30 intersection stations, and 13 traverse stations.

A report on the project advised that the primary triangulation was observed to U.S. first order class II specifications. The remainder of the network was observed to U.S. second order class I and II specifications.

Scale control was provided by twelve tellurometer distances, clustered in three groups across the island.

Orientation was provided by astronomic azimuths observed between TOGCHA (USE) and MACAJNA (GG).

7.1.2 Data Set

Evaluation of the triangulation was undertaken using:

1. The adjusted observations and coordinates generated during the 1963 network adjustment.
2. WGS84 coordinates for ten triangulation stations, generated by John Beavan (Lamont-Doherty Geological Observatory, Columbia University, Palisades, New York) in 1992.

It would have been preferable to have had access to the unadjusted triangulation data when analysing the quality of the network. However, the fact that the data was stored in Washington D.C. rendered this impractical. It was therefore decided to utilise the adjusted data during the initial investigation. A decision regarding acquisition of the raw data was to be delayed pending the outcome of the investigations.

7.1.3 Assignment of Observation Accuracies

Accuracy estimates were assigned to each of the derived observations on the basis of triangle closure statistics and weighting information supplied in the 1963 report. The estimates were as follows:

First Order Class II Observations	1 S.D = 0.50"
Second Order Class I Observations	1 S.D.= 0.75"
Second Order Class II Observations	1 S.D.= 1.00"
Tellurometer Distances	1 S.D.= 5 cm + 5 ppm
Azimuths	1 S.D.= 1.5"

7.1.4 Method of Network Assessment

Assessment of the 1963 triangulation network was undertaken in two phases.

The first phase involved an internal assessment of the expected accuracy of the network. This was implemented by incorporating the adjusted coordinates and observations for 95 stations into a network adjustment file. The file was then processed using the least squares adjustment program NEWGAN. The program generated error ellipses for each point and line in the network. These were derived from the network geometry and the accuracy estimates assigned to the adjusted observations.

The second phase involved a comparison of the triangulation with an independent data set. This was achieved by reprocessing the network adjustment file, holding fixed the coordinate set generated by John Beavan. This adjustment was performed on WGS84, necessitating the application of geoid-spheroid correction to the tellurometer distance. All azimuths were removed from the adjustment, allowing the fixed stations to orient the network.

7.1.5 Results - Phase 1

The results of the first phase were as follows:

1. Initial processing revealed the presence of three significant inconsistencies between the adjusted data and adjusted coordinates. These were:
 - a. A mis-identified quadrant identifier on bearing SANTA ROSA - PATI (should be E instead of W),
 - b. An incorrect bearing from MACAJNA to MERCY (No obvious reason

for this could be identified),

- c. A minor inconsistency on the bearing from MANALISAY to SCHROEDER (No obvious reason for this could be identified).

The direction from MACAJNA to MERCY was deleted to allow processing to proceed.

2. Corrections to adjusted data were within the round-off level in the vast majority of cases. This confirmed a high degree of numerical consistency between the adjusted coordinates and adjusted observations.
3. The largest point ellipse occurred at Pati, this having a semi-major axis of 0.170 metres.
4. Only 3 of the 264 line ellipses failed to satisfy Australian Class A and Class B accuracy criteria. Each of these was associated with a short line.

7.1.6 Results - Phase 2

The adjustment of the triangulation network onto the ten GPS stations produced the following summary statistics:

Variance Ratio	0.5433
F Test Factor	1.3630

The fact that the variance ratio statistic returned a value less than unity and the F Test statistic returned a value greater than unity suggests a high degree of consistency between the data sets.

Four observations (out of 541) received excessive corrections, this being less than 1%. The maximum distance correction was 10.3 ppm. All other distance corrections were less than 6.0 ppm.

7.1.7 Conclusions and Recommendations

The results of both phases have to be treated with caution. The absence of the raw data is an impediment to concluding a satisfactory data analysis. Indeed, it is impossible to validate the accuracy estimates produced by the software without access to observation residuals. In addition, the earthquake of 8th August 1993 may have disturbed the stations, degrading the applicability of the results. Subject to those qualifications, however, the following conservative conclusions may be drawn:

1. Assuming that the accuracy estimates assigned to the observations are representative of the actual situation, the primary and secondary stations in the GGTN network satisfy Australian Class A and B accuracy specifications.
2. Given the consistency between the GGTN stations and the WGS84 coordinates, it seems likely that an adjustment involving the original observations and hypothesised accuracy estimates would produce a statistically valid outcome.

This leads to the conclusion that the 1963 triangulation is of a very high quality, and provides excellent support to Guam's existing geographic referencing system. It is, therefore, unlikely that further analysis of the original observations will be necessary.

Accordingly, it is recommended that no further action be taken to acquire the original observations for the 1963 triangulation at this stage.

7.2 Vertical Control - The 1963 Levelling Network

7.2.1 The Vertical Datum

The Guam vertical datum is based on mean sea level. It was derived from tidal observations taken at Apra Harbour over a period of 13 years, 10 months (January 1949 - October 1962).

A second datum, mean lower low water, is related to the Guam Mean Sea Level datum, through the addition of 1.35' to the mean sea level elevations. It is understood that this latter datum is favoured by engineering organisations.

7.2.2 The Primary Levelling Network

The core of the Guam vertical network was established by the U.S. Coast and Geodetic Survey in 1963. It comprises three inter-connected levelling loops. These loops traverse much of the perimeter of the island, as well as crossing the island in the central and northern regions.

The original data and reductions for the network are stored in Washington D.C. As copies are not kept on Guam, it was not possible to initiate a thorough analysis of the network. However, a copy of a single level reduction sheet indicated that:

1. All level measurements were read to four decimal places,
2. The difference between forward and backward levelling was typically at the

2 millimetre per kilometre level,

3. During adjustment, the correction to each bay was at the 0.1 millimetre per kilometre level.

If typical of the remainder of the network, this suggests that the levelling network is of a very high quality, and should be capable of supporting the height requirements of Guam for the foreseeable future.

However the following should be noted:

1. A significant number of Bench Marks have been destroyed since the levelling was completed in 1963. Further losses will adversely affect foundation of the Guam height system. It is imperative that the remaining marks be protected to prevent further loss.
2. There is considerable uncertainty regarding the impact of recent geophysical activity on the Guam land mass and thus the stability of the height datum. The most recent effects could be identified through a repetition of the GPS survey undertaken by Dr Beavan in 1991/92. Long-term changes, however, could only be resolved through an analysis of tide gauge records and a re-levelling of the island. Such activities are beyond the scope of this project. They should, however, be considered for further investigation.

7.2.3 Conclusions and Recommendations

Given the limited information available, it would appear that the datum definition and levelling network underpinning the height system in Guam were soundly based. However, its longevity is threatened by the progressive destruction of Bench Marks. In addition, there is uncertainty regarding the currency of datum due to recent geophysical activity.

It is therefore recommended that:

1. The existing Guam Mean Sea Level datum continue to be the principal datum for heights in Guam,
2. Immediate action be taken to ensure the on-going preservation of surviving benchmarks,
3. The forthcoming results of post-earthquake surveys be analysed to identify any recent displacements in the vertical datum,

4. An investigation of tidal records be undertaken to identify possible long-term changes in the datum,
5. Subject to the outcome of the earthquake studies and tidal investigation, consideration be given to re-levelling the island.

SECTION 8 TRANSFORMATION REQUIREMENTS STUDY

8.1 Introduction

The adoption of a new geodetic datum and map projection will necessitate the generation of new coordinate values for all survey marks and geographically defined objects in Guam.

This can be most efficiently accomplished through a coordinate transformation between datums.

Typically, a transformation process proceeds in two stages. Stage 1 involves generating a set of transformation parameters relating the two datums. This is accomplished by identifying stations which possess coordinates in both old and new systems. Typically, these coordinate sets will have been generated by two independent surveys (for example, GGTN-63 and a GPS survey).

Once generated, the parameters are applied to other old-system coordinates, thus converting them to the new system. This constitutes Stage 2 of the process

The effectiveness of the transformation technique is dependent on the geometric consistency between the two networks. If both networks were accurately measured, the integrity of the parameters will also be high, and provide consistent transformations between the systems. However, if the accuracy of one (or both) of the systems were poor (for example, due to regional network distortions), the accuracy of the parameters will also be poor, providing less satisfactory results. In such circumstances, multiple sets of local transformation parameters may be needed to satisfy accuracy requirements

As part of this consultancy, two investigations were undertaken to determine the feasibility of adopting a single set of transformation parameters for Guam. Their outcome is described in the following paragraphs.

8.2 Transformation Investigation - Geodetic Datums

The datum transformation investigation involved generating a set of seven transformation parameters relating the existing Guam datum to WGS84.

The process utilised 16 stations which possessed coordinates in both systems. The Bursa-Wolf 3D transformation model was used in the processing.

The input coordinate values are included as Appendix 6. The WGS84 coordinates for

11 of the stations were generated by John Beavan during the Philippine Sea Plate survey of 1991/92. Values for the remaining five stations were determined by the consultants using GPS receivers. Two of Beavan's points were used as base stations during this process.

The Guam datum coordinates (1963) were obtained from supplied DLM records.

Both sets of coordinates were entered as latitude, longitude and height. The WGS84 coordinate set included spheroidal heights generated by the GPS system. Spheroidal heights for the GGTN coordinates were fabricated by subtracting 56 metres (the approximate geoid-spheroid separation) from the WGS84 heights. This procedure, while not rigorous, permitted a representative analysis of the horizontal coordinates to take place.

All latitudes and longitudes were assigned standard deviations of 6 centimetres.

8.3 Transformation Investigation - Map Grids

The grid transformation investigation involved generating a set of four transformation parameters relating the existing GGTN grid to the proposed local transverse mercator grid.

The process utilised the same 16 stations employed in the datum transformation investigation. The Helmert similarity transformation model was used in the processing.

The input coordinate values are included as Appendix 7. The local transverse mercator coordinates were rigorously derived from WGS84 coordinates using Redfearn's Formulae.

The GGTN coordinates were obtained from supplied DLM records.

All eastings and northings were assigned unit weight.

8.4 Results

8.4.1 Datum Transformation

The datum transformation parameters generated are listed in Table 1.

Table 1

Datum Transformation Parameters

Parameter	Value
X Translation	35.053 m
Y Translation	-24.375 m
Z Translation	99.214 m
W1 Rotation	-2.76"
W2 Rotation	-4.39"
W3 Rotation	-8.72"
Scale	2.76 ppm

It should be noted that the scale factor between the two datums is less than 3 parts per million. This is consistent with the expected accuracy of both:

- a. the GPS baselines, and,
- b. the tellurometer distances used to scale the 1963 triangulation.

The post-transformation residuals are listed in Table 2. These represent the differences between the WGS84 coordinates and the Guam datum coordinates following application of the transformation parameters. The following should be noted:

1. In general, the residuals are small, the largest single residual being 0.11 metres at USO.
2. The residuals in the Agana area (BARRIGADA, CRUSHER, MACAJNA, WETTENGEL, YPAO) are particularly small, the largest values being at YPAO (0.021 metres latitude, 0.033 metres longitude)
3. The stations in the south of the island (ASOLONSA, BOAGA, IPACHOL, SOLEDAD, TOGUAN) displayed larger longitude residuals than the northern stations, ranging from 0.072 at BOAGA to -0.077 at SOLEDAD. It is believed that this is partly a consequence of the sparse geometry of the GPS network. The effect is expected to be reduced when a full GPS network is observed.

Table 2

Post-Transformation Residuals

Number	Name	Latitude (Metres)	Longitude (Metres)
76	ASALONSA	-0.024	0.052
34	BARRIGADA	0.020	0.027
93	BEACH	0.051	0.054
116	BOAGA	0.039	0.072
62	CHACHAO	-0.026	0.008
35	CRUSHER	0.005	-0.005
112	IPACHOL	-0.045	0.031
59	LOOK	-0.035	-0.055
51	MACAJNA	-0.015	0.004
9	SALISBURY	-0.003	-0.026
102	SOLEDAD	0.034	-0.077
101	TOGUAN	0.020	-0.040
10	URUNO	-0.027	0.003
64	USO	-0.016	-0.112
30	WETTENGEL	0.001	0.031
42	YPAO	0.021	0.033

8.4.2 Grid Transformation

The transformation parameters generated are listed in Table 3.

Table 3

Grid Transformation Parameters

Parameter	Value
E Translation	50124.646 m
N Translation	147113.023 m
Rotation	1.211"
Scale	-5.94 ppm

It should be noted that the orientation difference between the two datums is less than 2 seconds of arc. This could be ignored for most practical purposes.

The post-transformation residuals are listed in Table 4. These represent the differences between the LTM coordinates and the GGTM coordinates following application of the transformation parameters. The following should be noted:

1. In general, the residuals are small, the largest single residual being 0.11 metres at USO.
2. The residuals at each station agree very closely with their corresponding values in Table 2 (usually within 1 cm).

Table 4

Post-Transformation Residuals

Number	Name	Northing (Metres)	Easting (Metres)
76	ASALONSA	-0.028	0.058
34	BARRIGADA	0.025	0.029
93	BEACH	0.051	0.054
116	BOAGA	0.048	0.073
62	CHACHAO	-0.022	0.008
35	CRUSHER	0.008	-0.002
112	IPACHOL	-0.049	0.028
59	LOOK	-0.029	-0.052
51	MACAJNA	-0.017	0.000
9	SALISBURY	-0.005	-0.017
102	SOLEDAD	0.029	-0.077
101	TOGUAN	0.019	-0.044
10	URUNO	-0.030	0.003
64	USO	-0.020	-0.112
30	WETTENGEL	-0.002	0.030
42	YPAO	0.022	0.027

8.5 Conclusions and Recommendations

The transformation parameters in Tables 1 and 3 must be treated as preliminary values. They are dependent on a series of GPS baselines which are structurally weak. This deficiency will be overcome during the re-observation of the primary network.

It must also be stressed that the parameters in Table 1 are applicable only to latitude and longitude values. The fabricated heights associated with GGTN coordinates preclude their use for transforming vertical data.

Despite this, however, the results are very encouraging, and suggest:

1. A high degree of geometric consistency between the GGTN and preliminary GPS networks,

2. A high probability that a single set of datum transformation parameters could be adopted for the entire island,
3. A high probability that a single set of grid transformation parameters could be adopted for the entire island.

It should be noted that these results are based on data acquired before the August 1993 earthquake. There is no certainty that they now represent the actual situation. It is therefore recommended that final transformation parameters (grid and datum) be computed following completion of the GGN primary and secondary networks, and that the parameters be subsequently considered for adoption.

SECTION 9 **ESTABLISHMENT OF VERTICAL CONTROL**

9.1 **Introduction**

The 1993 Guam Geodetic Network Project will establish an extensive network of tertiary geodetic marks across the island. Coordinates, including spheroidal heights, will be generated for each of these marks. The expected accuracy of these heights relative to the secondary control is expected to be no worse than five centimetres. The relative accuracy between adjacent marks is expected to be significantly higher.

Spheroidal heights are the heights of points above the reference ellipsoid. They suffer the disadvantage of not being related to the physical environment. Thus, for example, a series of points along the sea shore may have different spheroidal heights. In order to find practical application, spheroidal heights must be converted to orthometric heights. Orthometric heights are the heights above the geoid (approximately mean sea level). Orthometric heights are used on an everyday basis, as they are consistent with the earth's physical environment. Points along the sea shore have the same orthometric height.

A spheroidal height can be converted to an orthometric height by applying the geoid-spheroid separation. This necessitates the availability of a sufficiently accurate geoid map for the area of interest.

9.2 **A Geoid Map for Guam**

At present, no precise geoid model exists for Guam. The rigorous generation of such a model would require the application of considerable specialised resources. The resources are not available at the present time.

An alternative approach is to generate a close approximation to a geoid map based on the differences between levelled and GPS-derived heights at a series of bench marks. Such derivations assume the levelled heights to be orthometric, and the GPS heights to be spheroidal. The procedure is as follows:

1. A series of points (benchmarks) are identified which have sufficiently accurate levelled heights. These points should be uniformly distributed around the perimeter of the island. Additional points internal to the island should be included where possible.
2. GPS-derived heights are determined for each of the bench marks.
3. The levelled and GPS-derived heights at the bench marks are differenced to produce geoid separation values.

4. Geoid separation values are calculated for other points in the network by interpolating between the control point values.
5. GPS-derived spheroidal heights are determined for all other primary, secondary and tertiary stations in the network.
6. The GPS-derived heights are made compatible with levelled heights by applying interpolated geoid separations.

It should be noted that the accuracy of the calculated orthometric heights will be dependent on:

1. The accuracy of the GPS-derived heights at all stations,
2. The accuracy of the levelled heights at the control stations,
3. The accuracy of the interpolation procedure. (This, in turn, will be dependent on the distance between control points and the behaviour of the geoid in the area.)

9.3 Geoid Mapping Investigation

To investigate the feasibility of interpolating geoid separations for each GGN station, an investigation was initiated to generate a preliminary separation map for Guam. The procedure was as follows:

1. A series of eight bench marks were selected which provided uniform coverage of the island,
2. GPS heights were derived for each of the benchmarks.
3. Separation values were calculated at each bench mark by differencing the GPS height and levelled height (Vide Table 5).
4. A geoid map was derived by interpolating contours between the computed separations.

The map is included as Diagram 1. It can be seen that contours suggest a relatively linear gradient over much of the island, the gradient increasing towards the south-western corner. In addition, there appears to be some variation to the linearity of the gradient in the northern part of the island. Insufficient information is currently available to determine the extent of this variation.

Table 5

Geoid-Spheroid Separation at Benchmarks

Station	GPS Height	Levelled Height	Separation Value
9 SALISBURY	244.398	187.899	56.499
30 WETTENGEL	146.851	90.195	56.656
64 USO	60.162	3.621	56.541
35 CRUSHER	143.700	87.493	56.207
93 BEACH	58.022	1.897	56.125
76 ASOLONSA	129.676	74.063	55.613
112 IPACHOL	146.766	91.320	55.446
102 SOLEDAD	99.911	44.437	55.474

9.4 Conclusion and Recommendations

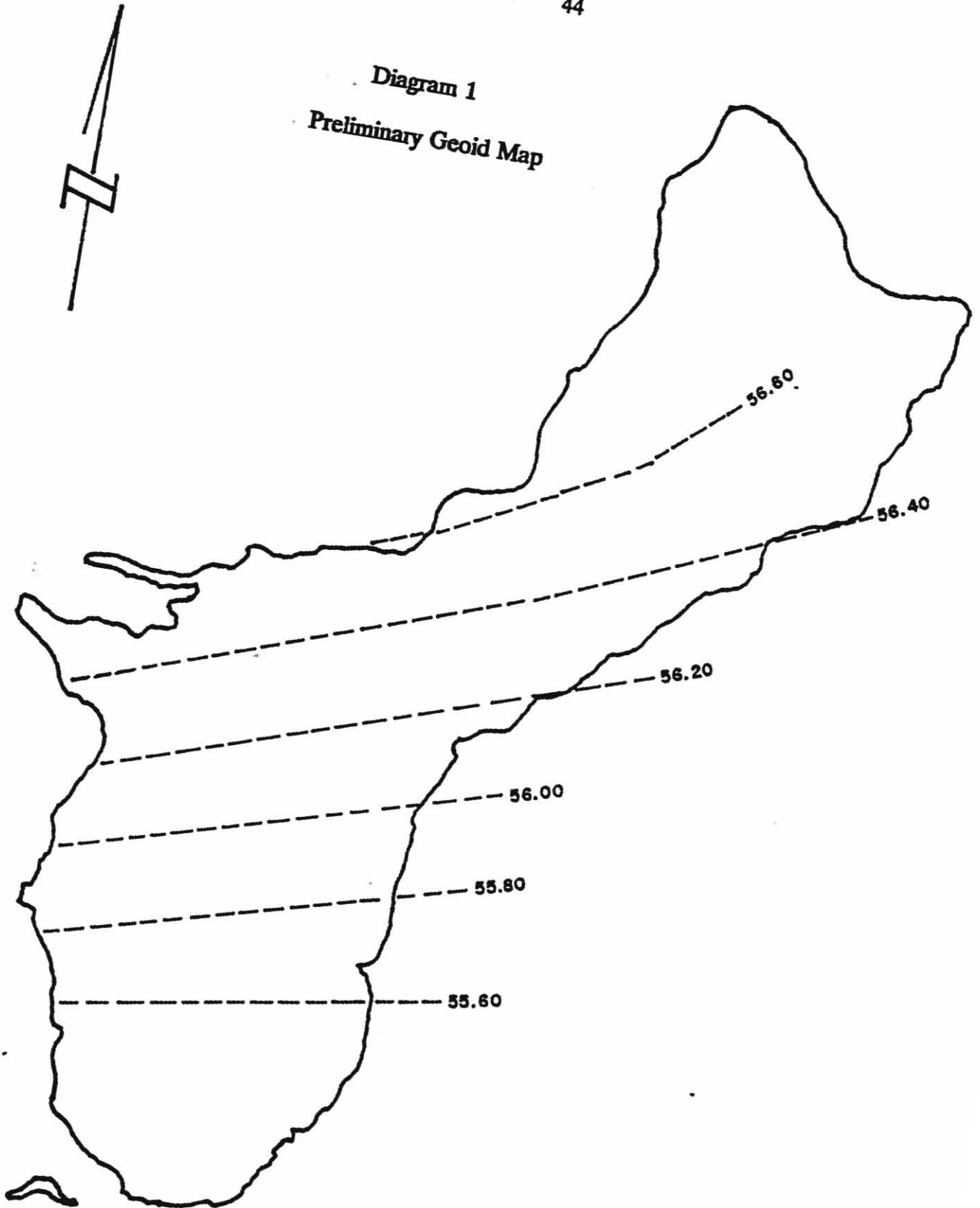
The separation map included as Diagram 1 must be treated as a preliminary document. It has been generated from sparse information which has subsequently been earthquake affected. Its reliability must therefore be limited by those facts.

However, the results suggest that, with more complete information, it would be possible to interpolate separations to an accuracy of 1 centimetre.

It is therefore recommended that (subject to a satisfactory outcome of post-earthquake studies):

1. All existing 1963 benchmarks be included in the secondary GPS network,
2. A separation map (or table of interpolated separation values) be prepared by differencing the levelled and GPS-derived heights at the benchmarks,
3. Interpolated separation values be applied to the GPS-derived heights at the tertiary stations to produce heights compatible with conventional levelling.

Diagram 1
Preliminary Geoid Map



SECTION 10 DESIGN FOR THE GUAM SURVEY MARK SYSTEM

10.1 Background

The following paragraphs set out a broad system design for the proposed Guam Survey Mark System (GSMS).

The proposal is divided into ten sub-sections, these being:

- . System Components - A general conceptual picture of what the GSMS is going to provide,
- . Design Considerations - A discussion of database and screen designs,
- . Hardware and Software - Consideration of the hardware and software to be used,
- . System Development Plan - A detailed plan for the completion of the four phases in the GSMS development process which follow the Broad System Design,
- . Data File and Location Card Creation - Loading the 1993 GGN into the system,
- . Survey Mark Index Creation - Issues relating to data drawn from the GIS system,
- . Records Maintenance - Maintaining the currency of the data,
- . Organisational Issues - Issues associated with the implementation of the new system (eg allocation of responsibility for the development and maintenance of the GSMS),
- . Associated Issues - Any other relevant issues concerning the GSMS,
- . Future Development of GSMS - A brief discussion of future system enhancements.

It is recommended that the proposed system be implemented by the Survey Data Base expert in close consultation with DLM personnel.

10.2 System Components

10.2.1 Overview

It is proposed that the GSMS comprise three inter-related sub-systems, these being:

- (i) The Survey Mark Data Base;
- (ii) The Survey Mark Index;
- (iii) The Location Cards.

The function of each is described below.

10.2.2 Survey Mark Data Base

The Survey Mark Data Base (SMDB) will be a computer-based information system storing attribute data for all 1993 GGN survey marks.

The stored information will be accessible to the public through an on-line enquiry system. Two screen displays will present the information, these being:

1. The Mark Detail Form: This will display information about the mark, including:
 - . Mark Number
 - . Rectangular Coordinates and Projection
 - . Geographical Coordinates and Datum
 - . Horizontal Order
 - . Horizontal Class
 - . Horizontal Purpose
 - . Horizontal Agency
 - . Horizontal Fixing Method
 - . Adjusted (Horizontal)
 - . Adjustment Date (Horizontal)
 - . Entry Date (Horizontal)
 - . Elevation and Vertical Datum
 - . Vertical Order
 - . Vertical Class
 - . Vertical Purpose
 - . Vertical Agency
 - . Vertical Fixing Method
 - . Adjusted (Vertical)

- . Adjustment Date (Vertical)
- . Entry Date (Vertical)
- . Mark Type
- . Previous Reference
- . Status
- . Special Note

2. The Mark Reference Form: This will display a record of visits to each mark for Mark Maintenance purposes. It will show:

- . Mark Number
- . Reference
- . Status
- . Date

Full descriptions of the attributes in the Mark Detail and Mark Reference forms are included as Appendices 8 and 9. Examples of the proposed screen layouts are included as Appendices 10 and 11.

10.2.3 Survey Mark Index

The Survey Mark Index will comprise a series of large scale hard-copy maps (eg 1:2500) depicting the geographic position of all 1993 GGN survey marks.

The map information will be generated by the Department's Geographic Information System (GIS) utilising cadastral data stored in the Planning Layer.

The survey mark data will be provided via the SMDB, and will include:

- (i) the survey mark numbers;
- (ii) the horizontal coordinates;
- (iii) the mark status indicators (existing or gone).

An example of the Survey Mark Index is included as Appendix 12.

10.2.4 Location Cards

A Location Card will be produced for each survey mark. The card will contain a diagram showing the position of the mark in relation to street furniture (for example, power poles, concrete curbs and fences). Each card will be numbered with the

appropriate survey mark number.

This sub-system of the Guam Survey Mark System will be completely manual in form, as distinct from the other two which are computer-based.

An example of a Location Card is included as Appendix 13.

10.2.5 Method of Operation

The way in which the GSMS will operate is illustrated by the following example.

Suppose a surveyor wishes to search for survey marks in an area of Agana. He would first consult the appropriate Survey Mark Index Map and note the numbers of the survey marks which fall within his area of interest (for example, survey marks 1241, 1242, 1245 and 1258).

He would then enter each mark number into the SMDB to obtain the coordinates and related information. A print-out of this information would be available.

Finally, the surveyor would obtain copies of the relevant Location Cards for each survey mark. He is now ready to embark on the survey with all relevant survey mark information at his disposal.

10.3 Design Considerations

10.3.1 Data Model

A preliminary data model for the system is depicted by the entity-relationship diagram in Appendix 14.

It is proposed that all information be stored in two tables within a relational database, one holding the mark details, the other holding the mark references. The relationship between Mark Details and Mark References would be one-to-many. Thus for each survey mark, there could be:

- . no entries in the Mark Reference Table;
- . one entry in the Mark Reference Table;
- . many entries in the Mark Reference Table.

By the completion of the 1993 GGN Project, every participating survey mark will have:

- . a record in the Mark Details table, and,
- . at least one reference in the Mark References table (ie the reference to the placement or discovery of the mark).

However, it is likely that other marks that do not form the 1993 GGN will be included in the SMDB at a later date. For these marks, it will be possible that only the mark details are stored, with no corresponding mark references. Hence, there will be no business rule which stipulates that, for every survey mark, there must be at least one mark reference (although this will be the case for marks that form the 1993 GGN).

10.3.2 Data Dictionary

A preliminary data dictionary for the system is included as Appendices 8 and 9. The dictionary provides a basic explanation of the elements which will comprise the SMDB. Examples of each element can be found in Appendices 10 and 11.

A complete Data Dictionary will be produced during the Detailed System Design Phase.

10.3.3 Data Flow Diagram

Appendix 15 shows a Data Flow Diagram for the GSMS. This indicates the nature of data flows into, out of, and between the three sub-systems.

10.3.4 Proposed Screen Layouts

Appendices 10 and 11 show the preliminary proposals for the Mark Detail and Mark Reference enquiry forms respectively.

Additional forms will be developed to facilitate the update and maintenance of the SMDB by DLM personnel.

The structures of all forms will be finalised during the Detailed System Design Phase. This will be the responsibility of the Survey Data Base Expert.

10.3.5 Interfaces Between Sub-Systems

It is essential that the following business rules be rigorously maintained between the three system components:

- (i) The Survey Mark Index must be a graphic display of the 1993 GGN and must therefore reflect the contents of the Survey Mark Data Base.

As the Survey Mark Index is a static (rather than dynamic) view of survey mark positions, each map sheet must be replaced as required.

- (ii) For every survey mark in the SMDB, there must be an associated Location Card.

10.3.6 Volume and Frequency of Use

The GSMS will hold a relatively small quantity of strategic data for use by a specific group of professionals.

The anticipated volume of users of the GSMS will be low (estimated maximum at any one time: 3 people). The frequency of enquiries will also be low.

It is therefore anticipated that two terminals will be sufficient for public access to the SMDB. In addition, one complete copy of Location Cards and a set of up-to-date maps that form the Survey Mark Index will be sufficient for user demand.

No consideration is being given to remote SMDB access at this stage. One central searching area will adequately meet the needs of the public.

10.4 Hardware and Software

It is proposed that DLM's existing Geographic Information System (GIS) computer environment be used to host the SMDB. The environment consists of the following elements:

Hardware

- . IBM RISC 6000/950 (256 MB Memory, 9.8 GB Disk). Operating System AIX V3.1.

An upgrade to the 980 model is imminent (512 MB Memory and AIX V3.2.3).

- . 12 X-Terminals, eight of which are used for data capture. The remainder are used for system and data base administration which is carried out by staff from Data Processing Division (DPD), Department of Administration.

Software

- . Genasys, which includes the following modules:
 - (i) Genamap V5.1 (GIS module);
 - (ii) Genacivil V2.1 (Civil Engineering module).
- . Ingres V6.3 (an upgrade to V6.4 is imminent).
- . Uniface V5.1.d2 (an upgrade to V5.2.e2 is imminent).

It is recommended that the necessary query, update and maintenance forms be built using the Uniface development environment.

It is recommended that the survey mark data be stored in the Ingres data base.

It should be noted that disk storage requirements for the survey mark data will be minimal and will be adequately met by the existing configuration. As queries will be text-based (as distinct from graphics queries), the present quantity of memory will be satisfactory for on-line enquiries.

It will be necessary for DLM to acquire two additional text-based terminals to service public access to the SMDB. The existing X-Terminals will be suitable for data entry.

10.5 System Development Plan

10.5.1 Stages of Development

It is proposed that development of the GSMS take place in four phases as follows:

- (i) Detailed System Design (five weeks);
- (ii) Development (five weeks);
- (iii) Testing (one week);
- (iv) Implementation (two weeks).

It is recommended that a Survey Data Base Expert from the South Australian Department of Environment and Land Management (SADELM) be the coordinator for these four phases. The expert will be on-island for a period of thirteen weeks during the second phase of the Guam Geodetic Network Project.

10.5.2 Detailed System Design

The objective of this phase is to compile a detailed system specification from the information contained in the Broad System Design document. The Detailed System Design should consider each of the three sub-systems of the GSMS separately. It is anticipated that the SMDB and Survey Mark Index will require much closer attention than the Location Card sub-system.

The Detailed System Design document will include:

- (a) Finalisation of the SMDB Data Dictionary,
- (b) A detailed description of all screen displays forming the Uniface interface to the SMDB,
- (c) The Hardware and Software Configuration/Requirements

This will include estimates of resources required, interfaces to proprietary software, and use of packages,

- (d) The Test Plan (in readiness for the Testing Phase),
- (e) The Implementation Strategy

This will be a refinement of the System Development Plan presented in the Broad System Design, and will include a task list and project schedule,

- (f) Initial File Creation

This will comprise a statement of how SMDB files are to be created (including design of coding sheets for data entry into the SMDB and specification of data import from GeoLab to Ingres).

Also, a decision regarding the type of symbols to be used on the Survey Mark Index will be made at this time.

In addition, the most suitable searching medium for Location Card display will be chosen (ie photocopy or microfilm).

(g) Training Plan

A preliminary training plan for users will be provided.

10.5.3 Development

This phase will primarily involve the production of forms for the SMDB using the Uniface development environment. The designs generated during the Detailed System Design Phase will be used during this process.

The development of prototype maps for the Survey Mark Index, using the Planning Layer in combination with test data from Ingres, will also take place at this time.

10.5.4 Testing

The Testing Phase will involve implementing the Test Plan developed during the Detailed Design Phase. All aspects of the GSMS will be tested, including backup and recovery procedures for the Ingres data base.

10.5.5 Implementation

This phase incorporates the final stages of testing and documentation prior to the system becoming operational in a production environment. The four main issues to be addressed during this phase are:

(i) Implementation Plan

This plan is based on the Implementation Strategy prepared as part of the Detailed System Design. The plan should comprise a detailed task list outlining all tasks and responsibilities up to the time when the system becomes operational.

(ii) User and System Manuals

Both manuals must be produced during this phase. The System Manual will include backup and recovery procedures.

(iii) User Training

This training will be aimed at two groups - users and staff involved in maintenance of the GSMS. It is suggested that the training programs for both take the following format:

- (a) a presentation describing the functional operation of the system,
- (b) a demonstration of system operation including (for DLM staff only) error procedures and system failure procedures,
- (c) a detailed explanation covering the use of the user manual and its contents.

(iv) System Test

This is the final test of the system. It is based on the description of the system contained in the Broad System Design and is aimed at ensuring that the original broad description of functionality agreed to in the Broad System Design has been achieved.

10.6 Data File and Location Card Creation

The 1993 GGN Project will proceed in stages. Data will become available for entry into the SMDB every few months in groups of 200-700 survey marks.

Horizontal and vertical coordinates for each mark will be imported directly into the Mark Details table within Ingres from GeoLab output files. Other details (such as order, class and adjustment date) will be entered via coding sheets by staff involved in the geodetic adjustment. All data will be entered by Survey Division staff.

The Location Card for each 1993 GGN survey mark will be produced by field staff during the course of the survey. Upon delivery to Survey Division, each card will be copied (either photocopied or microfilmed) and the original stored in a fire-proof room.

10.7 Survey Mark Index Creation**10.7.1 Base Mapping Information**

DLM's GIS Planning Layer is due for completion at the end of 1993. The efforts of DLM's GIS/LIS Division are currently directed at completing the cadastral data

capture phase. Survey plans are being input using the Coordinate Geometry (COGO) program within Genacivil. The resultant drawing files are then migrated to the Planning Layer (in Genamap), where gaps or overlaps between adjoining plans are adjusted to produce an up-to-date digital cadastral map.

Unfortunately, the Planning Layer is not survey-accurate. Consequently, the position of some survey marks (which are survey-accurate) may not appear in their correct position relative to the cadastral detail. This is only a possibility - testing during the Development Phase may reveal that the differences in position are insignificant for the purposes of an index. However, if this was found to be a problem, the displayed positions of some survey marks may have to be shifted.

10.7.2 Coordinate System Considerations

The GIS Planning Layer is based on the Clarke 1866 datum and an Azimuthal Equidistant projection. (These parameters are set within the Genamap environment.)

It has been recommended that the 1993 GGN survey marks be based upon the WGS84 datum and a Local Transverse Mercator (LTM) projection.

If the recommendation is accepted, it will be necessary to perform a coordinate transformation prior to overlaying the 1993 GGN survey marks on the Planning Layer. This can be accomplished in one of two ways.

The short-term solution is to transform the coordinates of all 1993 GGN marks from LTM to 1963 GGTN values using transformation parameters provided by SADELM. The survey marks could then be combined with the existing Planning Layer to produce the Survey Mark Index.

In the long term, however, the Planning Layer would have to be transformed into the new coordinate system (ie WGS84/LTM). It would then be able to directly accommodate survey marks which are connected to the 1993 GGN (This matter is also considered in section 11.4.2).

10.8 Records Maintenance

Maintenance operations will be required to:

- . record the establishment of new survey marks,
- . record visits to existing survey marks,

- record the destruction of survey marks.

The following paragraphs will describe the update procedures for both Mark Details and Mark References.

- It is recommended that the Mark Details table in Ingres be updated following the placement of every new survey mark. Specifically, a new survey mark record must be created in the SMDB by entering the appropriate data (eg mark number, coordinates, etc) in a Mark Details update form.
- It is recommended that the Mark References table in Ingres be updated following every official visit to each mark. This means that when a new survey plan is approved by the Territorial Surveyor, the plan number is entered (by Survey Division personnel) for all survey marks shown on the survey plan. The status of the mark (ie placed, found or gone) and date of visit will also be entered. [It should be noted that the resulting record of plan numbers will become a valuable searching tool for the surveying profession, as it will indicate the relevant plans in the area surrounding a particular survey mark.]
- It is recommended that new marks be immediately recorded on the Survey Mark Index by producing a new index map of the area. Survey marks which have been destroyed must be shown with an appropriate symbol on the new index.

In the situations where minor amendments are required to an index map (eg one mark has been destroyed), it is recommended that a new map be produced following the accumulation of (say) five such amendments or every six months. This will avoid the uneconomic task of producing a new map for a single modification.

All new Location Cards must be drawn according to specifications and copies made before the original is stored in a secure environment. The copies will then be used together with the SMDB and the Survey Mark Index.

10.9 Organisational Issues

10.9.1 Development and Implementation

It is recommended that the GSMS be developed and implemented by a team consisting of the following personnel:

- (i) Surveyor, Survey Division, DLM;
- (ii) Mapping Technician, GIS/LIS Division, DLM (experienced in the

production of maps from the Genasys environment);

- (iii) Systems Analyst, Data Processing Division, Department of Administration (experienced in the use of Genasys);
- (iv) Systems Programmer, Data Processing Division, Department of Administration (experienced in the use of Uniface and Ingres);
- (v) Survey Data Base Expert from SADELM.

The involvement of Survey Division is vital to the successful development of the GSMS, since it will be Survey Division staff who are responsible for the on-going maintenance of the system. Hence, the part-time involvement of a Surveyor is recommended to ensure DLM's needs are met.

A Mapping Technician from GIS/LIS will be required on a part-time basis to produce various maps that will form the Survey Mark Index.

A representative from Data Processing Division will be required to produce the various forms in Uniface that will provide data entry and query ability to the Ingres tables that store the survey mark data. Another will provide expertise concerning the Genasys system.

It is recommended that the Survey Data Base Expert will be the coordinator for the development and implementation of the GSMS. It will be the expert's task to ensure that the system is implemented according to the Broad System Design and the needs of DLM.

As outlined in the Guam Geodetic Network Proposal, it is recommended that the Survey Data Base Expert will be required for thirteen weeks to ensure the development and implementation of the GSMS is successful.

10.9.2 Maintenance

It is recommended that the GSMS be maintained by Survey Division, DLM. The GSMS will contain information which relates to the 1993 GGN and therefore it is appropriate that the system be under the control of the Chief of Cadastre.

Survey Division will be responsible for the maintenance of the three sub-systems. Primarily, this will involve the update of the SMDB to record the placement of new marks and the outcome of mark maintenance activities.

There will also be maintenance responsibilities associated with the Survey Mark

Index, new maps being produced when the need arises.

Also, the record of Location Cards must be monitored to ensure that standards are maintained and that the originals are safely housed.

Upon implementation of the GSMS, it is recommended that the system be placed under the control of a Registered Surveyor in the Survey Division of DLM. The Surveyor would supervise the data entry of survey mark information by several staff (either Engineering Technicians or Engineering Aides). These staff would be required on a part-time basis.

The Surveyor would also liaise with the following:

- (i) GIS/LIS Division for the production of new Survey Mark Index maps;
- (ii) Mark maintenance staff regarding entry of data to the GSMS from field trips;
- (iii) Data Processing Division regarding system difficulties or enhancements required to the GSMS.

10.10 Associated Issues

10.10.1 Feasibility of Incorporating GSMS into GIS

Based upon detailed analysis of DLM's GIS and interviews with personnel from Land Management and Data Processing Division, Department of Administration, it has been determined that the GIS is a suitable environment (in terms of hardware and software) in which to house the GSMS.

Maps showing the position of survey marks will be produced using Genasys software.

Note: It is therefore not necessary to consider a stand-alone system, since the GIS environment is deemed suitable.

10.10.2 Inclusion of Non-Network Marks in GSMS

The design of the GSMS will accommodate the inclusion of information relating to existing non-network marks if this is deemed necessary at some later date. Initially however, the focus will be on 1993 GGN survey marks.

10.10.3 Production of Network Diagrams

It is recommended that a Network Diagram be produced which shows the 1993 GGN primary marks. This diagram will be at a scale of 1:50000 and will show:

- (i) the coastline of Guam;
- (ii) the positions of all primary marks with respective names and numbers;
- (iii) the observed baselines that constitute the primary network.

It is also recommended that Network Diagrams be produced showing the Secondary Network in a particular area at the completion of the Tertiary Network in that area.

These diagrams will be produced from the GIS using Genasys.

10.11 Future Development of the GSMS

It is suggested that the following modifications to the GSMS could be considered following the successful implementation of the system and given appropriate resources over the next few years:

- (i) scan Location Cards and provide ability for users to view image and request print,
- (ii) utilise digital orthophotos as the base for the Survey Mark Index, enabling the marks to be accurately depicted relative to all cultural detail (The GIS/LIS Division are planning to store the digital orthophoto data as a layer within Genamap),
- (ii) integrate Planning Layer and survey mark data such that the Survey Mark Index becomes available through graphic enquiries.

Hence, the manual systems known as the Survey Mark Index and Location Cards would be superseded by graphics enquiries on X-Terminals in the public search area.

These suggestions are in line with future plans made by the GIS/LIS Division for an on-line graphic enquiry facility to DLM's GIS which would include the ability to view individual survey plan data on-screen in vector form following an initial enquiry from the Planning Layer.

SECTION 11 GUIDELINES FOR THE COLLECTION OF DATA

11.1 Introduction

In 1991, a report entitled "Land Information Management Strategy" was prepared for the Territorial Planning Council by the South Australian Department of Lands.

The report stated (Page 160, Section 2.2.1 Cadastral Surveying - Short Term Strategy):

"(a) In order to allow the collection of digital cadastral data for planning purposes to proceed, but to avoid significant duplication of effort, guidelines should be established for the collection of such data (that is, survey-accurate digital cadastral data)...

Guidelines should cover such things as:

- a facility to ensure that data will be able to be transformed to the new coordinate system without a significant loss of accuracy;
- the need to keep the original data, records of its origin, and perhaps records of any adjustments made in creating a digital cadastral map;
- requirements for date stamping, accuracy criteria, etc..."

The following summarises the present situation in GovGuam regarding digital cadastral data, and recommend guidelines for the future collection of such data.

11.2 Collection of Digital Cadastral Data by DLM

11.2.1 Overview

A computer-based cadastral map is currently being generated for Guam by DLM. The map, known as the Planning Layer, will reside in DLM's GIS system. The Planning Layer will be used by other GovGuam agencies as the base cadastral layer for their GIS applications. These may include the display of power pole locations, underground telephone cables, water pipelines, and similar geographically related data.

Digital cadastral data for the planning layer has been derived from two sources, these being:

- (i) Survey-accurate data captured by the GIS/LIS Division using the Coordinate

Geometry (COGO) facility within Genasys,

(ii) Digitised data captured by the Bureau of Planning (BOP).

The focus of the COGO data capture has been on private lands. The capture process uses plan data to produce a drawing file for each survey. The COGO drawing files are then migrated to the Planning Layer in Genamap (the GIS module of Genasys) where each plan is manipulated to fit into the surrounding cadastre. Gaps or overlaps are removed during this process.

Federal and government lands have been captured by digitising the best available maps. However, government land data is now being replaced by data captured via the COGO method.

The data capture phase is due for completion in December 1993. The maintenance phase will then begin. The Planning Layer will be kept up-to-date by capturing survey plans via the COGO process as they are registered.

11.2.2 COGO Data Capture

The COGO data capture process uses survey plan data (bearings and distances) to generate numerically consistent boundary coordinates for each survey. The origin for the computations is a nominated Point of Beginning (POB), this having been coordinated from a 1963 GGTN survey mark. The connection from the POB to the 1963 GGTN mark constitutes the sole link between the plan and the control network. The 1963 GGTN coordinates of the POB are included on the plan.

It should be noted that the single connection to the GGTN mark does not control the survey. It merely provides the mechanism by which bearings and coordinates can be introduced into the survey plan. The absence of connections at other boundary points prevents verification of the scale and orientation of the survey. Any errors in the connection may go undetected.

There must, therefore, be an element of uncertainty regarding the reliability of the calculated COGO coordinates. Indeed, gaps and overlaps between adjacent surveys could well be the result of poor control, rather than an actual difference between the surveys. This distinction is important. If the Planning Layer is to be adjusted to remove gaps and overlaps, it is important to understand the cause of the inconsistencies between surveys.

A key impediment to the adequate control of cadastral surveys has been the sparse distribution of 1963 GGTN marks across Guam. Following the completion of the 1993 GGN, it will be comparatively easy for two or more boundary points on each

survey to be connected to different survey marks. The additional connections will control the surveys, and enable the positions of all parcels to be confidently calculated. This, in turn, will assist the resolution of gaps and overlaps in the cadastre, and improve the integrity of the Planning Layer.

It is therefore recommended that enabling legislation be introduced compelling at least two boundary points on every survey to be connected to different 1993 GGN marks. This matter will be further considered by the Survey Legislation Expert.

It should be noted that the present method of data capture using the COGO facility in Genamap is entirely satisfactory. No changes to current entry procedures are recommended at this time.

11.2.3 Digitised Data in the Planning Layer

There is currently no formal documentation identifying:

- . The map sources for the various digitised data sets,
- . The agencies responsible for data capture.

It is imperative that this situation be rectified. If other agencies are to use the Planning Layer as the base cadastre for their applications, it is essential that they be aware of the source and quality of that data.

It is therefore recommended that an inventory of metadata be established for the digitised data in the Planning Layer (metadata are data about data). It is further recommended that this inventory conform with the specifications in the draft report: "Content Standards for Spatial Metadata" (Federal Geographic Data Committee, November 1992). This document provides a common set of metadata elements for use in GIS. It is recommended that DLM's GIS/LIS Division use this set of metadata elements as the basis for the construction of an inventory of digitised data within their Planning Layer.

It is further recommended that the compilation of metadata be extended to other (non-cadastral) data types and to all GovGuam agencies.

11.3 Collection of Cadastral Data by Other GovGuam Agencies

11.3.1 Introduction

During the Phase 1 study, a series of interviews were conducted with GovGuam agencies to determine their interest in cadastral data. The following paragraphs summarise the status of cadastral data collection throughout GovGuam.

11.3.2 Bureau of Planning

BOP is the coordinating agency for the development of GIS among the utility agencies in Guam. A GIS User Group was established by BOP in late 1991 with the following objectives:

- (i) to coordinate infrastructure data collection and computerisation efforts;
- (ii) to develop data standards;
- (iii) to assure integration of data.

In addition to BOP, the User Group consists of:

- (i) Department of Land Management;
- (ii) Guam Power Authority;
- (iii) Guam Telephone Authority;
- (iv) Public Utility Agency of Guam;
- (v) Guam Environmental Protection Agency;
- (vi) Department of Public Works;
- (vii) Data Processing Division, Department of Administration.

As a result of this initiative, there is now a coordinated approach to GIS development in Guam. Of particular significance is the recognition within this group that DLM will provide the base cadastral layer for other agencies (this being the Planning Layer).

Therefore, the concerns expressed within the 1991 Land Information Management (LIM) Strategy (regarding duplication of effort in the collection of cadastral data) are no longer valid.

11.3.3 Guam Power Authority (GPA)

GPA are about to begin a program to capture the positions of all power poles using the Global Positioning System (GPS). Two ASHTECH GPS receivers have been purchased. Field work will commence early in 1994.

GPA do not intend carrying out any cadastral data capture. Rather, they propose using DLM's Planning Layer or Orthophoto Layer. This data will form the foundation of their GIS development.

11.3.4 Guam Telephone Authority (GTA)

GTA are currently seeking proposals to provide consulting services for the provision of a GPS/CPR/GIS System (ie Global Positioning System/Continuing Property Records/Geographic Information System).

This system will be similar to GPA's in that the position of facilities will be captured using GPS. DLM's GIS will be used to provide the base cadastral framework.

11.3.5 Public Utility Agency of Guam (PUAG)

PUAG are about to engage a consultant to digitise the information on 128 water and waste-water maps. In addition, 3500 as-built drawings (mainly of pipelines) will be captured by entering the coordinates of bends and adding linework and symbology. (Note: the coordinates for this work will be based on 1963 GGTN.)

DLM's Planning Layer will be used as the cadastral base for this application.

11.3.6 Guam Environmental Protection Agency (GEPA)

The representative for GEPA was off-island during the course of this study. However, personnel from Data Processing Division (DPD) provided information on GEPA's status regarding GIS and cadastral data.

GEPA's information requirements mirror those of PUAG. Consequently, GEPA is waiting on the development of PUAG's program so that they can make use of the

same data for other applications.

11.3.7 Department of Public Works (DPW)

DPW are not involved in GIS development at present.

11.3.8 Summary

All concerns expressed in the 1991 LIM Strategy regarding duplication of effort in the collection of cadastral data have been addressed, mainly through the coordinating efforts of BOP. No further recommendations are necessary in this area.

11.4 Transformation of Coordinates

11.4.1 Transformation of Existing COGO Files

The COGO data capture of survey plans is approximately 70% complete and is scheduled for completion at the end of 1993. Each COGO file contains coordinates for all boundary corners within the plan, based on 1963 GGTN.

Following the completion of the 1993 GGN, surveyors will begin producing survey plans based on the new control.

In the long term, it would be advantageous to have all COGO files in a common coordinate system.

It is therefore recommended that all existing COGO files be transformed to 1993 GGN over a five year period. It should be noted that there is no urgency associated with this task. The production (and subsequent maintenance) of the Planning Layer is not dependent on the conversion of existing COGO files based on 1963 GGTN.

An ultimate goal should be to replace the Planning Layer with survey-accurate data as the errors in the cadastre are gradually rectified. The COGO files based on 1963 GGTN control would serve as a valuable source of data for such an exercise. The provision of more control on those surveys based on 1963 GGTN would also improve the quality of the data.

11.4.2 Transformation of Planning Layer

The Planning Layer within Genamap is based on an Azimuthal Equidistant Projection and the Clarke 1866 datum.

It has been recommended that a local Transverse Mercator (LTM) projection be adopted by DLM together with the WGS84 datum.

In discussions with staff from DPD and Genasys, it has been determined that the process of transforming the Planning Layer from an Azimuthal Equidistant projection to a LTM projection is feasible.

Therefore, subject to acceptance of the datum/projection recommendation, it is recommended that DLM initiate planning to transform the Planning Layer to the new projection and datum. This planning should subsequently be expanded to include non-cadastral data sets.

11.5 Associated Issues

11.5.1 Retention of Source Data

It is strongly recommended that all original source data acquired for inclusion in an adjustment process (for example, COGO files for the Planning Layer) be retained in an archive for later reference.

11.5.2 Spatial Data Transfer Standard

Spatial Data Transfer Standard (SDTS) is a GIS transfer standard. It provides a set of formats for the exchange of graphics information and associated attributes.

SDTS was developed by the US Geological Survey (USGS) and has been presented to the US National Institute of Standards and Technology for approval as a Federal Information Processing Standard.

It is recommended that the SDTS be implemented by all agencies in GovGuam.

[For more information, contact:

Mr. Robin Fegeas
 Chief, Branch of Applications
 Office of Geographic and Cartographic Research
 National Mapping Division
 US Geological Survey
 521 National Centre
 Reston, VA 22092, USA]

11.5.3 Date Stamping

The issue of date stamping was raised in the LIM Strategy (Part B, Section 2.2.2, Page 91 & 92: Opportunities For Improvement - Survey Data Base):

"...It is therefore proposed that a Guam Survey Data Base be created from survey-accurate data. The SDB should use the proposed new geodetic network coordinate system. Hence, in the short-term, data should be collected in a manner which facilitates its transformation into new coordinates..."

"...The concept of "date-stamping" all records should be incorporated into the SDB. No record should ever be removed from the SDB; instead, the data base will gradually grow as more and more data is entered and stored. Using date stamping, the state of the cadastre at any point in history should be able to be regenerated."

The date-stamping of individual survey plans is considered unnecessary because each survey plan number provides a link to the date. For example, "048-FY 82" is the forty-eighth plan registered with the Territorial Surveyor during Fiscal Year 1982 (which begins on 1st October 1981). It would be relatively simple to structure a query within Genasys which displays, for example, all survey plans registered in the second half of Fiscal Year 1995.

11.5.4 Accuracy Codes

Accuracy codes should be used to distinguish COGO files based on 1993 GGN control from original COGO files (based on 1963 GGTN control) that have been transformed to the new system.

It is recommended that a system of accuracy codes be implemented which will distinguish high quality data from poor quality data within the GIS.

The following accuracy codes are suggested:

- Acc.Code 1 - digitised data from small scale mapping;
- Acc.Code 2 - digitised data from large scale mapping;
- Acc.Code 3 - COGO files transformed into 1993 GGN coordinates;
- Acc.Code 4 - COGO files captured in 1993 GGN coordinates.

11.5.5 Custodianship of Cadastral Data

DLM is now generally recognised throughout GovGuam as the authority in charge of cadastral data. It is recommended that this recognition be formalised through the introduction of legislation which identifies DLM as the custodian of cadastral data.

As the Lead Agency for cadastral data, DLM would be the single authority responsible for the capture and maintenance of this data.

If another agency had a need for cadastral data which DLM could not provide or capture, the agency would be required to adopt strict procedures in the capture of the data. Following completion of the data capture, a copy would be given to DLM with the appropriate documentation describing the source of acquisition and methodology used in capture.

APPENDIX 1 - SCOPE OF WORK

1. **PHASE 1** - Phase 1 has been divided into two parts, Phase 1A and Phase 1B, to divide the primarily on-island activities from the off-island activities to be undertaken by SADELM in preparation for Phase 2

1.1 **PHASE 1A (On-island Studies)**

There are four studies to be completed during Phase 1A of the project, namely:

- . Preliminary Study;
- . Transformation Requirements Study;
- . Broad Systems Design for a Mark Register; and
- . Development of Guidelines for Collection of Data Study

(i) **Preliminary Study and Transformation Requirements Study**

These studies will be undertaken concurrently during three weeks on-island and one week in Australia by the Geodesist, the Project Leader and the Tertiary Network Expert. Upon completion of the studies, SADELM will have determined the following in consultation with the Government of Guam, and presented the information in a report to GovGuam:

- . the actual number of primary marks to be established and their preferred sites;
- . a revised estimate of the number of secondary and tertiary marks required;
- . the form of construction to be used for the primary, secondary and tertiary marks, and the form of "witnessing";
- . a site for the datum monument and its form of construction;
- . whether Department of Public Works road centre-line monuments will be connected into the Tertiary network, and if so, the number of such marks, who will locate the marks, etc;
- . the need to connect existing GGTN marks into the network;
- . the need to connect existing survey (non-network) marks into the tertiary network;
- . the most appropriate density or spacing for tertiary network marks;
- . the desirability of placing network marks in some easements as well as rights of way;

- as estimate of the percentage of the network which will be able to be completed using kinematic GPS techniques;
- the likely atmospheric problems to be encountered using kinematic GPS techniques;
- the way in which GPS vehicles will be required to be fitted out by GovGuam;
- the format for location diagrams (or station summaries) describing the positions of network marks;
- the format for traverse pages and GPS field sheets;
- an appropriate numbering system to be used for the network marks;
- the most appropriate datum, map projection and coordinate system;
- availability of access to the absolute position of points observed as part of the Philippine Sea Plate Survey;
- the need and the strategy for providing vertical control on each network mark;
- the suitability of the existing height datum (if a new height datum is chosen, the suitability of existing tide gauges and tidal records would need to be assessed);
- the likely legal implications of a change in datum for both horizontal and vertical values;
- the feasibility of creating transformation parameters between 1963 coordinates and the new coordinate system, together with an indication of their likely accuracy and usefulness;
- the feasibility of incorporating 1963 data into the network adjustment to generate new coordinates for missing GGTN marks;
- the specifications (for each order of accuracy) to which network marks will be measured;
- the role to be played by U.S. National Geodetic Survey (NGS) office in adjustment of the primary network;
- the specifications to be met by SADELM to satisfy NGS requirements;
- the number and possible identification of Gov Guam personnel (DLM and other) to be trained in GPS techniques as part of the project;
- the level of need for GovGuam to develop in-house expertise in final geodetic

adjustments;

- . the type of training which would be required for in-house expertise in final geodetic adjustments;
- . the suitability of proposed GovGuam personnel for training in final geodetic adjustments.

Having determined these aspects, SADELM will develop a refined scope of work for Phase 2.

(ii) Broad Systems Design For a Mark Register

Upon completion of this study by the Survey Data Base Expert (one week on-island and one week in Australia), a broad system design and implementation strategy for a Guam Mark Register* will be developed. As part of the study, the following will be determined, and presented in a report:

- . the feasibility of immediately incorporating the Mark Register into the existing GIS environment in DLM;
- . a strategy to migrate a stand-alone system to the DLM GIS (if an interim stand-alone approach is adopted, and if applicable);
- . the data items considered necessary for a Guam Mark Register;
- . the likely in-coming and out-going data flows relating to maintenance of the mark register;
- . the feasibility of including existing non-network marks in the register;
- . the way in which location diagrams will be stored and maintained;
- . the way in which the location of marks will be displayed with respect to the cadastre;
- . the means of access to be provided to the surveying industry, other Government agencies, and the general public;
- . the way in which network diagrams will be produced.

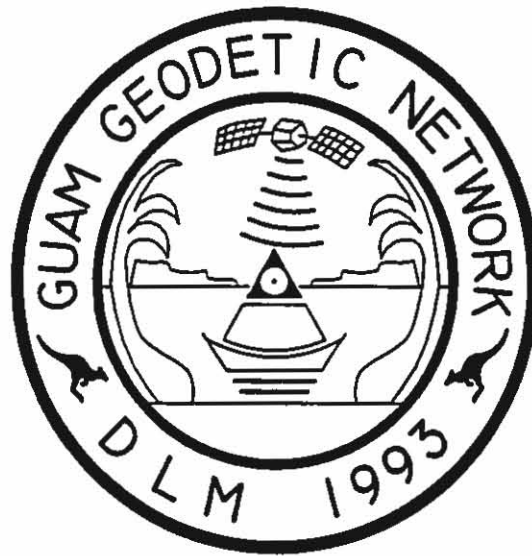
Having determined these aspects, DELM will refine the scope of work for the Mark Register Implementation component of Phase 2 as necessary.

- * The term "Mark Register" has subsequently been replaced by "Guam Survey Mark System" (GSMS).

(iii) Development of Guidelines for the Collection of Data

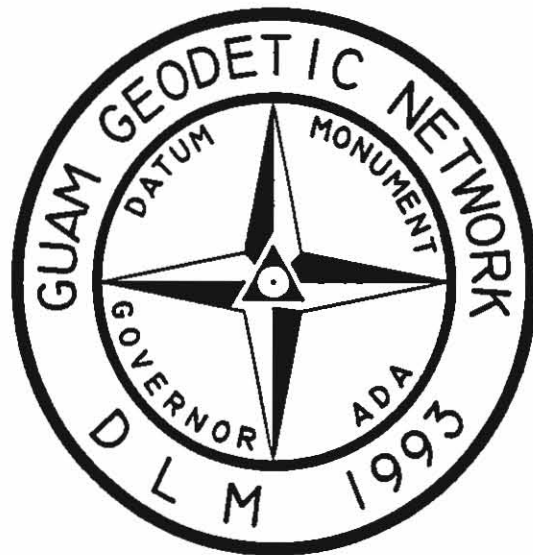
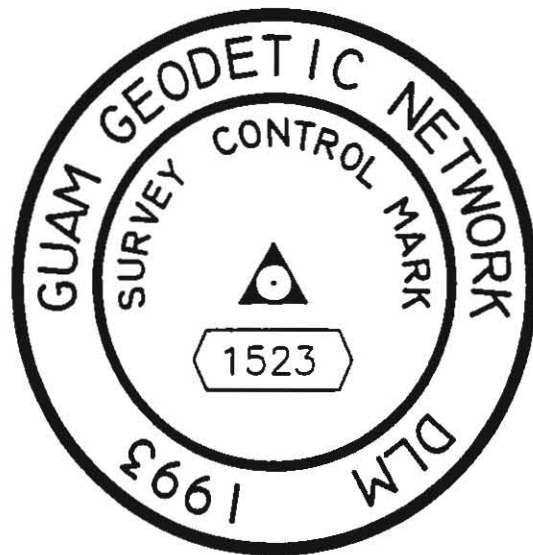
Upon completion of this study by the Survey Data Base Expert (two weeks on-island and one week in Australia), a report will be submitted outlining proposed guidelines for the collection of cadastral data throughout GovGuam. Topics which will be investigated in this study include the following:

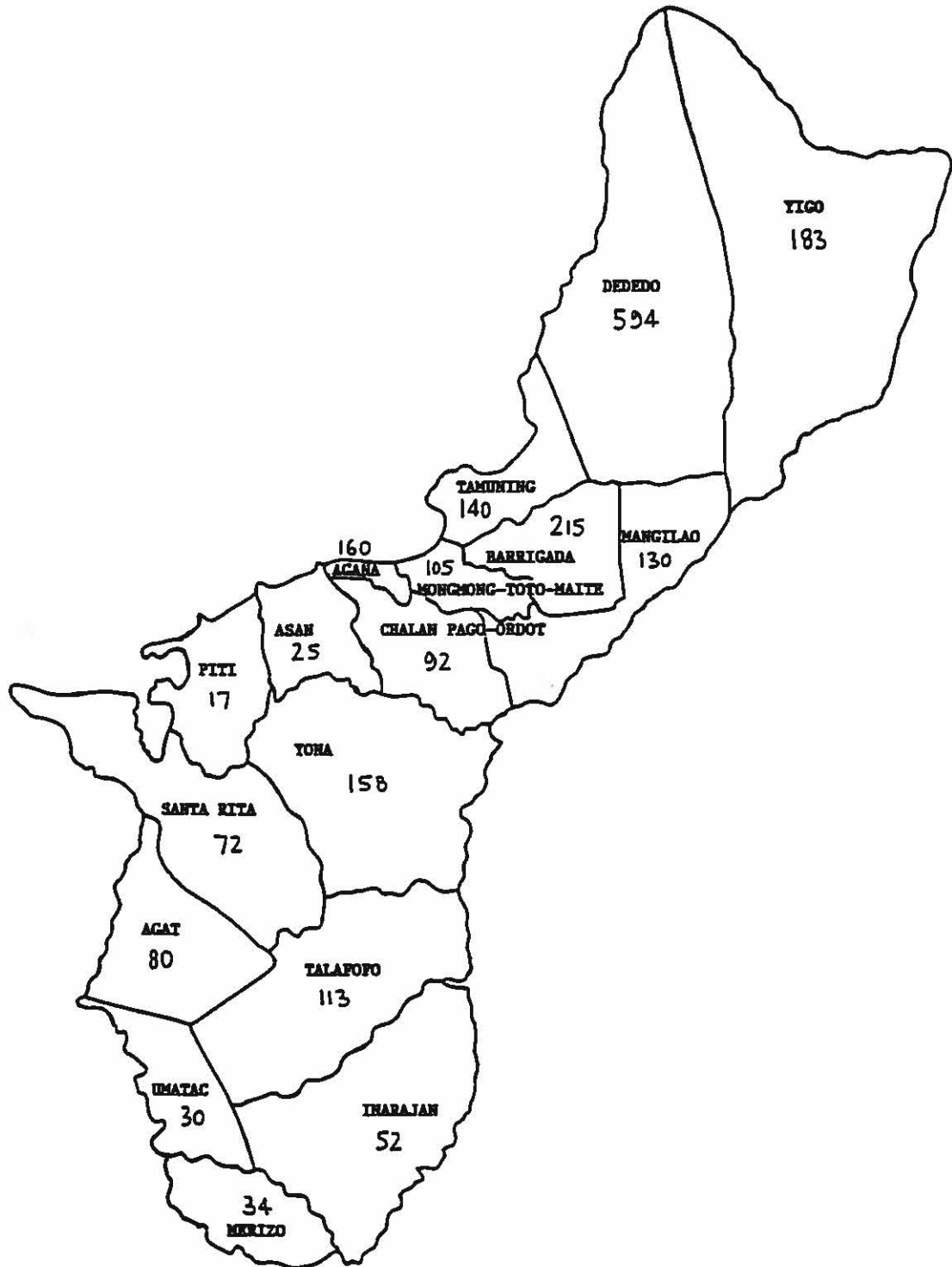
- . the need for data to be transformed into a new coordinate system without significant loss of accuracy;
- . maintenance of records (e.g. the origin of data, adjustments made);
- . the possible need to maintain the original data where subsequent adjustments have corrupted the original data;
- . the possible need for date stamping;
- . the possible need for accuracy criteria to be held against all data; and
- . the possible need for DLM to be consulted wherever cadastral data is collected by outside agencies.

APPENDIX 2 - PROPOSED PROJECT LOGO

APPENDIX 3 - PROPOSED 1993 GGN PRIMARY NETWORK STATIONS

.	RITIDIAN 1993	In Andersen Air Force Base (New Mark)
.	URUNO 2 1945	In Andersen Air Force Base
.	PATI 1993	In Andersen Air Force Base (New Mark)
.	AAFB 1990	In Andersen Air Force Base (PSP Mark)
.	NCS 1963	
.	SALISBURY 1963	
.	AMANTES 1963	
.	YIGO 1963	
.	PAGAT 1993	(New Mark)
.	YPAO 1963	
.	BARRIGADA 1963	
.	GOVERNOR 1993	Proposed Datum Monument (New Mark)
.	FADIAN 1963	
.	MACAJNA 1963	
.	CHACHAO 1963	
.	ADOFGAN 1963	In Apra Harbor Naval Base
.	TIDAL 4 1949	In Apra Harbor Naval Base (Tidal Bench Mark)
.	CUB 1963	
.	TOGCHA 1963	
.	BEACH 1963	
.	YPAN 1963	
.	TOGUAN 1963	
.	IPACHOL 1963	
.	BOAGA 1963	
.	COCOS 1963	On Cocos Island

APPENDIX 4 - PLAQUE DESIGN

APPENDIX 5 - NETWORK MARK DISTRIBUTION

APPENDIX 6 - DATUM TRANSFORMATION STATIONS**WGS84 Coordinate Values**

	Station	Latitude	Longitude	Sph.Ht.
76	ASALONSA	N13 19 25.96140	E144 45 52.48637	129.676
34	BARRIGADA	N13 29 23.87710	E144 49 45.41750	256.638
93	BEACH	N13 21 52.43870	E144 39 00.76680	58.022
116	BOAGA	N13 15 13.75880	E144 43 29.99820	118.548
62	CHACHAO	N13 26 13.86650	E144 42 39.12400	374.671
35	CRUSHER	N13 26 57.71058	E144 48 59.04763	143.700
112	IPACHOL	N13 17 46.11546	E144 45 16.26088	146.766
59	LOOK	N13 25 12.56290	E144 44 58.85550	194.220
51	MACAJNA	N13 27 17.30550	E144 44 15.39910	272.594
9	SALISBURY	N13 33 54.62440	E144 53 58.40360	244.398
102	SOLEDAD	N13 17 42.34740	E144 39 35.99440	99.911
101	TOGUAN	N13 17 22.53440	E144 39 36.42850	119.603
10	URUNO	N13 37 34.17410	E144 50 33.05640	232.849
64	USO	N13 27 47.33301	E144 41 28.69897	60.162
30	WETTENGEL	N13 31 25.01292	E144 49 30.61396	146.851
42	YPAO	N13 30 24.86950	E144 46 58.64100	119.329

GGTN-63 Coordinates

	Station	Latitude	Longitude	Sph.Ht.
76	ASALONSA	N13 19 20.74847	E144 45 43.84249	73.676
34	BARRIGADA	N13 29 18.70074	E144 49 36.77230	200.638
93	BEACH	N13 21 47.23330	E144 38 52.12833	2.022
116	BOAGA	N13 15 8.52783	E144 43 21.35510	62.548
62	CHACHAO	N13 26 8.68004	E144 42 30.48466	318.671
35	CRUSHER	N13 26 52.52542	E144 48 50.40389	87.700
112	IPACHOL	N13 17 40.89685	E144 45 07.61801	90.766
59	LOOK	N13 25 7.37261	E144 44 50.21636	138.220
51	MACAJNA	N13 27 12.12262	E144 44 6.75873	216.594
9	SALISBURY	N13 33 49.46577	E144 53 49.75727	188.398
102	SOLEDAD	N13 17 37.12647	E144 39 27.35948	43.911
101	TOGUAN	N13 17 17.31266	E144 39 27.79229	63.603
10	URUNO	N13 37 29.03058	E144 50 24.41208	176.849
64	USO	N13 27 42.15234	E144 41 20.06464	4.162
30	WETTENGEL	N13 31 19.84497	E144 49 21.96900	90.851
42	YPAO	N13 30 19.69724	E144 46 49.99782	63.329

Warning

The spheroidal heights associated with the GGTN-63 coordinates are approximations of the true values. They were determined by subtracting 56 metres from the WGS84 values, and were intended for use only in transformation parameter derivation. They must not be used for any other purpose.

APPENDIX 7 - GRID TRANSFORMATION STATIONS**GGTN-63 Coordinate Values**

	Station	Easting	Nothing
9	SALISBURY	66062.68	60102.41
10	URUNO	59886.33	66846.69
30	WETTENGEL	58012.86	55500.86
34	BARRIGADA	58459.19	51778.21
35	CRUSHER	57065.85	47285.83
42	YPAO	53443.21	53651.52
51	MACAJNA	48533.82	47887.16
59	LOOK	49840.97	44053.55
62	CHACHAO	45637.63	45937.88
64	USO	43519.98	48810.72
76	ASOLONSA	51454.82	33401.91
93	BEACH	39065.84	37905.53
101	TOGUAN	40135.96	29610.53
102	SOLEDAD	40123.15	30219.41
112	IPACHOL	50364.67	30333.47
116	BOAGA	47165.76	25651.37

Guam Map Grid (LTM) Coordinate Values

	Station	Easting	Nothing
9	SALISBURY	116187.125	207215.426
10	URUNO	110010.786	213959.604
30	WETTENGEL	108137.426	202613.859
34	BARRIGADA	108583.775	198891.261
35	CRUSHER	107190.438	194398.882
42	YPAO	103567.811	200764.527
51	MACAJNA	98658.457	195000.133
59	LOOK	99965.570	191166.542
62	CHACHAO	95762.304	193050.843
64	USO	93644.530	195923.656
76	ASALONSA	101579.583	180514.976
93	BEACH	89190.646	185018.575
101	TOGUAN	90260.711	176723.599
102	SOLEDAD	90247.864	177332.485
112	IPACHOL	100489.428	177446.526
116	BOAGA	97290.609	172764.532

APPENDIX 8 - MARK DETAIL ATTRIBUTES

1. Mark Number

Each mark will have a unique number. It is proposed that the marks are numbered sequentially, beginning at Number 1 (the new datum monument). At the completion of the 1993 Guam Geodetic Survey, there will be approximately 2500-3000 marks contained in the GSMS. As new subdivisions are surveyed, more marks will be placed and new numbers assigned accordingly.

2. Rectangular Coordinates and Projection

The 1993 Guam Geodetic Survey will produce rectangular coordinates for each survey mark. It is proposed that these coordinates will be based on a Local Transverse Mercator Projection.

3. Geographical Coordinates and Datum

The 1993 Guam Geodetic Survey will produce geographical coordinates for each survey mark. It is proposed that these coordinates will be based on the WGS 84 datum.

4. Horizontal Order

Order is a function of:

- (i) the Class (see 5. below);
- (ii) the conformity of the new survey data with the existing network.

Order is rated from 01 (commensurate with A2 Class) through 0, 1, 2, 3, 4 to 5. (9 indicates there is no Order.)

Appendix 16 contains an extract from the Australian Inter-Governmental Committee on Surveying and Mapping (ICSM) Publication Number One (Standards and Specifications for Control Surveys). This extract provides additional information on the definition of Class and Order and a guide to the application of each.

5. Horizontal Class

Class is a function of the precision of a set of coordinates relating to a survey mark and is assigned on the basis of:

- (i) the field survey methods;
- (ii) the reduction techniques;
- (iii) the results of a network adjustment.

Class is rated from A2 for very high precision work, through A1, A, B, C, D to E for work such as cadastral surveys. (Z indicates there is no Class.)

6. Horizontal Purpose

The purpose for the placement of a mark which is to be used for horizontal control may be one of the following:

- (i) Geodetic;
- (ii) Cadastral;
- (iii) Engineering;
- (iv) Hydrographic.

7. Horizontal Agency

While DLM will be the sole authority for the 1993 GGN, it will be advantageous to store information in the SMDB which relates to marks placed by other agencies.

The Agency for the placement of a mark for horizontal control may be one of the following:

- (i) DLM;
- (ii) Department of Public Works (DPW);
- (iii) Private Survey Firm;
- (iv) Air Force;
- (v) Navy.

8. Horizontal Fixing Method

The initial method used to fix the position of survey marks will be the Global Positioning System (GPS) but other methods will be used later. For example:

- (i) conventional traversing with theodolite and EDM;
- (ii) digitising or scaling the position of the survey mark from a map. (This may be a requirement if the mark initially has only a height and no horizontal coordinates.)

Values for this field are GPS, Traversed, Digitised and Scaled.

9. Adjusted

All survey marks that are fixed during the 1993 Guam Geodetic Survey will receive adjusted horizontal coordinates. However, in the future it will be possible for survey marks to be added to the SMDB and not have adjusted coordinates. Hence, this field will indicate (via Yes or No) that the coordinate values are adjusted.

10. Adjustment Date

The date of the adjustment associated with the adjusted horizontal coordinates will be shown in this field.

11. Entry Date

The date at which the horizontal data was entered into the SMDB will be shown in this field.

12. Elevation and Vertical Datum

The value shown will be the height in relation to the vertical datum. It is not envisaged that all marks in the SMDB will have an associated height.

13. Vertical Order

The definition of Vertical Order is similar to Horizontal Order (see 4. above).

14. Vertical Class

The definition of Vertical Class is similar to Horizontal Class (see 5. above).

15. Vertical Purpose

The purpose for the placement of a mark for vertical control will be obtained from the list in Section 6. above.

16. Vertical Agency

The Agency for the placement of a mark which is to be used for vertical control will be obtained from the list in Section 7. above.

17. Vertical Fixing Method

The method of fixing the height of a survey mark will be one of the following:

- (i) GPS;
- (ii) Levelling.

18. Adjusted

This field will be either "Yes" or "No" to indicate whether the value is adjusted or not.

19. Adjustment Date

The date of the adjustment associated with the adjusted elevation will be shown in this field.

20. Entry Date

The date at which the vertical data was entered into the SMDB will be shown in this field.

21. Mark Type

The type of mark will vary depending upon the order of mark (ie primary, secondary or tertiary) and the situation (limestone, concrete paths, deep soil, etc).

The following list proposes a variety of mark types:

- (i) Brass Plaque in Concrete;
- (ii) Shell Case in Concrete;
- (iii) Brass Rod in Concrete.

A facility will be provided within the SMDB which will enable the addition of further mark types as required.

22. Previous Reference

For existing marks placed by Authorities such as DLM and DPW, the previous mark number will be noted in the SMDB. For example, the survey mark may be an existing GGTM mark in which case the GGTM number will be entered in this field.

23. Status

In the event that a mark is destroyed, this field will indicate the status of the mark via "Gone". ("Existing" indicates the mark is intact.) Note the similarity of this field with the Status field in Mark References.

24. Special Note

This field enables information relevant to a particular mark to be entered in the form of several short sentences. For example, special instructions regarding access to the mark.

APPENDIX 9 - MARK REFERENCE ATTRIBUTES**1. Mark Number**

As described earlier, each mark will have a unique number. It is proposed that the marks are numbered sequentially, beginning at Number 1 (the new datum monument).

2. Reference

The Reference List associated with a particular mark shows the history of visits to the mark. Possible references are as follows:

- (i) DLM Survey;
- (ii) DLM Mark Maintenance;
- (iii) Survey Plan Number.

3. Status

The Status field may contain the following items:

- (i) Placed;
- (ii) Found;
- (iii) Covered;
- (iv) Gone.

4. Date

The Date field indicates when the mark was visited by the particular agency.

APPENDIX 10 - PROPOSED MARK DETAILS SCREEN DISPLAY

Page 1 of 1
Date: 22 JUL 95

DEPARTMENT OF LAND MANAGEMENT
SURVEY MARK DATA BASE
MARK DETAILS

MARK NUMBER: 1008

HORIZONTAL DETAILS:

Easting: 116015.332 metres Northing: 207287.701 metres
Projection: Local Transverse Mercator

Latitude: 13 21 23.8771 N Longitude: 144 43 45.4175 E
Datum: WGS84

Order: 3 Class: C

Purpose: Cadastral Agency: DLM

Fixing Method: GPS Adjusted: Yes

Adjustment Date: 12 NOV 93

Entry Date: 10 DEC 93

VERTICAL DETAILS:

Elevation: 23.543 metres Datum: MSL

Order: 4 Class: D

Purpose: Engineering Agency: DPW

Fixing Method: Levelling Adjusted: No

Adjustment Date:

Entry Date: 10 DEC 94

MARK INFORMATION:

Mark Type: Brass Plaque in Concrete

Previous Reference: GGTN TS YG-2 Status: Existing

Special Note: Permission Required to enter Apra Harbour Naval Reservation.

APPENDIX 11 - PROPOSED MARK REFERENCE SCREEN LAYOUT

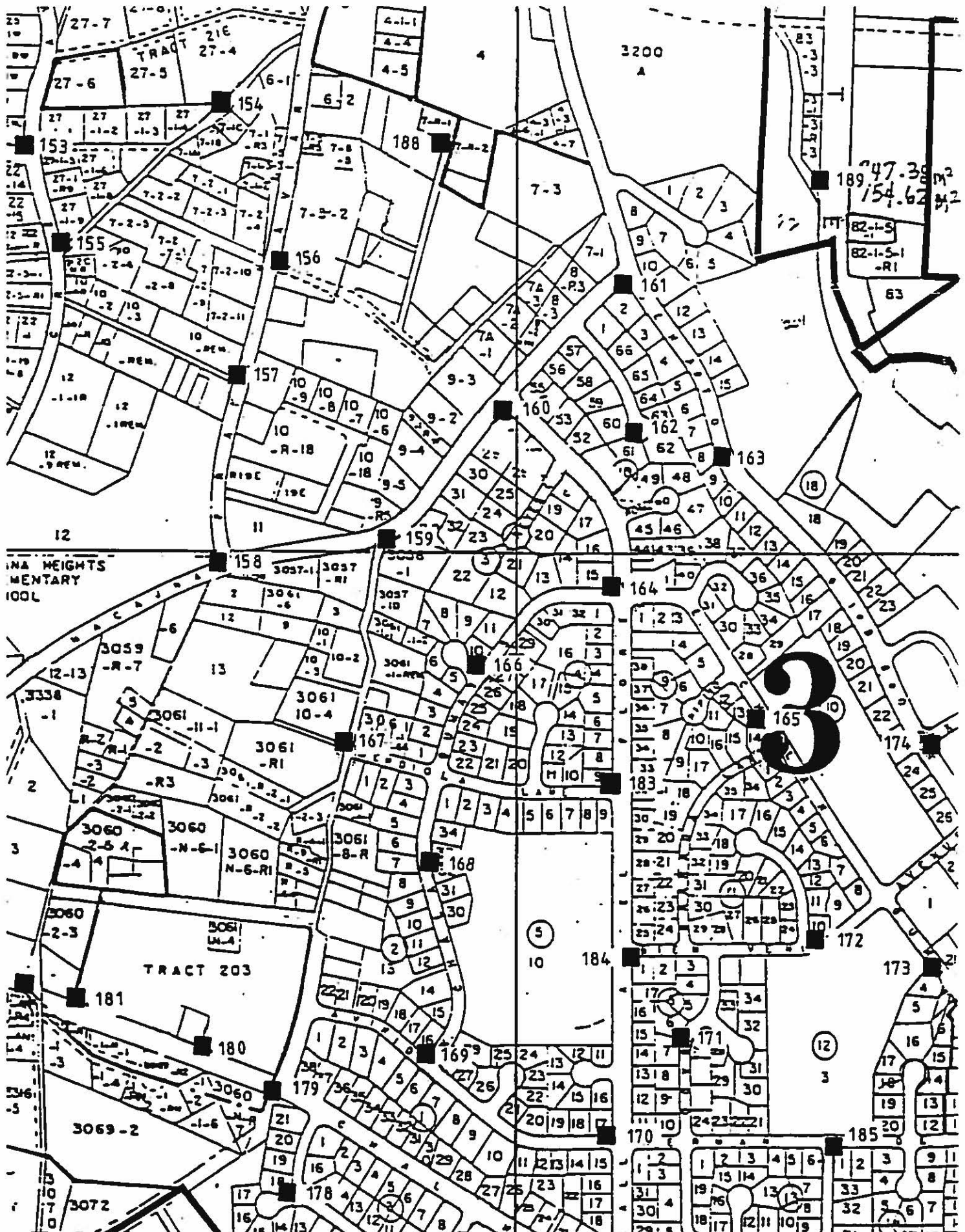
Page 1 of 1
Date: 22 JUL 95

DEPARTMENT OF LAND MANAGEMENT
SURVEY MARK DATA BASE
MARK REFERENCES

MARK NUMBER: 1342

<u>Reference</u>	<u>Status</u>	<u>Date</u>
DLM Survey	Placed	22 OCT 93
DLM Mark Maintenance	Found	12 APR 94
259FY94	Found	18 AUG 94
078FY95	Found	03 DEC 94
DPW Level Page 13322	Found	10 DEC 94
DLM Mark Maintenance	Found	10 SEP 95
161FY95	Gone	23 JAN 95
DLM Mark Maintenance	Gone	02 FEB 95

APPENDIX 12 - EXAMPLE OF SURVEY MARK INDEX



APPENDIX 13 - EXAMPLE OF LOCATION CARD

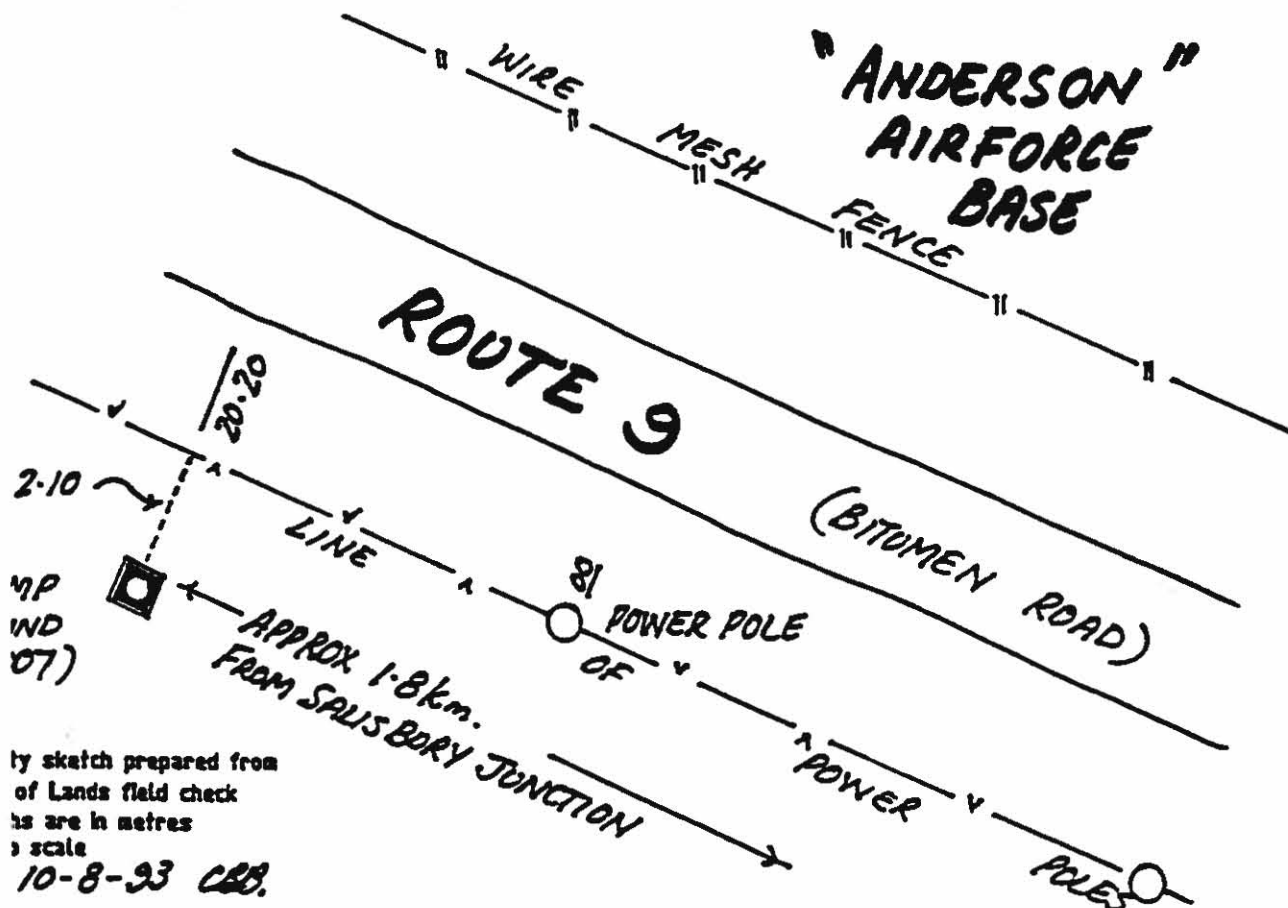
NESS DROPPER
ADJACENT

NETWORK PSM

0007

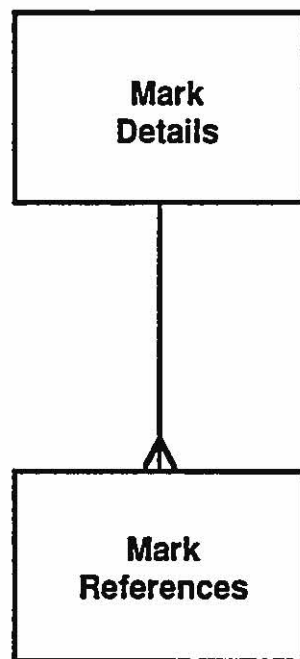
MUNICIPALITY OF YIGO

"CASTRO"

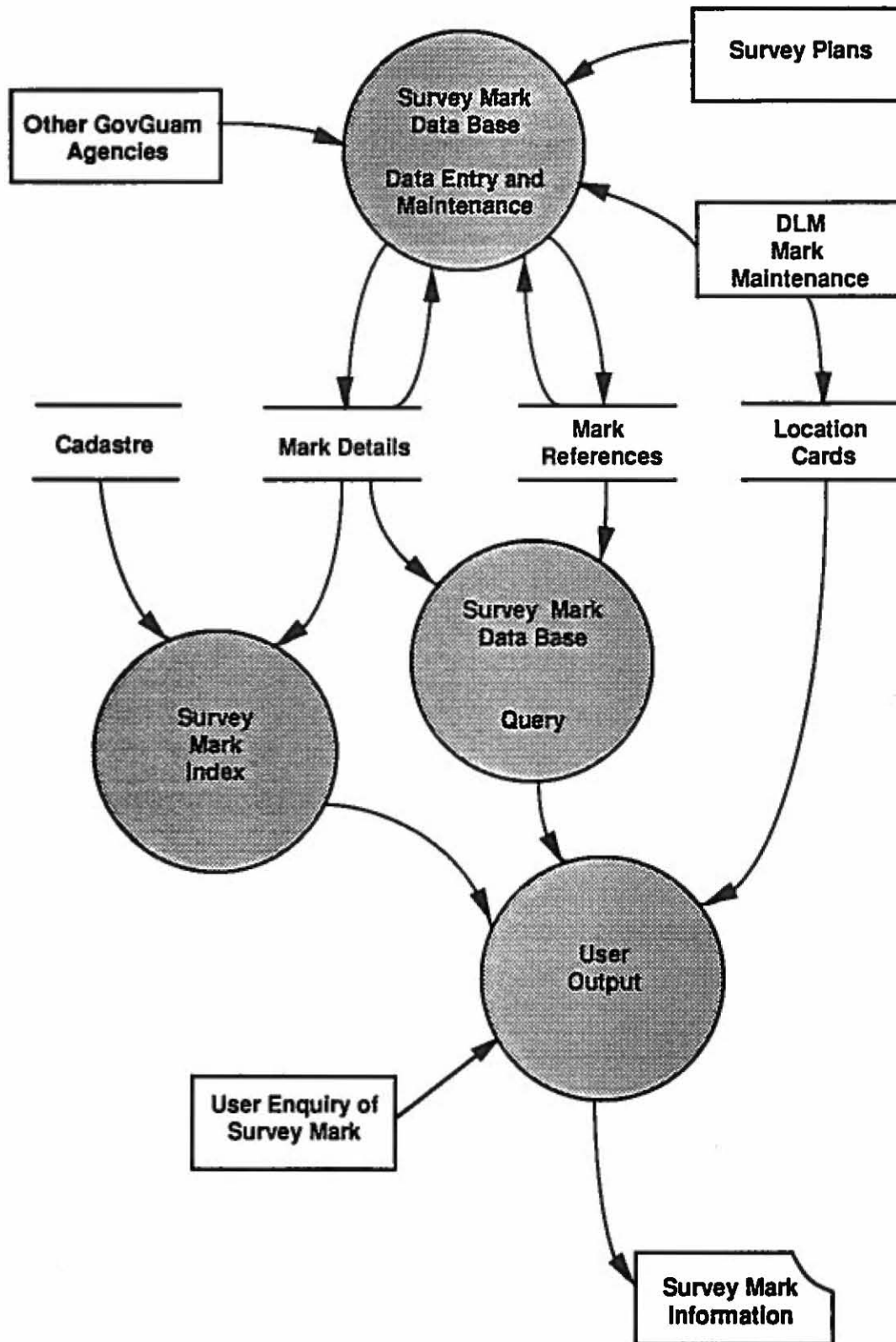


by sketch prepared from
of Lands field check
is are in metres
scale
10-8-93 C.B.B.

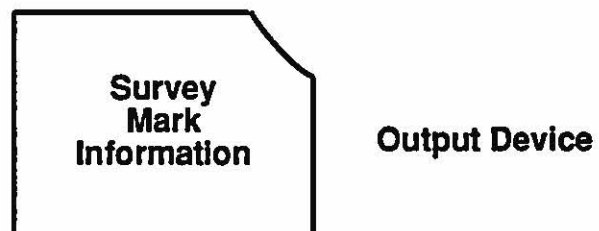
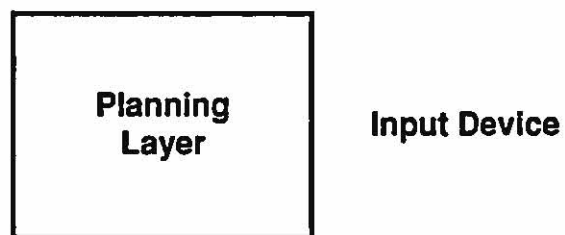
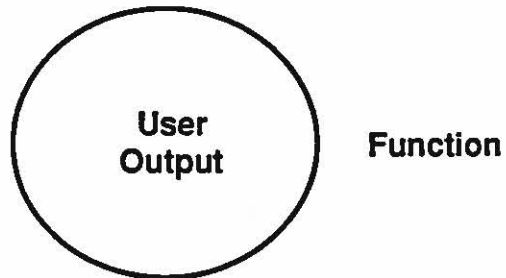
Survey Mark Data Base
Entity - Relationship Diagram



Guam Survey Mark System Data Flow Diagram



Data Flow Diagram Symbols



Arrows are used to Represent Data Flows

APPENDIX 16 - ICSM EXTRACT RE CLASS AND ORDER**PART A****STANDARDS OF ACCURACY****2. HORIZONTAL CONTROL****2.1 DATUM FOR COORDINATES**

Geodetic coordinates for the Australian mainland, Tasmania and close inshore islands which can be connected to the Australian Geodetic Datum by conventional terrestrial geodetic techniques are to be computed using either:

- . the 1966 coordinate set (AGD66) for geographical coordinates and the associated Australian Map Grid (AMG66) for projection coordinates, or
- . the 1984 coordinate set (AGD84) for geographical coordinates and the associated Australian Map Grid (AMG84) for projection coordinates.

The decision as to which coordinate set is to be adopted within a State or Territory is the responsibility of that State or Territory.

Geodetic coordinates for Australian External Territories and for offshore islands which cannot be connected to the Australian Geodetic Datum by conventional terrestrial geodetic techniques are to be computed on the World Geodetic System 1972 (WGS72) (see NMC SP10).

2.2 STANDARDS OF CLASS AND ORDER

CLASS is a function of the precision of a set of coordinates relating to a survey mark, assigned on the basis of the field survey methods, reduction techniques AND the results of a minimally constrained network adjustment.

ORDER is a function of the **CLASS** of a survey, the conformity of the new survey data with an existing network coordinate set AND the precision of any transformation process required to convert results from one datum to the AGD and/or AHD71.

These Standards and Specifications use the standard confidence level (1 σ) as the standard for statistical testing for allocation of **CLASS** and **ORDER**. Information relevant to higher levels of significance is given in Part A, Annex A.

2.2.1 Class

Horizontal control surveys are to be assigned a **CLASS** limited by the planned precision and that which is achieved. This will be a function of:

- . the network design,
- . the survey practices adopted,
- . the reduction techniques, and
- . the results of a minimally constrained least squares network adjustment computed on the ellipsoid associated with the datum on which the observations were acquired.

Horizontal Control

Recommended Survey and Reduction Practices (Part B) documents proven survey techniques designed to achieve a specific CLASS of survey. However, the responsibility for ensuring that any practice adopted is commensurate with the CLASS of survey planned lies with the Authority undertaking that survey. If the survey methods or reduction techniques adopted are not commensurate with the desired CLASS of survey, or if the minimally constrained adjustment fails to achieve the desired CLASS, the stations in the survey should be assigned the highest CLASS common to all three aspects.

The statistical concepts of variance and confidence region are used to express the results of a minimally constrained least square network adjustment, and replace the concept of maximum anticipated error. For any such adjustment, it is imperative that the quality of the field observations and the mathematical model be tested.

This may be achieved by an analysis of the aposteriori adjustment statistics including the application of a variance ratio test. If the statistics suggest an anomaly, or if the variance ratio test fails, then the data and the model must be examined to find the reason. After correction, the data must be readjusted and the assessment reapplied.

The allocation of CLASS to a survey on the basis of the results of a successful minimally constrained least squares adjustment may generally be achieved by assessing whether the semi-major axis of each relative standard error ellipse or ellipsoid (ie one sigma), is less than or equal to the length of the maximum allowable semi-major axis (r) using the following formula:

$$r = c (d + 0.2)$$

Where r = length of maximum allowable semi-major axis in mm.

c = an empirically derived factor represented by historically accepted precision for a particular standard of survey.

d = distance to any station in km, with a minimum distance of 1km.

The values of c assigned to various CLASSES of survey are shown in Table 1.

Horizontal Control

2.2 Table 1

Classification of Horizontal Control Survey

CLASS	c (for one sigma)		Typical applications
	2D	3D	
3A	1	2	Special high precision surveys
2A	4	6	High precision National geodetic surveys
A	10	15	National and State geodetic surveys
B	20	30	Densification of geodetic survey
C	45	60	Survey coordination projects
D	75	100	Lower CLASS projects
E	150	200	Lower CLASS projects

Experience has shown that with most modern methods of establishing closely spaced control, the overall pattern of error propagation is not proportional to distance but rather to the combination of instrumental and centring errors, the effects of network configuration and a host of other contributing errors, most of which defy individual identification. The errors of measurement contributing to this pattern can be divided into two groups:

- (i) those proportional to distance which are dominant on lines longer than one kilometre;
- and (ii) those non-proportional to distance which are dominant on lines shorter than one kilometre.

The adoption of the formula $r = c(d + 0.2)$ as one element in the determination of CLASS will generally provide these specifications with the flexibility necessary to accommodate survey networks containing control stations which are closely spaced, widely spaced or with variable spacing. Nevertheless, it is recognised that the nature of survey adjustment is such that it is not always possible to fully describe the results of a survey simply by considering the statistical output of the adjustment. Part of the assessment of the quality of a survey is also dependent upon a subjective analysis of both the adjustment and of the survey itself. The ultimate responsibility for the assignment of a CLASS to the stations of the survey network must remain within the subjective judgement of the geodesists of the Authority or State or Territory responsible for that survey.

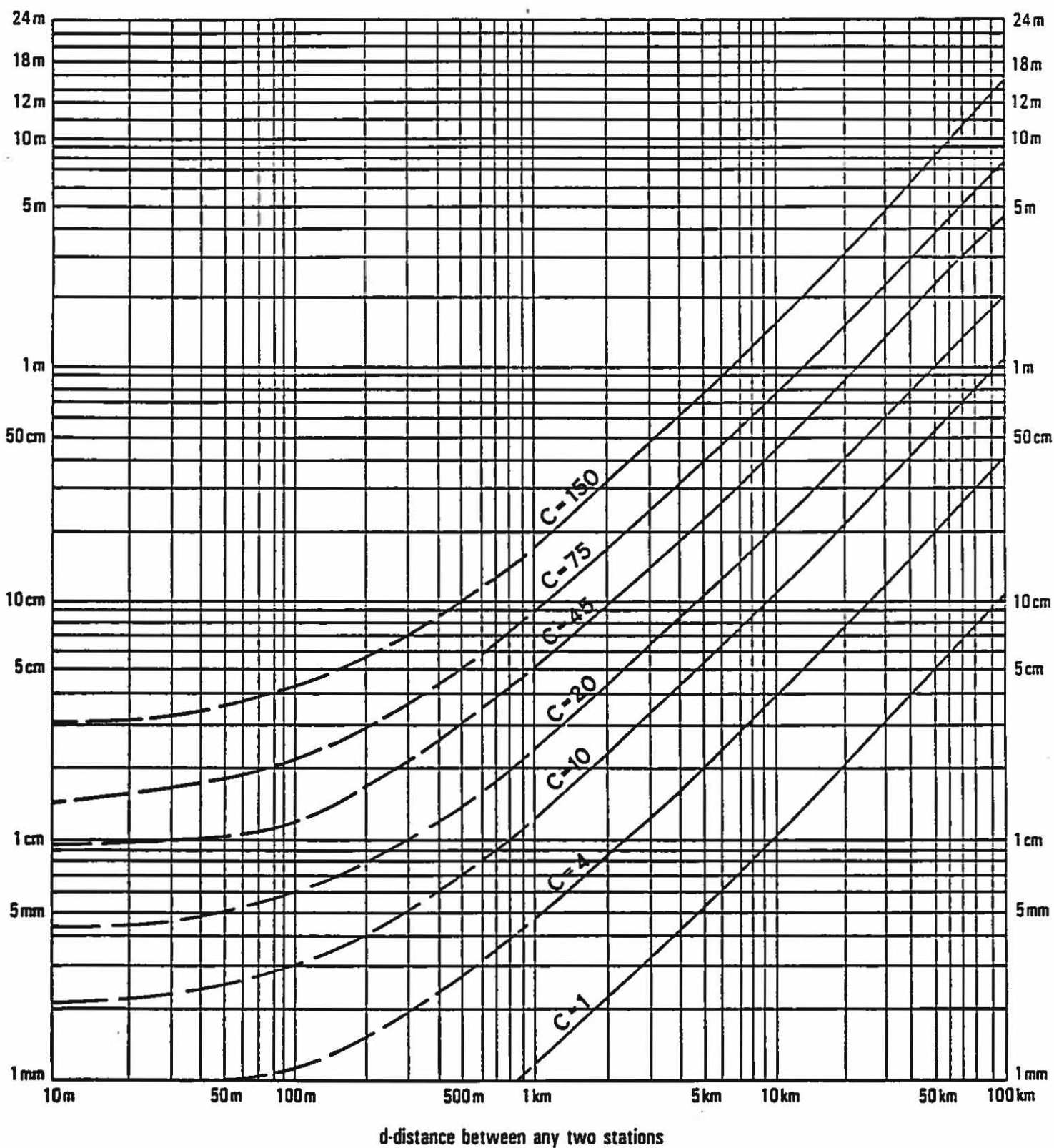
The relationship between the assigned values of c and commonly adopted confidence regions is shown in Annex A, Table 1.

A graph of the length of the maximum allowable semi-major axis against distance between any two stations (r against d), is shown in Section 2.2, Figure 1.

Horizontal Control
2 Dimensional Surveys

2:2 Figure 1

CLASS RELATED VALUES OF C (for one sigma)



Horizontal Control

2.2.2 Order

Stations in horizontal control surveys are assigned an ORDER commensurate with the CLASS of the survey and the conformity of the survey data with the existing coordinate set.

The ORDER assigned to the stations in a new survey network following constraint of that network to the existing coordinate set may be;

- (a) not higher than the ORDER of existing stations constraining that network, and
- (b) not higher than the CLASS assigned to that survey.

The highest ORDER which may be assigned to a station from a survey of a given CLASS is shown in Table 2.

2.2 Table 2

Survey of a CLASS - Highest ORDER Relationship

CLASS	ORDER
3A	Special High Precision
2A	0
A	1
B	2
C	3
D	4
E	5

As the concept of ORDER is based upon the CLASS of the station as well as the fit of the survey network to the existing coordinate system, the ORDER correlated to CLASS alone may be degraded by its fit to the existing coordinate set or as a result of the configuration of the ties used to constrain it to the existing system.

The allocation of ORDER to a station in a network, on the basis of the fit of that network to the existing coordinate set, may generally be achieved by assessing whether the semi-major axis of each relative standard error ellipse or ellipsoid, with respect to other stations in the fully constrained network, is less than or equal to the length of the maximum allowable semi-major axis. This technique is identical to that employed in the determination of CLASS and makes use of the same formula...

$$r = c (d + 0.2)$$

Where r = length of the maximum allowable semi-major axis in mm.
 c = an empirically derived factor represented by historically accepted precision for a particular standard of survey.
 d = distance to any station in km, with a minimum distance of 1km.

Horizontal Control

The values of c assigned to various ORDERS of survey are shown in 2.2 Table 3.

2.2 Table 3

ORDER of Horizontal Control Survey

ORDER	c value (for one sigma)	
	2D	3D
00	1	2
0	4	6
1	10	15
2	20	30
3	45	60
4	75	100
5	150	200

With ORDER, as with CLASS, it is recognised that assessment of the quality of a network following a constrained adjustment remains dependent upon a subjective analysis of the adjustment, the survey, and the ties to the existing coordinate system. The ultimate responsibility for the assignment of ORDER to the stations in a survey network must remain within the subjective judgement of the geodesists of the Authority, State or Territory responsible for that survey.

3. VERTICAL CONTROL

Vertical control will normally be provided by differential levelling, trigonometrical heighting, GPS, Inertial Survey systems or by other techniques.

3.1 DATUM FOR HEIGHTS

Heights should be referred to the Australian Height Datum (AHD71). When connection to the Australian Height Datum is not possible, heights shall approximate as closely as possible to heights above mean sea level, and the datum used should be carefully defined.

Further information on the AHD can be found in NMC Special Publication 10, The Australian Geodetic Datum Technical Manual (NMC SP10).

3.2 STANDARDS OF CLASS AND ORDER [UNDER REVIEW] * * * * *

In general, the definition and assignment of CLASS and ORDER, as outlined in Section 2.2, is applicable for Vertical Control.

It is accepted that some heighting techniques (eg. differential levelling) propagate errors in proportion to the square root of the distance. Other techniques (eg. GPS and trigonometric levelling) propagate errors mainly in proportion to the distance. Regardless of how levelling errors propagate with specific techniques, the one system of allocation of CLASS and ORDER needs to be applied so that all results can be uniformly classified.

3.2.1 CLASS

The allocation of CLASS to a vertical survey on the basis of the results of a successful minimally constrained least squares network adjustment may generally be achieved by assessing whether the standard deviation of each height value is less than or equal to the maximum allowable value (r) using the following formula:

$$r = c\sqrt{d}, \quad \text{for } r > 0.25c$$

Where

r = maximum allowable error, in mm.

c = an empirically derived factor represented by historically accepted precision for each particular CLASS of survey result.

d = distance to any station in km, with a minimum distance of 1km.

The values of c assigned to each CLASS of survey are shown in 3.2 Table 1.

Vertical Control [UNDER REVIEW] * * * * *

3.2 Table 1

CLASS	c (for 1σ)
A	4
B	8
C	12
D	50
E	100
F	250

3.2.2 ORDER

Similarly to the case with CLASS, assignment of an ORDER is largely technique independent.

ORDER assigned to the constrained network adjustment height of a bench mark will be commensurate with:

- the CLASS of the new levelling;
- the magnitude of the discrepancy between the newly levelled and existing height differences of the bench marks at the abbutal of the new and existing levelling routes;
- the precision of the transformation from another height datum to AHD71.

The highest ORDER which may be assigned to a height from a survey of a given CLASS is shown in 3.2 Table 2.

3.2 Table 2

CLASS	ORDER
A	1
B	2
C	3
D	4
E	5
F	6

Annex B

A Guide to the Application of CLASS and ORDER

EXAMPLE

Assigning CLASS to a survey.

Consider a closed spirit levelling network, done using CLASS C techniques in the field with appropriate data reduction and a closure of 0.007m, around a 15km long loop. The standard deviation of each of the heights assigned to the 5 newly established Bench Marks, after a minimally constrained network adjustment, is approximately 0.001m.

Despite the closure rate and height values of better than CLASS A, the equipment and procedures used requires that CLASS C be assigned to the network.

Alternatively had the closure rate around the loop and the standard deviation of the final assigned values of each BM been lower than CLASS C, then CLASS D or E would be an appropriate allocation.

Assigning ORDER to a survey.

The same survey as above is connected into one FIRST ORDER, two SECOND ORDER and three THIRD ORDER existing Bench Marks. The constrained adjustment of the levelling loop achieved better than FIRST ORDER agreement with the existing control. From TABLE 2 the highest ORDER to be allocated for a CLASS C survey is ORDER 3.

Had the agreement with the existing BM's been to THIRD ORDER, the assigned ORDER would remain as THIRD.

Should agreement have been to less than THIRD ORDER, the CLASS C survey would be assigned a FOURTH or FIFTH ORDER, as appropriate.

All of the above assumes proper field and office checks were made on the data prior to adjustment and final allocation of CLASS and ORDER.

Using CLASS and ORDER.

Users of geodetic information from the above survey example would refer to the individual station summaries for information. They would not be able to tell from the summary how the survey was effected in the field. However, from the respective precisions and accuracies for the CLASS and ORDER classifications, a relative accuracy between marks could be ascertained quickly and easily.