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Association of Surveyors
of Papua New Guinea

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THE ASSOCIATION OF SURVEYORS OF PAPUA NEW GUINEA

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Vol. 14 March 1985

Editor: Jerry Sipuman
PNG University of Technology
Private Mail Bag
LAE.

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HYPOTHESIS ON THE EVOLUTION OF SURVEYING

(the first 7 days)

1st Day

In the beginning the Lord created Adam and Eve.

Adam was wild and untamed and there was much disarray within his head; and the ghost of darkness was within him. The light did not want to come and the chaos in his mind was great.

The Lord spoke:

> "There shall be a system to the chaotic disarray and its name shall be "mathematics".
>
> - thus, plus and minus made up the first day -

2nd Day

And the earth gave birth to straight lines, circles, ellipses, parabolas and other curves with and without single points.

> - thus from straight lines and curves the 2nd day emerged -

3rd Day

The fertile earth generated numbers and letters with and without indices, round, straight and other brackets, and

> the Lord put his blessings upon them and spoke:
>
> "Be fertile and multiply!"
>
> - thus, from equal and unequal, the 3rd day emerged -

4th Day

And the Lord spoke:

> "The earth shall give birth to formulae and definitions to that extent that their number will be infinite and Adam shall be their slave so that he may pass his time with them."
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5th Day

Co-ordinate system grew in polar and orthogonal disorder squeezing out logarithms and angular functions; and long rows of logarithms paraded in all their transcendental beauty.

- thus, from sine and cosine
emerged the 5th day -

6th Day

On the 5th day, however, an earthquake of great magnitude transformed the wellshaped earth; first into an ellipsoid and then into a shape of no math. definition called geoid and there was no end to the confusion.

- thus, from up and down, the
6th day emerged -

7th Day

And the Lord decreed:

"Let us bring back order and survey the earth!"

The valleys filled themselves with water exactly to mean-sea-level and the levelled survey marks grew like mushrooms.

Triangulations from 1st to 4th order generated themselves across mountains and valleys.

The Lord contracted Adam and said:

"You shall survey all of the earth and I will give you the whole of the mathematical paradise to do it with.

You may multiply and divide; use the numbers with and without exponents and take square roots with all numbers in this paradise - <u>but</u> - you are not allowed to divide by ZERO, because it is a creation of the devil!"

However, the snake - being cunnier than all other animals - spoke to Eve:

ZERO is not a creation of the devil but if one divides by 0, one will learn to distinguish between right and wrong."

The woman thought that it was easy to divide by 0 and that it was a funny No.

So she spoke to Adam:

> "Divide by ZERO, can´t you see how it simplifies the equation?"

Adam took all his courage and divided by Z E R O.

However, he was ashamed of his doing and hid behind a first order trigonometrical point.

The Lord was angry with him and decreed:

> "Because you have disobeyed my commandment, I will eliminate you from the mathematical paradise.
>
> Your work shall be damned and you shall for time coming survey the earth
>
> > from Coonabarabran to Mt. Hagen to Berlin,
> >
> > from the Antarctic to the Arctic including
> >
> > the new World that will be discovered by Columbus.
>
> All your surveys shall be prone to errors, and with sweat behind your ears you shall remeasure, remeasure, remeasure ....
>
> You shall adjust your surveys over and over again and your hands will be swollen from interpolation work on the slide rule.
>
> But never shall you be able to project the earth´s surface simultaneously correct in length, angles and areas.
>
> The noise of the hand calculator shall haunt you on every day of your life.
>
> Survey marks shall hide from you and in all climates you shall always, always be thirsty."

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Ed. Taken from The Journal of the A.S.P.N.G., December 1973
Vol. 3, No. 4

A PROPOSAL ON THE REGISTRATION OF CUSTOMARY LANDS IN PAPUA NEW GUINEA AND SURVEY TECHNIQUES THAT GO WITH IT

By

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WAIGANI

1. Introduction

This paper discusses the registration of a customary land in Papua New Guinea and some survey techniques necessary for its implementation. It is an expression of my views rather than official policy.

Registration of customary land has been widely discussed in recent years. The Commission of Inquiry into Land Matters (CILM) of ten years ago recommended the immediate preparation and introduction of the legislation and administrative machinery for the registration of customary land. Though assurances were given by responsible Ministers over the years of it receiving government blessing and legislation, the issue seems to be sinking deeper into the waters of the Waigani bureaucratic and political swamps.

To discuss whether it should be given a decent burial or revived one way or another is not the purpose of this paper. I wish to only discuss the flesh and bones of surveying and customary land registration in relation to the guidance provided by the wisdom embodied in the CILM report and other reports and writings that have their roots in situations within and abroad.

2. The Customary Land Tenure in PNG

The customary land accounts for 97% of all land in PNG. The remaining 3% is alienated or non-native land alienated from the traditional sector either by voluntary or by compulsory process which comprise two basic sub-divisions; state land and privately owned freehold. However, the latter is not significant in actual terms, and the law itself seem to favour government leasehold only.

TOTAL LAND AREA = 47 615 700 hectares

CUSTOMARY	GOVT/ALIENATED
46 310 419 hectares	1 305 281 hectares
97%	3%

Customary land or native land is land owned or possessed by an indigenous person or community by virtue of rights of a propritary or possesory kind, which belongs to that individual or community and arise from and are regulated by traditional custom.

There is a great variation throughout Papua New Guinea in the nature of customary ownership of land. In most areas the principal interest remains in the land holding group, and indidviduals within the group have limited right of use, either for life or for a shorter period. The normal system by which rights or ownership in land use are acquired is by birth into a land holding group. The transfer of right by sale was unusual in the past but is now an established and increasing practise.

A large number of Papua New Guinea's communities are organized into groups based on one or the other of the two forms of unilateral decent i.e. patrilineal for the highlands and most coastal areas and matrilineal for other areas e.g. West New Britain. However, in either system there is great flexibility in ways of land inheritance, ownership and the way the land itself is exploited or utilized.

Customary rights to land in most of PNG are widely fragmented, physically often into many small plots; also different kinds of rights to the same land are distributed with complexity among groups and individuals.

3. Land Registration and Surveying

Land registration is the system of registration of title based on Land Registration Acts and Rules. Its purpose is simplification of transfers of land. Title is entered in a central register and the time needed for effective transfer of titles is reduced. The main part of the register are: property (e.g. description of land); proprietorship (e.g. whether title is absolute); charges (e.g. mortgages, restrictive covenants). In a sense title is guaranteed by the state.

The above definition of land registration implies the Torrens System* which has been transformed into the land law situation in this country during the colonial era and applies to the alienated lands of the country and also the registration of customary land by Papua New Guineans under the Land Tenure Conversion Act.

The Torrens system of title registration is in contrast to registration of deeds. A deed is a record of an isolated transaction and is evidence that particular transaction took place, but it is not in itself proof of the legal right of the parties to carry out the transaction and consequently is not evidence of its legality. Thus before a dealing can be safely effected the ostensible owner must trace his ownership back to a good root of title (i.e. a title which the law will deem to be good without going behind it) through a sequence of transactions and events each of which can be properly proved. The deeds register will help in ths, but it may still be a long and skilled task.

Registration of title on the other hand is a process whereby the state maintains a register of parcels of land showing all the relevant particulars affecting their ownership, and guarantees those particulars to be correct. The register is the final authority. Transactions are effected by making an entry in the Register - and only by this means. A simple procedure with simple forms exists for this purpose, and so dealing in land becomes easy, quick, cheap and certain.

The branch of surveying involved in land registration is cadastral surveying, that is surveying carried out for the cadastre, roughly defined as the land register or office, is the most important of the many types of land measurements included in the general term "surveying". The main purpose of cadastral surveys is the demarcation of landed properties, giving the area, boundaries, value, location, and ownership of each individual holding or lot. Records of these surveys serve a dual purpose: they afford the state a basis for purposes of taxation and they verify owners' rights to possession of property. Thus under the Torrens Acts the boundaries of land registered are guaranteed but in fact this does not follow from the decisions of the courts; more correctly the boundaries are "survey defined".

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* First introduced in South Australia by Sir Robert Torrens in 1858. The essential feature of the Torrens System is that the state guarantees the accuracy of a register, which specifies the interests existing in all land under the system.

In some countries cadastral surveys are being undertaken for first registration of title and land surveyors are involved in the adjudication of ownership and boundaries as well as in the survey of the boundaries. In others, where a title register exists, land surveyors are preparing sub-divisional schemes for approval, are setting out such schemes and in some are responsible for their implementation.

4. Surveying and the Registration of Customary Lands in Papua New Guinea

In the preceding chapter it was seen that surveying is an essential or prerequisite of a completed land registration process.

The CILM recognised this and recommended that more survey staff and facilities should be available to meet the needs of land registration. Necessary land registration should not be held up for want of survey facilities, but neither should land registration be pursued at a pace that over-strains reasonable supply of survey staff and facilities.

Looking further at the CILM report, it recommended machinery for the registration of customary land, to be introduced only in areas where there was a clear need for these rights to be recorded in a systematic manner. In keeping with its major recommendation that new land policies should be based on and evolve from a customary base, the CILM recommended that the basic pattern of registration should be to register group titles whereby groups could get title to their traditional land and to allow the group to grant rights of use over its land in the form of registered occupation rights (to members of the group) and leases (to non-members of the group). The role of the group in administering its land was therefore clearly recognised and preserved, while provision was made to protect the enterprises developed by members of the groups and outsiders on group land.

An alternative to the above - only a small deviation at least technically - is to allow for the clans or villages to have their land boundaries defined and registered (i.e. through a compulsory process) which is to say the registration only of the clan boundaries. The internal divisions of land rights (i.e. fragmented holding, multiple ownership, subsidiary rights etc.) of land rights remain unofficial which family groups or individuals can use or exploit at their own discretion. The necessity for land registration (at least in the first place) is not so much the individualisation and consolidation of fragmented holdings but the physical definition of the boundaries of clans or land holding groups into their territorial organisation which of course is not only the basis of customary land law but the principle upon which social, political and economy of any traditional PNG community is built. There is no evidence in PNG that individual ownership leads to beter economic development than communal ownership thus clan demarcation and registration is more required than individualisation.

In many places the people are themselves modifying the traditional distribution of land rights usually for the purposes of gaining more secure tenure for cash cropping and certain rights of succession for their children. Thus, whilst the adjudication of a strictly customary distribution of land rights would indeed be a costly, contentious and largely futile if not impossible proceeding (as experience of the Land Titles Commission in the 1960´s reveals), what is possible in some areas (i.e. after the clan boundaries are demarcated and registered) is an administrative proceeding by which villagers agree among themselves on what is essentially a new demarcation of rights on part of their territory or individuals themselves on their own parcels.

In earlier case villagers could produce a series of small-holder blocks, or a group owned farm, with selected named villagers acknowledged to have the right of farming those parcels. Old garden rights and much of the complex of intersecting claims by members of the lineage are set aside by agreement, in this process. Naturally it is a process which can more easily take place where groups have a surplus of largely ungardened land, where the demarcation can take place.

This sort of division which has been carried through in some places under the now-suspended Land Tenure Conversion Ordinance, was proposed to be carried further in the abortive 1971 Land Bills and is now proceeding unofficially in several parts of the country (in the highlands the 25 years lease-back agreement is one aspect of it). It is in fact an aspiration in which villagers would welcome more assistance both in appropriate land law to ratify their agreements and the provision of adequately trained lands officials, who can help them make the modification of rights which they are seeking.

I wish to elaborate in more detail the different steps for implementation. They can be divided into six stages namely:

(i) Final determination of ownership or the process of adjudication;

(ii) Consolidation;

(iii) Demarcation;

(iv) Survey;

(v) Registration;

(vi) Control of transactions in registered land.

4.1 Adjudication

The first stage in registering customary land is the process of adjudication or the final determination of ownership i.e. who owns what land. In other words adjudication is the means by which a final assessment/definition is made of existing rights in land. Its cardinal principle is that it recognizes and confirms rights which are actually in being; it does not alter or create rights, though it may substitute a right defined under statute for what is considered to be its equivalent under customary law.

Adjudication is not a new process in PNG. The Native Land Commission (1952 - 1962) and the one which superseded that, the Land Titles Commission, both had powers to determine the ownership of land in a systematic fashion or as and when applications were received....The process of systematically recording the ownership of customary land, called "adjudication" under the LTC where it was restricted to "adjudication areas" selected by the Commission, and the commission was to be assisted by advisory "demarcation committees" comprised of land owners. These two changes came partly from local experience and partly from Kenya. In 1957 the government had directed the Native Land Commission to give priority to registration in areas where cash crops had been planted or were planned, and the NLC had successfully used committees of landowners on an informal basis. The Committees in Kenya, on the other hand, actually decided ownership and an appeal lay from their decisions to the officer in charge of the adjudication scheme.

In the customary lands there are no distinct boundary monuments or plans showing the boundaries of clan lands and no recording of one group allowing another group use over a piece of land. This had resulted in a never ending inter-clan disputes and feuds among clan members as their only evidence to their claim is their memories. The Land Disputes Settlement Act set up the machinery for hearing and setting these disputes by Land Mediators appointed by the Provincial Land Disputes Committee or if they cannot settle the dispute, by the local land courts. It can be expected that as registration process commences dormant or new disputes will erupt everywhere but the situation should be brought under control especially if a whole area i.e. a district or a province is adjudicated or demarcated compulsorily or systematically. However if an area is too hotly contested by two opposing clans, their land should be declared national land. Some modification of the Land Disputes Settlement Act is necessary to meet registration requirements.

4.2 Consolidation

As discussed earlier, customary land in most of PNG is widely fragmented, physically often into many small plots; also different kinds of rights to the same land are distributed with complexity among groups and individuals. Those factors make any form of grand schemes for sweeping survey and registration largely impractical in this country. While I think most people in PNG accept the idea of registration of their land, prior consolidation is not acceptable to the people and will never work here.

Even with my little knowledge of land registration and being a land owner myself, I see that consolidation involves considerable upheaval in the lives of those concerned and presents many human problems. This natural opposition to consolidation underlines the imperative need to conduct a probe study of fragmentation in any particular locality and of the problems involved in consolidation before any decisions are taken to embark on a programme of consolidation. The Government must be satisfied that consolidation will result in material advantages which outweigh any possible disadvantages and must ensure that procedures are adopted which take into account the particular problems of the locality. If a decision is then taken to proceed with consolidation, the processes must be fully explained to the people and accepted by them, however long it takes to obtain acceptance.

4.3 Demarcation

This can be divided into two, the demarcation of clan boundaries and the demarcation of internal user lease-holds within the clan area. In the demarcation of clan boundaries, this can be carried out in conjunction with the adjudication process with each clan marking and working the boundaries. This survey can be carried out by a registered surveyor using electronic distance measurement (e.d.m.) and theodolite and tie in the survey to permanent or control survey marks i.e. a high order level of survey is required. Demarcation work will not be successful if the adjudication process was not successful, half done and the clan boundaries still disputed.

The next facet of demarcation is the division of defined clan land among clan members for their gardens, houses etc, over which they will get a registered lease if they so desire. It will be necessary for these people to mark the boundaries of their individual areas. As indicated in recommendation 7 of CILM, a team of specially trained people are going to be required to help in this. I see the person undertaking this work being a survey technician specially trained in land management as they will play a multiple role in the registration process i.e. demarcation of land boundaries, production of demarcation map adequate for registry purpose, help people to register their land at the registry and provide whatever advisory services people seek. As this is an ongoing work, these people will be stationed to look after the interests of the people (they are closest to them) in the area, and they are going to number into the hundreds so it is imperative that special training and planning is required at an early stage.

4.4 <u>Survey</u>

There is not much difference in the process of demarcation and survey - in fact they are one and the same, both concerned with definition of land boundaries. I am treating them separately purely for disscussion's sake.

It must firstly be emphasised that while surveys should be as rapid as possible they should not be held up purely on the grounds of accuracy. The end product of a survey is a map or survey plan. Maps are required by a registry to identify on the ground a plot marked on the map; secondly, to assist in the re-location of a boundary should it be moved or lost; thirdly, to enable subdivisions to be effected; fourthly, for the calculation of plot areas. In the survey of clan land "fixed boundaries" are required so that boundaries can be defined by accurate survey. The survey procedures required will produce for first registration a registry plan of sufficient accuracy to allow of the identification of plots (and tied into the cadastral survey of PNG), the computation of areas, the relocation of boundaries and whatever marks placed on the ground visible, permanently fixed on the ground and acceptable and understood by the villagers themselves. For the survey of subdivisions, "general boundaries" are required which means that the registry map is deemed to show only approximate boundaries and the approximate situation of each parcel of land but this implies surveys tied into the defined frame work of clan boundaries (connection from at least 2 corners) to show their relation. It is, of course, an essential part of a general boundaries system of registration (i.e. the subdivisional aspects or registration of individual parcels of land) that parts must be demarcated on the ground by physical marks each as lines of trees, hedge, fences or walls which are plain for all to see.

In the survey of clan boundaries what is important is the placing of <u>considerable sized</u> corner monuments or evidence of a boundary's location and this should have precedent over measurements.

I do not agree that photogrammetric survey should be introduced at any stage of survey. Photogrammetric survey requires suitable weather conditions and is an expensive process; outside financial aid and skill will be required and boundaries must be visible. I think the more important consideration with regards to customary land registration is that the people will appreciate a survey procedure and survey peg they can understand and see on the ground. A map or survey plan, or the photo or what else is very rarely understood by the common people. To merely expect people to interprete their land boundaries from such is only adding to the confusion (even now very few people understand and interpret a survey plan no matter how much one tells them). What people will appreciate and accept at best is what the surveyor places on the ground.

As stated earlier the method of surveying clan boundaries should be by the use of theodolite and chain or e.d.m equipment. For clan subdivisions chain and compass is most suitable. All that is required is the survey of plot boundaries and the production of a demarcation plan of sufficient accuracy to act as the registry map. An alternative to the chain and compass survey is the use of base maps (production after survey of clan boundaries) by plane table methods, the surveyor (or survey technician) using the detail on the base map to fix his position and orient himself, getting his distances with a simple quickest level with stadia hairs, and levelling staff.

The order of accuracies should be the following:

CONTROL SURVEYS	= 1:20,000 - 1:15.000
CLAN BOUNDARY SURVEYS	= 1: 2,000 - 1: 5,000
SUBDIVISION SURVEYS	= 1: 200 - 1: 500

4.5 Registration

I have defined what land registration is and most of what I want to say has been covered in the early parts of the paper. Also it will be too lengthy for me to discuss the procedures or technical aspect of title registration. However I wish to mention that the main criteria in registration are simplicity and ease of registration and land dealings at the grass-root level. If these are not achieved then the whole system will fail, as it will not get the backing of, or use by the people - as happened in the past. Again I see the local survey technician acting as the local registrar, by being present at a transaction and filling out the necessary forms correctly for the persons concerned. These forms will then be forwarded to a district registry, and the information placed into the district register. The alterations would be forwarded to both the provincial and national registries. The registers at a provincial and national level will be computerised for east of handling transactions and searching. It is intended they will be developed into full cadastres.

I do not see any other method of land registration acceptable to the PNG situation other than the Torrens System of title registration in operation in the country now. For it to apply to the vast tracts of customary land in this country there might be need for some modification and to decentralise the central registry to provincial and district levels (bring it closer to the people). However, the central registry should keep the clan registration proceedings.

The discussion and insights stated here are mine alone and whatever official policy that is adopted (when customary land registration do come into effect), it will be interesting to see how much difference there is.

4.6 Control of transactions in registered land

In brief the controls that will be required will be effective through a separate Land Control Ordinance or Act like the Land Dispute Settlement Act. Some of its important provisions would be to give the Provincial Secretary or whoever is in charge of the whole registration process to divide the customary lands in his province into divisions which would not necessarily correspond with administrative districts or census divisions, in respect of which divisional land control boards would be set up under the chairmanship of a district officer (or other person appointed by the Provincial Secretary) and comprising of othe representative members plus some say 6-10 local members. Any transactions at all must go through this Board and any appeal go through a Board under the chairmanship of the Provincial Secretary. This suggestions here are based on the Kenyan model but there is need for some restructuring to suit PNG needs. The whole area needs some careful research, consideration and planning before any kind of machinery is finally suggested for implementation.

The whole basis of customary land registration is to give a title to land which would provide a convenient form of security for loans from sources not previously available to the customary landowner or farmer, although it must be emphasised that the mere possession of title will not in itself make its holder creditworthy. There are also other recognised means of gaining credit, e.g. through co-operative societies. Moreover, the provision of a secure title which can be pledged as security for a loan may, if the loan is used for unproductive purposes or if the rate of interest is exorbitant, or even if there is a succession of crop failures, lead to a serious state of chronic indebtedness, as a result of which a farmer, even if he retains his land, will be deprived by debt charges of most of his income and will then lose the incentive to farm properly.

If a registered landholding clan goes into a group or communal farming or some other form of business activity on their land this needs to be closely supervised and whatever advisory and extension services provided by relevant governmet institutions e.g. DPI, Development Bank, Business Development etc go to the intended beneficiaries.

The government itself may decide to charge a minimal registration fee or stamp duty. The Registrar provides statistics of prices paid for land, plot sizes and the extent of fragmentation. Such basic information is of use in planning agricultural development, helps effective extension programmes to be undertaken and provides the machinery for the rating of land should this be deemed desirable.

And finally because transactions on registered land, will be as at local level, I think the whole process of customary land registration should be the major function of provincial governments to enable development at the grassroots level. Better still a pilot project should be started up in a province like Enga and if successful spread to other highland areas and the country as a whole.

5. Conclusion

The future of domestic and overseas investment in PNG is dependent on a system of land registration that works, that the country can afford and that the people can understand and accept. Ninety-seven per cent of the land in PNG is held under customary law with no format for registration despite seemingly lip-service by concerned ministers over the years. This land, the majority of which supports subsistence living is restricted in its development by the complete lack of an agrarian law common to the interests of the people, the government and the land.

However I must admit that it will be a problem to try to weave new concepts of land registration (be it in the format I have tried to explain or any other) with the traditional interests of Papua New Guineans. It wil take a very fine thread to sew the traditional interests and the necessary development that PNG must achieve to satisfy the ambitions and needs of the people. Whatever registration system or surveying procedures are used, they must discard or incorporate past attempts within and abroad, and take note of prevailing conditions (which include the desire and expectations of the people) and provide a solution that is cheap, quick, within the reach and easily understood and accepted by the people themselves.

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LAND ADMINISTRATION

OK TEDI PROJECT

BY

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1.0 ABSTRACT

In developing the Ok Tedi Project, large tracts of land were required for a variety of purposes including mining leases, leases for mining purposes, township development and access corridors, to name but a few. This paper describes the use of techniques such as aerial photography, orthophoto maps, doppler positioning systems, computer aided mapping/drafting and modern transport facilities to produce a variety of plans and sketches used to not only describe and obtain the necessary land, but also for its future administration.

2.0 INTRODUCTION

When the decision is taken for a project of any nature to proceed, site works cannot be commenced until some form of land title is in the hands of the owners of the project. The Ok Tedi Project was no exception and hence to ensure that the development could proceed once the green light was given, preliminary discussions with numerous people and groups were needed to ensure that all areas of concern were covered and all forms relating to the procurement of the land were completed.

As early as 1980 when the Ok Tedi Consortium was preparing a feasibility study for Government approval, the people of the Star Mountain area were expressing concern that land ownership questions be settled before mining operations commenced. Their concern reportedly stemmed from similar problems in other mining areas of Papua New Guinea.

Land ownership in Papua New Guinea is vastly different to that in Australia, the major differences emanating from customary ownership involving various groups as well as individual people in the area concerned. In searching the various acts and regulations pertaining to the procurement of land by acquisition or lease, it was found that other conditions and requirements for customary land would need to be met which were in turn dependent upon the form of title being sought.

As the people of this area knew nothing of major construction projects nor were they familiar with mining systems and the associated infrastructure required to support such a venture, it was obvious that a well equipped, knowledgeable, public relations team was required to explain to these people all aspects of the proposed development.

From the land requirement aspect, the following points needed processing:

Land requirements - mine and infrastructure

Land tenure - government or company

Plan presentation of requirements

Marking of boundaries

Walking the boundaries

Plans of Survey

Future administration of land parcels.

3.0 LAND REQUIREMENTS

Various tracts of land were required for a number of purposes which include the following:

mine area

tailing and disposal areas

township

water supply

electric power generation

access roads

power line access routes

construction and industrial areas

wharf and laydown facilities

gravel deposits

spoil areas

explosive magazines

navigational aids

In determining the land tenure needed for these areas, discussions were held with Government bodies and some of the factors under consideration were:-

(i) Land that must be obtained by either lease or acquisition by virture of its proposed use.

(ii) Land to be acquired by the Government so that present and future needs of the people could be met. This would also include land to benefit the people and the country once mining operations ceased.

(iii) Land that had benefits only for the company during its mining operations and that could, on cessation of mine production, revert to the people.

4.0 LAND OWNERSHIP

Where the government acquired the land it did so for either the benefit of its people or for specific departmental requirements.

Company leased land was procured for various reasons including such factors as it being of no benefit for local people and for protection of the mining operations.

The road corridor acquired by the Government from Kiunga to Tabubil via Rumganae and Ningerum can now be used by local people for faster access between these centres and their villages. It will also allow for a local bus transport system if desired. However other sections of roads e.g. for access to the mine operations would not service any useful purpose to local people and hence a mining easement was taken over these tracts by the Company.

In negotiating a suitable land tenure consideration is also given to such matters as present land use, timber, gravel, cleared areas, etc, and compensation for loss of existing rights is reflected in the purchase price or in the case of leased land; the annual rental.

5.0 PRESENTATION OF PLANS

To adequately describe the land being sought, a series of plans are required. These range from the feasibility stage of development through to lease plans registered with the appropriate Government agencies. Added to these are plans which may be understood and interpreted by people who have had no contact with such matters previously.

The rugged nature of the terrain made definition of boundaries both easy and difficult. The easy part of the boundary definition lay in the office compilation of the lines and survey stations using mapping and aerial photography. The actual marking of the points would be the difficult part.

Regulation 101 of the PNG Mining Regulations requires that:

(1) Before making an application, the applicant shall mark off the land applied for, to the satisfaction of the Warden by -

(a) erecting at each corner of the land a hardwood post or marker at east four inches in diameter and standing at least four feet above the surface of the ground;

(b) clearing lines along the boundaries of the land; and

(c) placing stakes or other markers at sufficiently close spacing to indicate clearly the boundaries of the land.

(2) Until the land in respect of which an application has been granted has been surveyed, the lessee shall -

(a) maintain the posts and markers erected in accordance with this regulation; and

(b) maintain the lines cleared in accordance with this regulations,

and therefore the lessee shall -

(c) maintain the survey marks; and

(d) maintain those lines.

In the case of the Ok Tedi Project leses, which embraced some 175 square kilometres with a perimeter in excess of 85 km, some relief from the requirements of this regulation was obviously necessary.

Following discussion with various government departments it was resolved that where practicable natural feature boundaries such as watersheds, ridges, creeks, etc, should be adopted as the boundaries of the subject land and where this was not practicable straight line boundaries between prominent mountain peaks should be adopted.

Early in the public relations stage it was realised by OTML that although the local people had difficulty in understanding contour plans they possessed a natural ability to relate to and interpret aerial photography.

With this in mind it was resolved that the identification of the extent of leased alnd would be clarified in the following manner:-

(1) The marking of boundary points at 1 - 2 km intervals around the perimeter of the leased land.

(2) The preparation of colour orthophotomapping of the leased land which would clearly show the cleared marks and accurately define the adopted boundaries.

(3) The lodgement of conventional survey plans to meet the statutory requirements of the Department of Lands Surveys and Environment.

Using early aerial photography and 1:100 000 national mapping series sheets, tentative boundaries were selected.

In view of the proximity of the Irian Jaya border care was taken to ensure that the leses did not extend into areas with catchmet discharge over the international border. Hence adoption of natural feature watersheds satisfied potential problems concerning drainage as well as providing the local villager with a clear understanding of where the boundary fell. ("Antap long maunten").

During the period December 1981 to April 1982 we were fortunate in obtaining aerial photography of the entire minesite relatively cloud free.

From this photography a series of AO size mapping sheets covering the area at a scale of 1:2 500 were completed. Over 90 such sheets were produced. This mapping was in turn reproduced at varying scales (see Figure 1) including 1:10 000, 1:25 000 and 1:200 000. A series of 10 colour orthophotomaps at a scale of 1:100 000 was also produced wit the lease boundaries and photogrammetric form line data superimposed on each map. Copies of this series, forming a comprehensive photographic record of the site and the intended boundary definition, were supplied to the Department of Lands Surveys and Environment.

Concern was still felt for the traditional land owners who would have difficulty in relating to the topographical plans. To overcome these problems uncontrolled aerial mosaics were made and superimposed on these prints was the lease boundary information. This information would then supplement the accurate mapping in the presentation of the areas required.

The only major problems encountered with the mosaics were the distortion and scale of the photographs due to the major differences in elevtion of the terrain. Hence the boundaries show on the photographic mosaic could give a different shape of the parcel of land when compared to the same area on the mapping due to distortion effects. (See Figures 2 & 3).

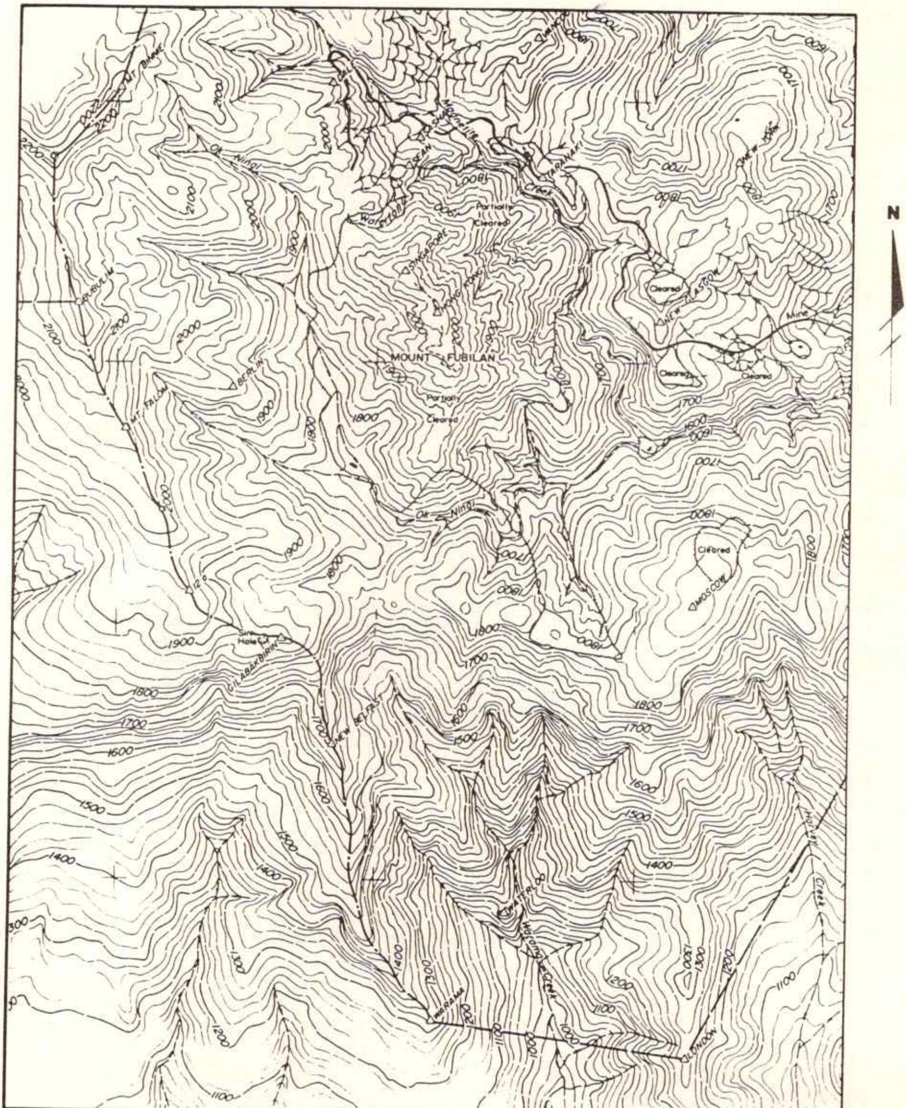


Figure 1

MT FUBILAN

SHOWING PART OF SML 1 BOUNDARY

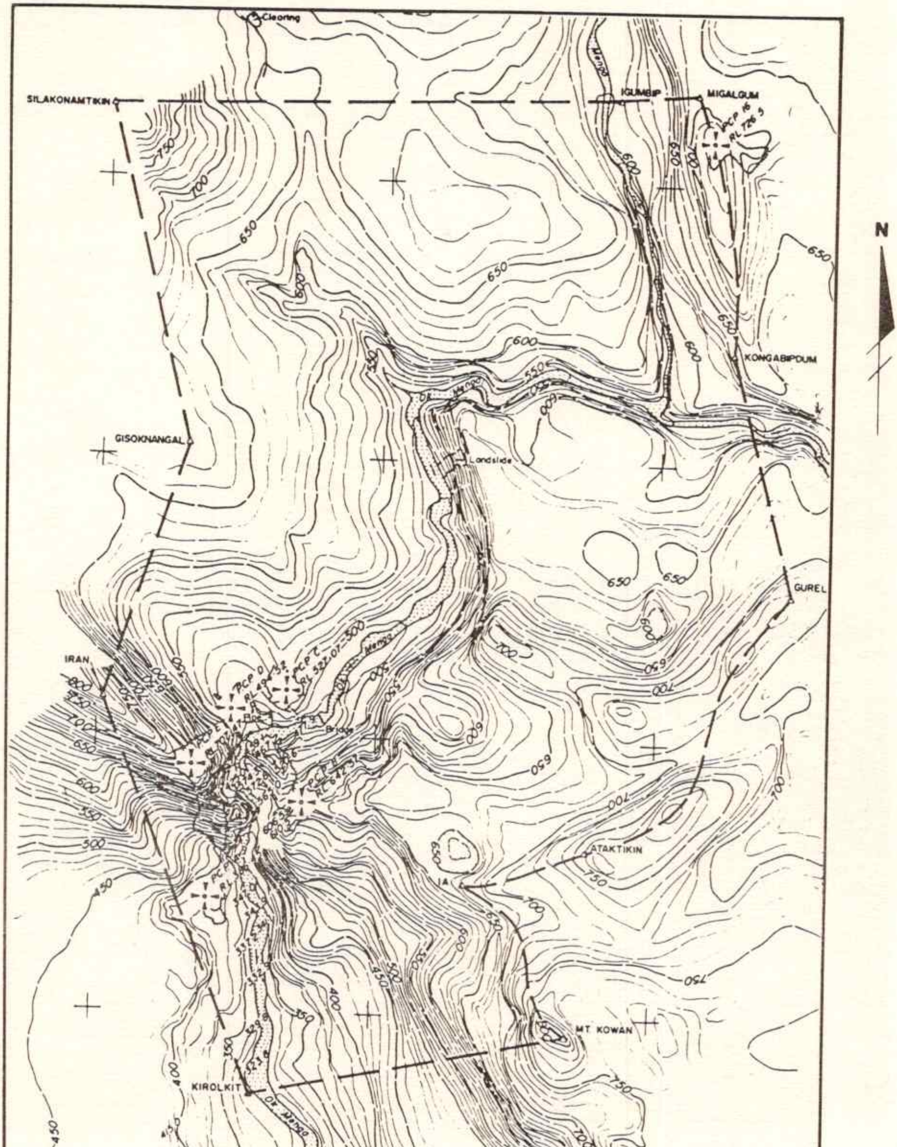
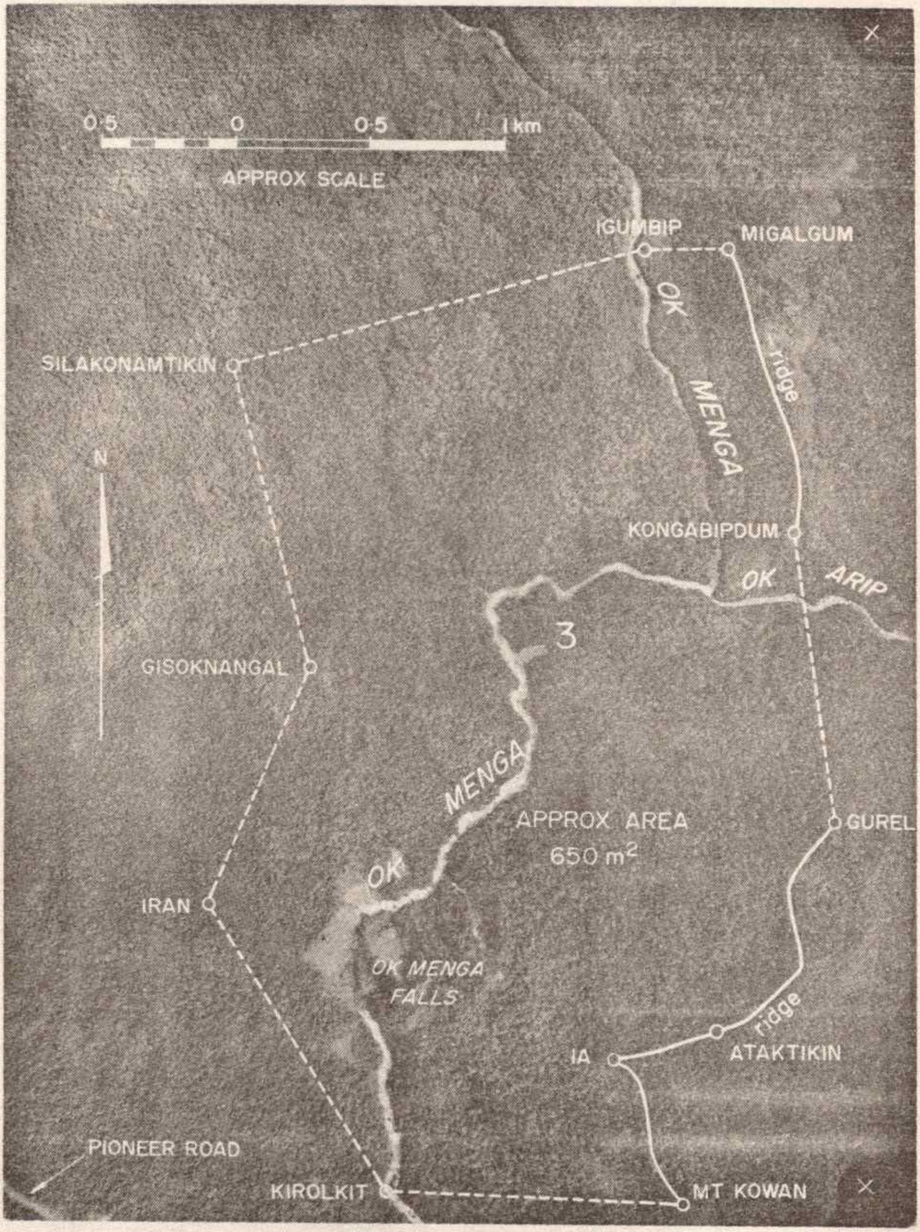


Figure 2

OK MENGA
SPECIAL (POWER SUPPLY FACILITIES) PURPOSES LEASE
SHOWING TOPOGRAPHIC MAPPING



PORTION 3, OK MENGA

Boundary definition by aerial photography

Figure 3

BHP ENGINEERING

6.0 MARKING OF BOUNDARIES

As previously stated, the boundaries of the leases were in general to follow natural features or form a straight line between two prominent features and survy stations would be cleared and marked at 1-2 km intervals. It was further agreed that minor direction changes and changes in river and creek courses would be coordinated by fixing such angle points photogrammetrically. (See Figure 1).

Field parties were dispatched into their areas and set down by helicopter as close as possible to the required site from whence they walked, climbed, slid, etc, until the site was reached, cleared and marked. It is well known to all that visibility is a major concern for a survey party coordinating a number of points and in the project area this was often rendered impossible by either the nature of the terrain and vegetation or because of low cloud and rising mists. Therefore it was decided to use satellite doppler techniques to coordinate the lease boundary points since, because of the nature of the opertion of this equipment, not only would the weather be overcome but also manpower needs for this survey would be reduced. During the course of this survey work, it was realised that, although the assumptions made were correct in most cases where the points were very remote, a number of points could be seen from a known station on top of Mt Fubilan and hence these were fixed using conventional methods.

These stations were also used as control targets for the aerial photography flown to produce the orthophoto maps of the mine project area. As the location of lease corners was required for position only, it was expected that heights obtained by doppler techniques would not be more accurate than about two metre whereas the expected position would be within - 1 metre.

7.0 WALKING THE BOUNDARIES

A requirement under the mining regulations relating to lease granting is that the mining warden, people with an interest in the land and representative of the lessee should walk the boudaries to see for themselves what land was being addressed. With 85 kilometres of uncleared boundaries involved this would indeed present a formidable task. Again through discussion it was agreed that helicopters would be used to "walk" the various people around the leases, point out the boundaries, be they natural features or straight lines between the survey stations as cleared and marked.

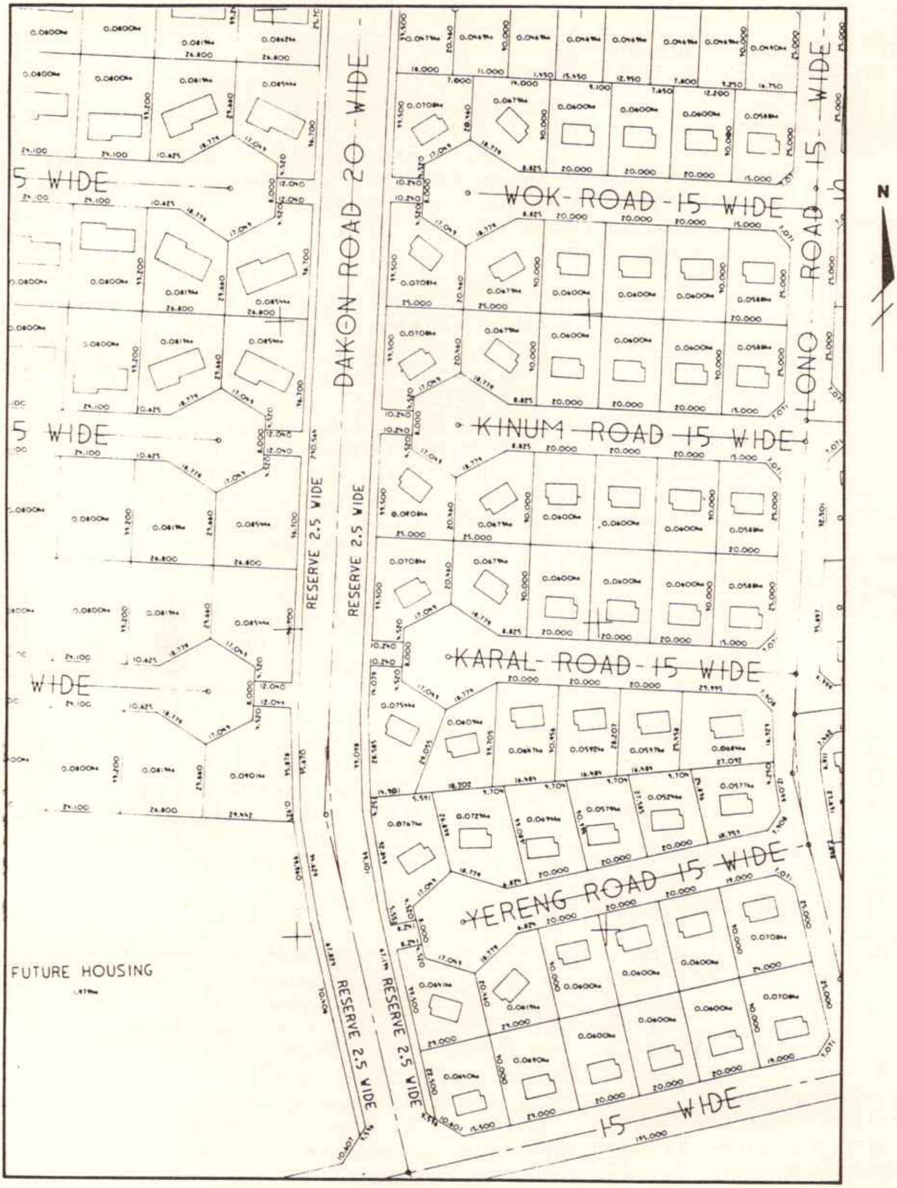


Figure 4

TABUBIL TOWNSHIP
TOWN SUBDIVISION DESIGN

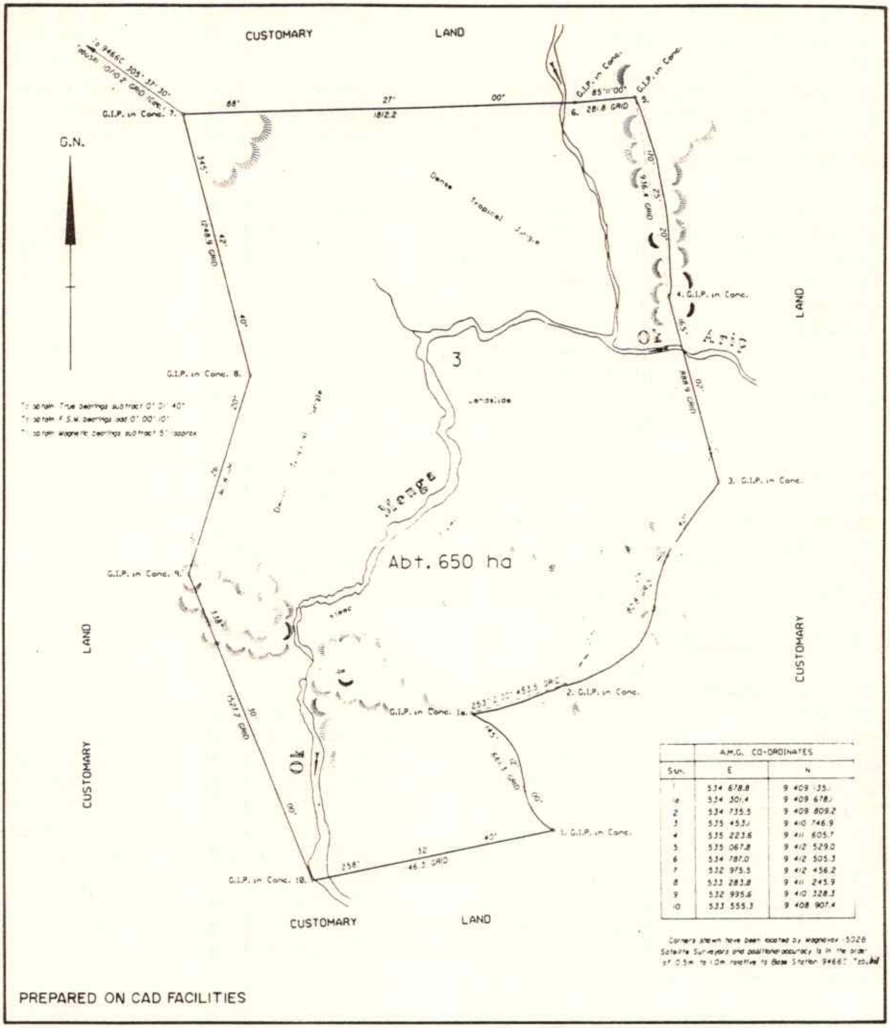


Figure 5

PLAN OF SURVEY OF PORTION 3, MILINCH OF DENEB, FOURMIL OF BLUCHER, OK MENGA

8.0 PLANS OF SURVEY

The plans of survey required for the various leases were produced by the draftsperson at the drawing board. Information for the natural features was obtained photogrammetrically and double checked from the topographic mapping of the project area.

In relation to the cadastral subdivision of Tabubil township, use is being made of computer aided drafting methods to prepare the plans required. This has involved the input of a large number of "as constructed drawings" of the town which show, roads, services and dwellings as well as superimposing over these details the proposed cadastral data (See Figure 4). From this information, preliminary plans are being forwarded to the DLSE for approval of the subdivision and similar working drawings are being provided to the survey parties to field check the boundaries with respect to the services and housing.

The final boundaries, fixed and marked in the field, will then be input into the data base and corrected to produce final plans of survey for registration (See Figure 5). The data base will also form te basis of a land information system for OTML Administration. Negotiations on the final format and utilisation of this package are presently being processed.

9.0 CONCLUSION

In the world today, with the vast increases being experienced in the avenues of technological change, care must be exercised to ensure that the basic requirements of communication and simple explanation are not swept aside by the processes involved with such change. It is the surveyors′ responsibility to ensure that, together with other members of a public relations team, the facts are presented simply and clearly so that all involved can benefit by understanding what is being asked, offered or described, as well as being kept up to date with the progress of such dealings. This concern will increase as we further develop into high technology and will indeed present a challenge to the surveyor until others involved in our sphere of operations understand the changes taking place.

10.0 ACKNOWLEDGEMENT

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AN ELEMENTARY INTRODUCTION TO INERTIAL SURVEYING SYSTEMS

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AN ELEMENTARY INTRODUCTION TO INERTIAL SURVEYING SYSTEMS

1 INTRODUCTION

Surveying systems based on the principle of inertial navigation are relatively new in geodetic practice. The development of these systems in the early seventies was sponsored by military agencies, in particular, the US Army Engineer Topographic Laboratories at Fort Belvoir, Virginia.

In 1975, the first systems of this kind became available to nonmilitary users. These systems were tested extensively during that year and since 1976, they have been used for production work by government agencies and private industry in Canada and the United States. The bulk of the work to date has been in establishing geodetic control that generally has second-order accuracy. Recent results indicate, however, that it may be possible to achieve first-order accuracy.

This is a brief and elementary review of the principles employed by an inertial measuring unit and it will note the major differences between the three systems presently available. The accuracy of intertial positioning will be examined. A note will be made that L- or V- shaped traverse causes problems, as do the effects produced by the imperfect knowledge of the anomalous gravity field.

The application to cadastral surveys will not be discussed in detail. However, some of the following points may be relevant. The current use of the system for control surveys and densification indicates one large area where inertial survey systems can be used to advantage. Favorable aspects of the systems include the speed of the survey, independence of lines of sight, homogeneity, output in coordinate form and, last but not least, the lower costs of the survey. In cadastral surveys, an obvious sequence would consist of Doppler control of 100 km to 300 km apart, inertial densification to 2 km to 10 km, and a detailed survey by classical or photogrammetric methods. At present, there are no data available as to the usefulness of the system in a detailed cadastral survey with a large number of points only a short distance apart. The obvious procedure here would be the accurate positioning of traverse points by the system and the measurement of all neighbouring points in a tacheometer fashion at the same time. The azimuth would come from the system, the distance from attached EDM equipment.

2 MEASURING PRINCIPLE

An inertial co-ordinate system is one in which Newton´s Laws of motion hold: it can be visualised as a system nonrotating with respect to the stars.

We begin with Newton´s second law of motion in the special form

$$f = m.a$$

where the mass m is considered to be constant. With f measured and m known, the acceleration a can be computed. Let us now assume that the acceleration is generated by the motion of a vehicle in three-dimensional space. Using a Cartesian coordinate system, the vector of acceletations a can be expressed as second time derivative of the radius vector r from the origin of the coordinate system

$$a = \frac{d^2r}{dt^2} \qquad (2)$$

Thus, coordinate differences between stations P_1 and P_2 can be determined by doubly integrating a:-

$$r_2 - r_1 = \int_{t_1}^{t_2}\int_{t_1}^{S} a \, dt \, ds \qquad (3)$$

where dt and ds both refer to time. This is the basic equation underlying inertial navigation. To use it for positioning purposes, an accelerometer triad has to be mounted on a vehicle in such a way that its orientation in space is known at each instant of time. While the vehicle moves from P_1 to P_2 , accelerations are measured and integrated along the three inertial coordinate systems, r_2 and r_1 strictly represent three-dimensional Cartesian vectors from the origin of the inertial system. However, it can by shown that, for measurements on the surface of the earth, the origin can be moved to the centre of gravity of the earth. The errors produced by this approximation are at least one order of magnitude smaller than the measuring errors.

The orientation of the accelerometer triad can be achieved by determining all orientation changes of the measuring unit against inertial space (strapdown systems) or by controlling the orientation changes in such a way that they can be described by a well defined mathematical function (gimballed systems). This second possibility is used in all inertial surveying systems presently available. It required the mechanical implementation of a so-called stable element - a stabilized platform that isolates the measuring unit from the vehicle motions. In the space-stabilized system, the platform frame is fixed with respect to inertial space; in the local-level system, it rotates against inertial space in such a way that the z-axis of the measuring system remains orthogonal to an initially defined ellipsoid. This second system can be related in a very simple way to the ellipsoidal coordinate systems used in geodesy. The transformation from the ellipsoidal coordinates to the conformal mapping system and the separation of the height component are well known.

The stabilization of the platform is done by a system of gyroscopes, i.e., by highly spinning tops. A gyroscope will maintain its orientation in space unless acted upon by a torque. Thus, a system of three orthogonal axes defined by gyroscopes at the start of the mission can be maintained independent of vehicle motions. This frame, which can be transported, is ideally suited to define the orientation of the three accelerometer axes.

An alignment precedes each inertial survey to relate the orientation of the measuring frame to that of the coordinate system, in which the control points are given. During this procedure, the measuring unit is levelled and oriented by gyrocompassing. The levelling aligns the z-axis of the system along the local plumb line. If the deflections of the vertical are known at the initial point, the transformation to an ellipsoidal system of coordinates can be done in a simpler manner. Gyrocompassing is based on precession, i.,e., on the specific movement the spin axis of the gyro undergoes when a torque is applied perpendicular to it. The same principle is used in gyrotheodolites to establish astronomic north.

Two problems arise when applying Formulas 1 and 3 to systems moving on the surface of the earth or its vicinity. First, the measuring unit moves in the gravity field of the earth and here Formula 1 has to be replaced by

$$f = a - g \qquad (4)$$

where, for convenience, m = 1 has been assumed. Formula 4 shows that to integrate vehicle acceleration the effect of gravitational attraction has to be subtracted first from the measurements. This is not difficult for the normal component, which comprises about 99 percent of total gravitation. However, it is more complicated for the gravity disturbance vector (see later). The second difficulty to be overcome is that the measuring unit moves on a body which itself rotates with respect to inertial space. Thus, the transformations between the acceleration vector in all inertial frame and one in a uniformly rotating frame have to be introduced into Equation 3. The final expression is of the form

$$r_2 - r_1 = \int_{t_1}^{t_2} \int_{t_1}^{t_2} [f(r, \dot{r}, \ddot{r}, \Omega)]\, dt\, ds \qquad (5)$$

where $f(r, \dot{r}, \ddot{r}, \Omega)$ indicates that the acceleration now depends on r, its first and second time derivatives $\dot{r}$ and $\ddot{r}$, and on a skew-symmetric matrix Ω containing angular velocities. The vector r now refers to a topocentric system. Again m = 1 has been assumed.

Thus, inertial positioning can be summarized as the determination of vehicle accelerations from measurements and their integration along three orthogonal axes whose orientation with respect to an inertial frame is known at any instant of time.

3 ERRORS AND THEIR PROPAGATIONS

In reality, measuring errors must always be taken into account and optimal procedures must be found to eliminate them. In the inertial surveying systems, all major errors are time dependent and show a very typical behaviour over certain periods of time. Thus, position errors governed by the Schuler period of about 84 min, show basically a sinusoidal error growth, while undamped altitude errors develop rapidly; e.g. errors from the accelerometers grow with $(\text{time})^2$ and a gyro drift produces an error dependent on $(\text{time})^3$. If the vehicle is stopped, the computer can reset the velocity to zero (zero velocity update, ZUPT), so removing all velocity errors contributed by the instruments to that time. In principle therefore the position errors can be kept small by stopping frequently enough. Usually these stops are made at 4 - 5 minute intervals. Further smoothing based on external constraints (eg. fixed control points) during a field operation results in relative positional errors of the order of about a metre; if crossover points, and post-operation smoothing are also used the error can be reduced to decimeter level.

4 SYSTEMS CURRENTLY AVAILABLE

At present, three companies offer inertial systems for surveying purposes. Litton´s AUTO-SURVEYOR has been on the market for the longest time and most of the actual results quoted in the literature on inertial surveying systems refer to this system. The name of the system changes somewhat with the user, thus the name Inertial Positioning System (IPS) may be found in the United States and the name Inertial Surveying System (ISS) in Canada. The Litton System and the Ferranti Inertial Land Surveyor (FILS) were originally designed for military purposes. The development toward accuracies needed in surveying applications for the Ferranti system has been done cooperatively by the company and Shell Canada Resources Ltd. over the last two years. The Honeywell GEO-SPIN is a system that was designed specifically for surveying purposes. A prototype was tested extensively during the summer of 1979 and production of the system began in 1980.

Because a typical survey mission is similar for each of the three systems, their common features will be described first. The system, mounted in a van or a helicopter, is aligned at a station that has coordinates known to within 100 m. This procedure usually takes about 1 hour and requires only occasional attention by the operator. The vehicle is then moved to the first point with accurately known coordinates and the first coordinate update is made. It proceeds along the traverse, stopping at intervals of about four minutes to make a zero velocity update for control. This update takes from one to two minutes and is required at each station to be surveyed. When a monument with known coordinates is reached another coordinate update takes place and the vehicle starts on the next leg. Progress is fairly rapid, typical values are 80 km to 100 km of traverse per hour for the helicopter mode and 30 km per hour for the van.

There are differences between the systems due to concepts, hardware, and software. Conceptually, the Litton and Ferranti systems are local-level systems and Honeywell´s GEO-SPIN is a space-stable system. The basic difference is one of mechanical versus computational complexity. In the first case, a simple computational model is possible because the z-axis is constantly kept orthogonal to the ellipsoidal normal, but the error budget is increased because of torquing errors. In the second case, the computational load is somewhat heavier but the gyros remain basically untouched during a mission. This excludes one important error source and gives more stability to the system, but a larger on-board computer is required. This however, does not seem to be a disadvantage with the present developments in minicomputer technology.

The hardware of the Honeywell and the Ferranti systems is more recent than the hardware of the Litton system. However, the differences in the accuracy of the hardware components, gyroscopes, accelerometers, and gimbal assemblies - is not a direct indication of the differences in the overall performance. Because of the complexity of the systems, a realistic error model must include software inadequacies as well as hardware errors. Recent investigations with the Litton system show that the internal consistency of repeated measurements is much better than could be inferred from the discrepancies obtained at stations with known coordinates. This indicates that the precision of the hardware is not fully used by the standard software. Thus, software improvements seem to be more urgent than hardware improvements at present.

The error control techniques for the three systems are quite different. The Litton system uses a Kalman filter at each update and a simplified smoothing routine when a station with known coordinates is reached. Thus the results are directly available in the field. At present, the user only has access to either the filtered or the smoothed data. This means that the actual measurements are not available, which makes an improvement of the software extremely difficult. The Honeywell system uses a simple zero updating procedure and stores the actual measurements in very small intervals. When arriving at known station, a Kalman filter is activated and smoothed values are obtained for all intermediate points. Thus, approximate positions are known while travelling, smoothed results are available in the field, and the measurements are also stored if an analysis is needed later on. This arrangement appears to be ideal for the system user. At present, the Ferranti/Shell system does not use filtering procedures. All data are stored in the field and evaluated in the office. Thus, there are basically no computer restrictions. Position determination is done by an integration procedure using a moving three poing curve fitting average. The difficulty with this approach is that no check is possible in the field and that small nonlinearities in the data can remain undetected. The advantage is that the actual measurements are available and that a more compact system can be built.

This brief enumeration shows that different approaches can already be used in acquiring and processing the data of inertial surveys and that perhaps a few more years of experience are needed to arrive at optimal procedures.

6 ACCURACY

The following points may be noted:

1 The system works best on a local, area mode basis with many crossover points which the computer handles as constraints in the adjustment. It approaches first order accuracies in this mode.

2 The system works least well on traverses, particularly if these are L- or V-shaped.

7 EFFECTS OF LOCAL GRAVITY ANOMALIES

The results given above are representative of areas with small changes in the anomalous gravity field. Typically, where the deflections of the vertical variations are larger, e.g., in the mountains, the effects of the anomalous gravity can be serious.

To study these effects in a quantitative manner, simulation software, which was developed for the local-level system, was augmented to include simulation of the anomalous gravity field. It was shown that the co-ordinate errors in and caused by deflection changes of 12 arc seconds and gravity anomaly changes of 20mgal over a distance of 60 km amount to several metres and do not average out for the mean of a forward and a backward run. The program used standard zero update periods of four minutes and Kalman filter techniques. A reduction to update periods of two minutes did not improve the situation.

If on-board gravity measurements are made (by "gradiometers") and fed into the computation process, this can result in much higher accuracies in both modes. Current research and development is directed therefore to such improvements to the systems.

7 CONCLUSION

In the USA, inertial survey systems have been used, inter alia, extensively in coastal and/or marshy areas in support of hydrographic surveys and for the location of fixed aids to navigation: in this context the potential for use in the many flat, and/or estuarine regions of PNG is significant. With the expected development of on-board gradiometry, inertial surveying could in the future become a most appropriate technique for many facets of survey work in this country, not least in the cadastral field, which is expected to gain even more importance in the years ahead. The fact that helicopter operation is ideal for inertial surveying work is also a big point in its favour, in view of the limited potential of van-mounted instrumentation generally in PNG.

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ANOTHER AZIMUTH TECHNIQUE REVISITED

by I. J. Billows, B. Surv. (Melb), R.S., M.I.S.A., Staff Surveyor
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ABSTRACT

This article does not introduce anything new to the sphere of azimuth determination but utilises well known methods to produce a quick solution to what is often a time consuming task. The method assumes the reader has a basic knowledge of the requirements of astronomical observation for azimuth and describes a system readily adapted to the tools of modern day surveying.

INTRODUCTION

Provision of adequate azimuth control has often provided some problems for the practising field surveyor in remote areas. Should there be no visible targetted trigonometrical stations or other relatively close co-ordinated marks he is usually left to his compass or a sun observation to orientate his survey. For much of our work a set of east and west sun observations will satisfy our mentors and it is in this area I propose a rather neglected technique - the use of "daylight stars". With the power of modern day computing aids it is possible to avoid the once prolonged series of calculation and prediction and replace it with a quick, simple method that is not limited to the number of charts or nomograms one has the time to compile.

Presented here is solely the method for finding an appropriate star whilst the observational and reduction techniques are left for the reader to pursue. This article presumes a familiarity with the HP 41CV pocket calculator and all input/output routines are not explicitly described. The package is written for both northern and southern hemispheres but as yet the author has not been fortunate enough to test the system on the other side of the equator and would appreciate anyones comments if they manage to do so.

THE PROCEDURE

The essentials of the method are a "rough" knowledge of position (latitude & longitude), co-ordinated time, an approximate azimuth from which to begin, a star almanac, a HP 41CV calculator (or equivalent) and card reader all of which seem readily at hand for the PNG surveyor of today. A thermal printer is an optional but nevertheless handy addition to the system.

Assuming all programs (See Appendix 1) are now on card first "SIZE" the calculator to 095 and load program PC (This assumes input of 20 stars but if less are required then SIZE 095 may be reduced by 3 *[20-number of stars to be used]). PC prompts for the appropriate Polynomial Coefficients for the month concerned. These "R" values are tabulated towards the rear of the Star Almanac.

Now load program STD and input the Star Numbers, Right Ascensions and Declinations. These values are found in the central section of the Almanac. In all, 20 suitable "daylight stars" are listed with a "d" noted near the left hand side adjacent to star number. Their Almanac numbers are 32, 116, 135, 136, 162, 179, 185, 212, 216, 273, 328, 353, 364, 369, 379, 441, 514, 548, 571, 632 and may be highlighted or underlined if the information is to be accessed on a regular basis. If it is intended to pursue work of a similar nature in the same month this data may be "saved" by loading program DA and copying onto cards. Later this same program may be loaded and executed to copy from cards back into main memory of the calculator. This system is set to input and saving of information month by month but may be adapted by the user to any other time scale.

With all star data in the calculator we are ready to begin. A position of the observing station is now required. This latitude (ϕ) and longitude (λ) may be obtained by a number of methods and I have found a value accurate to a few minutes of arc is adequate and not too difficult to obtain. Other data includes the UTM Zone in which the observation is to be made and the date. Local Time is also required accurate to five or ten seconds and a personal wrist watch set by reference to one of the broadcast time signals (say WWVH or VNG) is suitable. Input to the program is local Zone time which is 10 hours east of Greenwich for PNG ie if we expect to observe at 9.35am we input 9.35 or for 2.05pm, we input 14.05, all times in 24 hour mode.

Also required is an approximate (UTM) grid bearing of the line concerned. This may be obtained from a variety of sources including a carried through traverse bearing, a quick single or double face sun observation, original plan bearings or a corrected compass bearing may suffice although I have not tested this latter alternative.

In each case of position, time and direction an absolute value for required precisions is not suggested but obviously the better these values the closer the star should pass to the centre of the field of view of the telescope at the required time, assuming a small horizontal and vertical collimation in the theodolite. Out of interest a useful field of view of a theodolite telescope could be considered as about $\pm$ $^{1}/_{4}$ degree of arc and thus those starting values should be at least commensurate with this for the desired star to be found.

Having input the appropriate star data and holding a listing of the other necessary information load program STP and follow the prompts. If a printer is available plug it in as a "hardcopy" is preferrable to copying it off the display. The predictions can be run for various times throughout the day and will hold good a week or so for planning purposes. Each time the block of data headed with latitude and longitude is changed, including the day, it is considered a new station and all that data block must be re-entered by executing STP again. Initially it is suggested to enter 0 (Zero) degrees for the APPROXIMATE BRG RO prompt and leave the default value 0 (Zero) for the RO SET prompt and all output will show stars in their true quadrants thus aiding planning of observations. Later the approximate grid bearing of the line from sun observation or whatever may be entered along with any orientation (setting) of the horizontal circle of the theodolite and all directions will then relate to this (See Appendix II). Having produced initial planning output the program STP, Polynomial Co-efficients, Star Numbers, RA's and DEC's need only be present in the calculator for fieldwork. Other progams which do not affect register 19 thru to register 35 + (3 * no. of stars stored) may also remain or be executed without influencing any of the necessary star data. DEG mode and SIZE should be restored if altered.

Once in the field and prior to commencement of observation execute STP and enter ϕ, λ, UTM ZONE, TIME ZONE (10 for PNG), Day (of the month), APRX BRG RO (R/S after each entry) and follow this by pushing key "Σ+" (or A) to call up the desired star by its number. This initial data input section of STP must always be run first then key "A" may be pushed to jump into the search and predict routine any number of times. An important feature of this observation is that the star is a small, well defined and occasionally not so bright pin point of light and telescope focus is critical. Initially the observer should "set" his theodolite onto a distant object, focus clearly, then note or mark this setting of the focussing sleeve to enable it to be reproduced on both faces of the theodolite. Having found a star this will probably be slightly modified and I have found a pencil tick on the focussing sleeve and another on the adjacent part of the telescope barrel (on both faces) when lined up are sufficient for reproducing the correct focus from observation to observation. Once again the removal of optical parallax prior to this operation is of major importance. Having found the star it is not too difficult to keep it in the field of view and depending on the observers preference he may observe it passing one or both crosshairs if he is set to work with either the "hour angle" or the "altitude" method. Also worth nothing is that both horizontal and vertical tangent screws should be centralised on their runs prior to observing as is always good survey practice.

I have not presented any observing technique here but the method of directions as employed in a normal sun observation has worked satisfactorily. In addition more than one star may be observed on each face prior to returning to the reference object if so desired. In this case it is only necessary to run the search and predict portion of the STP program under key "A" or by pushing R/S again if already in that area of program and entering the alternative star number. In all cases careful preparation of booking sheets is necessary and a booker is useful to facilitate expedition of observation within a time not greatly different to a normal "Sun - shot". A major advantage of utilising "daylight stars" is that an east and west observation can be executed simultaneously either by using two or more stars or one star and a balancing sun observation within a relatively short time span. In the sun/star combination the adoption of a suitable mean is left to the readers discretion.

CONCLUSION

It is clear that preparations appear somewhat tedious to get the observation under way and becoming used to the system does take some time but with a little practice I have found it quite workable, particularly when there is a relatively clear blue sky and only limited time in which to get an azimuth.

The programs presented will work with any number of stars depending upon the calculators capacity. Clearly the programs can be utilised in an evening or night time observation for the less well known or fainter stars. As an initial test of the system brighter, higher magnitude stars should be observed to enhance the observers ability to identify a star in the field of view rapidly. The power of the technique is realised in familiarity with its use and its complimenting an overall azimuth determination program mounted on a hand held calculator. I am aware that many surveyors prefer to develop their own programs tailored to their particular needs but I would like to think they may now consider allocating a rather unheralded tool to a small space in their bag of tricks.

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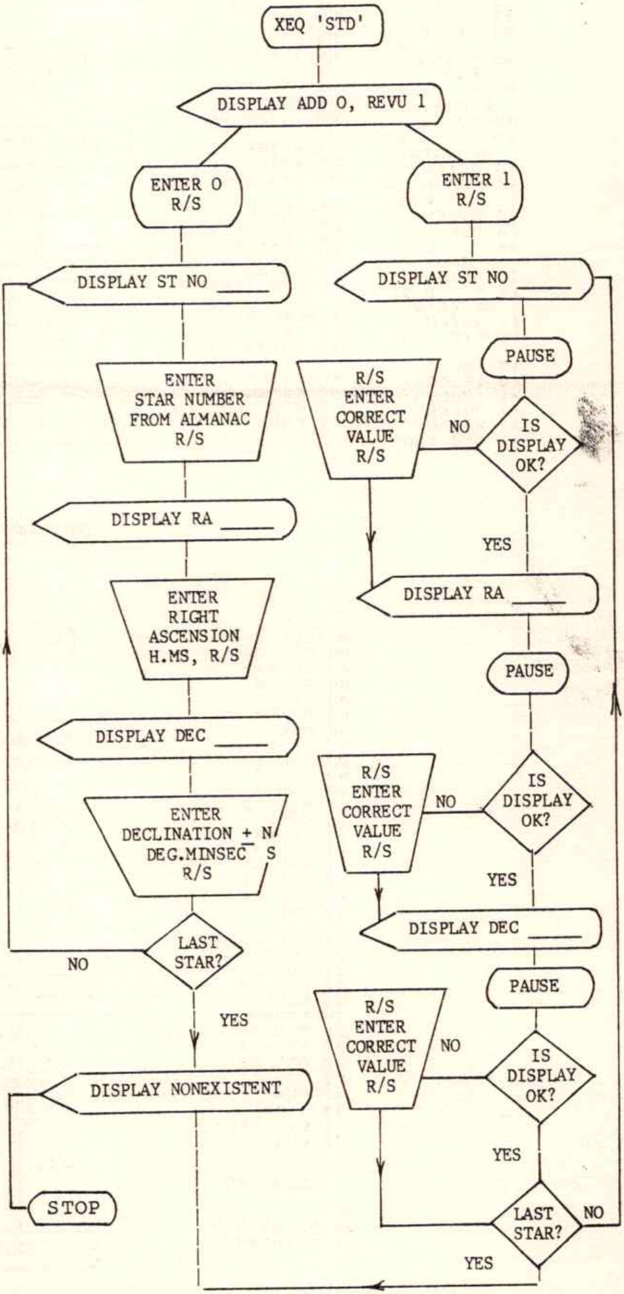
APPENDIX I

INPUT & REVIEW OF STAR DATA

SIZE: 35 + (3 * No. of stars used)
PRINTER: Optional
MODE: DEG

```
01•LBL "STD"
02 FS? 55
03 SF 21
04 CF 08
05 CF 09
06 SF 27
07 "ADD 0 , REVU 1"
08 PROMPT
09 X=0?
10 SF 09
11 35
12 STO 34

13•LBL 05
14 FIX 0
15 "ST NO "
16 ASTO 00
17 XEQ 02
18 FIX 5
19 "RA "
20 ASTO 00
21 XEQ 02
22 FIX 4
23 "DEC "
24 ASTO 00
25 SF 08
26 XEQ 02
27 CF 08
28 RCL 34
29 STO 19
30 ADV
31 GTO 05

32•LBL 02
33 RCL IND 34
34 FC? 08
35 GTO 03
36 90
37 -

38•LBL 03
39 HMS
40 ARCL X
41 CF 21
42 AVIEW
43 FC? 09
44 PSE
45 FC? 09
46 PSE
47 FS? 09
48 STOP
49 FS? 55
50 SF 21
51 CLA
52 ARCL 00
53 ARCL X
54 FS? 21
55 PRA
56 HR
57 FC? 08
58 GTO 04
59 90
60 +

61•LBL 04
62 STO IND 34
63 1
64 ST+ 34
65 END
```



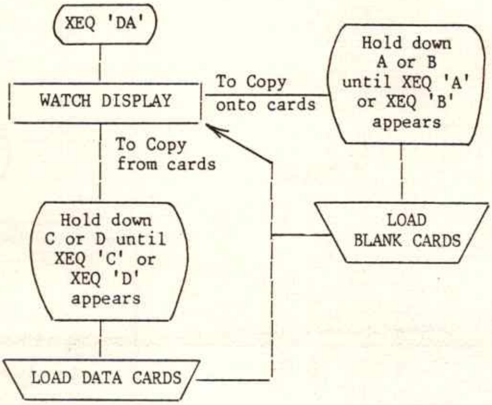
NOTES ON INPUT

1. IN 'ADD' OR 'REVU' MODE DISPLAYED DATA WILL BE GARBAGE UNTIL CORRECT VALUES ADDED.
2. TO ADD MORE DATA AFTER 'NON EXISTENT' RE 'SIZE', RTN, REVU AND INPUT AS REQUIRED, OR R/S THRU ADD MODE.

LOADING & COPYING CARDS OF POLYNOMIAL COEFFICIENTS FOR R & STAR DATA

SIZE: same as 'STD'
PRINTER: N.A.
Clear any key assignments under A, B, C or D.

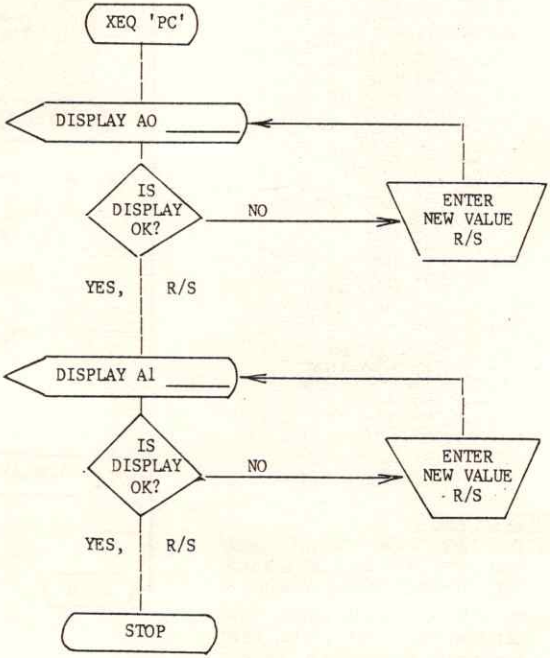
```
01+LBL "DA"
02 CF 21
03 SF 27
04 "TO CARD
         S"
05 AVIEW
06 PSE
07 "     A FO
  R POLY  "
08 AVIEW
09 "     B ST
  AR DATA "
10 AVIEW
11 "FROM CA
       RDS"
12 AVIEW
13 PSE
14 "     C FO
  R POLY  "
15 AVIEW
16 "     D ST
  AR DATA "
17 AVIEW
18 GTO "DA"

19+LBL A
20 19.033
21 "POLYS"
22 AVIEW
23 WDTAX
24 GTO "DA"

25+LBL B
26 RCL 19
27 1
28 -
29 1 E3
30 /
31 35
32 +
33 "STAR DA
        TA"
34 AVIEW
35 WDTAX
36 GTO "DA"

37+LBL C
38 19.033
39 "POLYS"
40 AVIEW
41 RDTAX
42 GTO "DA"

43+LBL D
44 35.2
45 "STAR DA
        TA"
46 AVIEW
47 RDTAX
48 GTO "DA"
49 END
```



INPUT OF POLYNOMIAL COEFFICIENTS FOR R

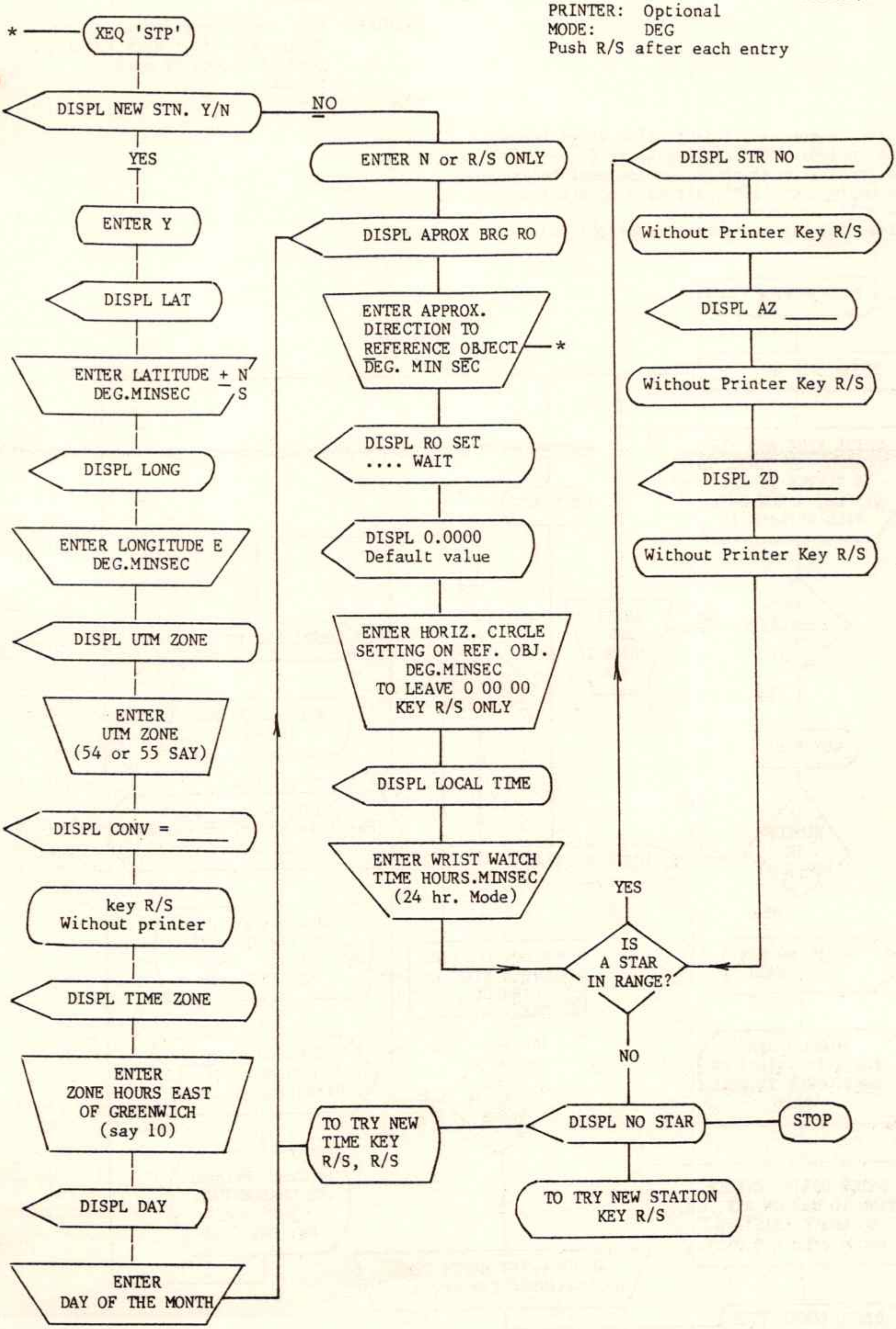
SIZE: 034
PRINTER: Optional

```
01+LBL "PC"
02 FS? 55
03 SF 21
04 FIX 6
05 "R"
06 AVIEW
07 PSE

08+LBL 01
09 CF 22
10 "A0 "
11 RCL 32
12 ARCL X
13 PROMPT
14 STO 32
15 FS? 22
16 GTO 01
17 FS? 21
18 PRA

19+LBL 02
20 CF 22
21 "A1 "
22 RCL 33
23 ARCL X
24 PROMPT
25 STO 33
26 FS? 22
27 GTO 02
28 FS? 21
29 PRA
30 STOP
31 GTO "PC"
32 END

     XEQ "PC"

R
A0 22.623533
A1 2.102697
```



STAR PREDICTION PROGRAM

SIZE: 35 + (3 * No. of Stars stored)
PRINTER: Optional
MODE: DEG
Push R/S after each entry



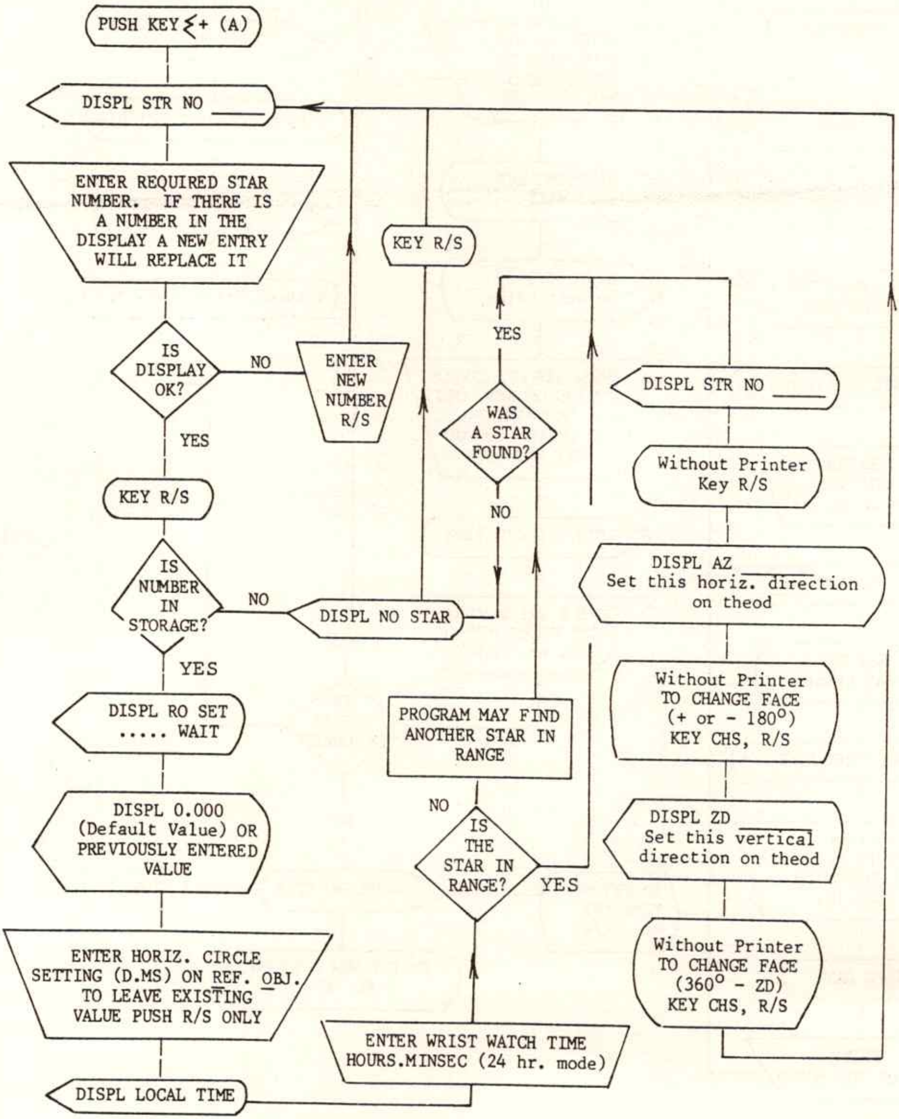
SEARCH & PREDICT SUBROUTINE WITHIN 'STP'

PRINTER: Yes, output continuous.
No, key R/S after each result, form of output is more flexible.

MODE: DEG

Note

1. Prior to entering this routine steps between and including the starred boxes (* -- -- *) in the star prediction section must be executed by keying XEQ 'STP'; altering of station data is still optional.
2. Clear any key assignment under Σ+ (A).



```
01◆LBL "STP"
02 FS? 55
03 SF 21
04 .
05 STO 06
06 36
07 STO 34
08 SF 00
09 CF 02
10 CF 04
11 CF 07
12 SF 27
13 XEQ 03
14 FIX 4
15 "APRX BRG RO "
16 PROMPT
17 ARCL X
18 FS? 21
19 PRA
20 HR
21 STO 05

22◆LBL 01
23 "RO SET"
24 ASTO X
25 PSE
26 RCL 06
27 HMS
28 STOP
29 ARCL X
30 FS? 21
31 PRA
32 ADV
33 HR
34 STO 06
35 XEQ 13
36 ADV

37◆LBL 06
38 RCL 09
39 RCL IND 34
40 -
41 15
42 *
43 1
44 P-R
45 R-P
46 X<>Y
47 SIGN
48 STO 16
49 LASTX
50 COS
51 ISG 34
52 CLX
53 RCL IND 34
54 SIN
55 *
56 RCL 01
57 SIN
58 *
59 RCL IND 34
60 COS
61 RCL 01
62 COS
63 *
64 +
65 ACOS
66 40
67 X>Y?
68 GTO 00
69 RDN
70 80
71 X<Y?
72 GTO 00
73 RDN
74 STO 04
75 STO 13
76 COS
77 1/X
78 .0147
79 *
80 ST- 13
81 RCL IND 34
82 COS
83 RCL 04
84 COS
85 RCL 01
86 COS
87 ABS
88 *
89 -
90 RCL 04
91 SIN
92 RCL 01
93 SIN
94 *
95 /
96 ACOS
97 RCL 16
98 *
99 180
100 +
101 STO 14
102 2
103 ST- 34
104 "STR NO "
105 FIX 0
106 RCL IND 34
107 ARCL X
108 AVIEW
109 FC? 21
110 STOP
111 FIX 4
112 "AZ "
113 RCL 14
114 RCL 03
115 +
116 RCL 05
117 -
118 RCL 06
119 +
120 360
121 MOD
122 HMS
123 ARCL X
124 AVIEW
125 FC? 21
126 STOP
127 X<0?
128 XEQ 11
129 "ZD "
130 RCL 13
131 HMS
132 ARCL X
133 AVIEW
134 FC? 21
135 STOP
136 X<0?
137 XEQ 09
138 ADV
139 CLD
140 FS? 02
141 GTO A
142 4
143 GTO 10

144◆LBL 09
145 "ZD "
146 360
147 HMS+
148 ARCL X
149 AVIEW
150 STOP
151 RTN

152◆LBL 11
153 "AZ "
154 CHS
155 180
156 +
157 360
158 MOD
159 ARCL X
160 AVIEW
161 STOP
162 RTN

163◆LBL 00
164 2

165◆LBL 10
166 ST+ 34
167 RCL 34
168 RCL 19
169 X>Y?
170 GTO 06
```

```
171♦LBL 14
172 ADV
173 ADV
174 ADV
175 ADV
176 "NO STAR
         "
177 PROMPT
178 FS? 02
179 GTO A
180 GTO "STP
         "

181♦LBL A
182 35
183 STO 34
184 RCL 07
185 ENTER↑
186 FIX 0
187 "STR NO
         "
188 FS? 02
189 ARCL 07
190 FIX 4
191 SF 02
192 PROMPT
193 CLA
194 X≠Y?
195 GTO 04

196♦LBL 05
197 RCL 07
198 RCL IND
         34
199 X=Y?
200 GTO 08
201 3
202 ST+ 34
203 RCL Z
204 RCL 34
205 RCL 19
206 X>Y?
207 GTO 05
208 GTO 14

209♦LBL 08
210 STO 07
211 1
212 ST+ 34
213 GTO 01

214♦LBL 04
215 STO 07
216 GTO A

217♦LBL 03
218 AON
219 "Y"
220 ASTO Y
221 "NEW STN
    . Y/N"
222 PROMPT
223 ASTO X
224 AOFF
225 X=Y?
226 GTO 02
227 RTN

228♦LBL 02
229 FIX 4
230 "LAT "
231 XEQ 15
232 HR
233 90
234 +
235 STO 01
236 "LONG "
237 XEQ 15
238 HR
239 15
240 /
241 STO 02
242 FIX 0
243 "UTM ZON
       E "
244 XEQ 15
245 6
246 *
247 183
248 -
249 RCL 02
250 15
251 *
252 -
253 RCL 01
254 90
255 -
256 SIN
257 *
258 STO 03
259 HMS
260 FIX 4
261 "CONV="
262 ARCL X
263 AVIEW
264 FC? 21
265 STOP
266 "TIME ZO
       NE "
267 XEQ 15
268 STO 12
269 FIX 0
270 "DAY "
271 XEQ 15
272 ADV
273 STO 15
274 RTN

275♦LBL 15
276 PROMPT
277 ARCL X
278 FS? 21
279 PRA
280 RTN

281♦LBL 13
282 FIX 5
283 "LOCAL T
       IME "
284 PROMPT
285 ARCL X
286 FS? 21
287 PRA
288 RCL 12
289 HMS-
290 HR
291 ENTER↑
292 X<0?
293 GTO 12
294 GTO 07

295♦LBL 12
296 1
297 ST- 15
298 RDN
299 24
300 +
301 SF 07

302♦LBL 07
303 ENTER↑
304 24
305 /
306 RCL 15
307 +
308 32
309 /
310 STO 00
311 RDN
312 RCL 33
313 RCL 00
314 *
315 RCL 32
316 +
317 +
318 RCL 02
319 +
320 24
321 MOD
322 STO 09
323 FC?C 07
324 RTN
325 1
326 ST+ 15
327 END
```

APPENDIX II

```
--------
PLANNING
OUTPUT
--------
    XEQ "STP"
LAT -9.0310
LONG 147.1012
UTM ZONE 55.
CONV=0.0136
TIME ZONE 10.0000
DAY 5.

APRX BRG RO 0.0000
RO SET 0.0000

LOCAL TIME 14.30000

STR NO 273.
AZ 293.2435
ZD 51.2754         NW

STR NO 328.
AZ 187.0317
ZD 54.4240         SW

STR NO 364.
AZ 172.4808
ZD 51.5650         SE

STR NO 379.
AZ 167.4857
ZD 53.5323         SE

STR NO 441.
AZ 117.2458
ZD 48.3057         SE
```

```
--------
FIELD
OUTPUT
--------
    XEQ "STP"
LAT -9.0310
LONG 147.1012
UTM ZONE 55.
CONV=0.0136
TIME ZONE 10.0000
DAY 5.

APRX BRG RO 91.3000

                XEQ A

RO SET 0.0010

LOCAL TIME 14.28000

STR NO 379.
AZ 76.0244
ZD 53.5944

RO SET 180.0020

LOCAL TIME 14.30000

STR NO 379.
AZ 256.1917
ZD 53.5323
```

POCKET COMPUTERS FOR SURVEYING STUDENTS

By T.M. Nacino, M.I.S. (Australia)

The rapid growth and technological advance in the field of personal computing prompted the Department of Surveying and Land Studies at the Papua New Guinea Univeristy of Technology to introduce the use of pocket computers in practically all routine calculations.

The pocket calculator was first intoduced in the early seventies and this was quickly followed by programmable calculators, desk top computers and micro-computers and pocket computers. This rapid development in computer hardware made a considerable impact in the computing field. Calculations associated with theoretical and practical subjects, which formerly took hours to perform, took only a matter of minutes. Consequently, assignments and class work which required labourious calculations were done more quickly, allowing more to be spent understanding the theory.

It is anticipated that government departments requiring repetitive calculations will soon acquire a pocket computer using some form of BASIC language. No doubt a few government departments will continue using programmable calcultors during the transition period. To allow for this need, first year students at the University of Technology are being taught how to write simple programs for the HP 33C and HP 11C.

The Department of Surveying and Land Studies has introduced the use of the wallet-size compute PC 1251 (featuring extended Basic) as early as in the second year of the Diploma course in Surveying and Survey Drafting. The advance features and capabilities of the PC 1251 have been found sufficient for most routine calculations required by students and members of staff.

One important feature that adds to the versatility of the PC 1251 is the possibility of integrating a printer/micro cassettee recorder which facilitates quick printouts and simple program saving and loading. Duty free cost of the PC 1251 in 1983 was under K70 and the integrated accessories under K90.

In my opinion, the PC 1251 or a similar unit, with the optional integrated printer/microcassette recorder could provide most, if not all, the booking and computing needs of a field surveyor.

A working program, together with a specimen computation, which surveying students find extremely useful, is included in this article. This program reduces sun observations for azimuth by the Altitude method. The algorithm used in calculating the sun's coordinates was obtained from the article of Dr. G.G. Bennet on solar ephemeris. It is to be noted that the algorithm used is primarily intended for the reduction of observations made up to the end of this century.

```
  5:REM SOLAR BY T. M. N
    ACINO * 1983
  6:"A": DEGREE : CLEAR
    : WAIT 150
  7:PRINT "***SUN AZIMUT
    H PROGRAM***"
  8:INPUT "YEAR?";A
  9:INPUT "MONTH?";B
 10:INPUT "DAY?";C
 11:INPUT "AM OR PM ?";N
    $
 12:D=0
 13:FOR I=1 TO 2
 14:INPUT "ZONE TIME OF
    OBS  0-24?";E
 15:D=D+ DEG E
 16:NEXT I
 17:D=D/2
 19:D=D-10
 20:D=D/24
 31:T=(367*A- INT ((7*(A
    + INT ((B+9)/12)))/4
    )+ INT (275*B/9)+C-6
    94006.5+D)/36525
 32:M=358.475+35999.050*
    T:M=M-( INT (M/360))
    *360
 33:V=63+22518*T:V=V-(
    INT (V/360))*360
 34:Q=332+33718*T:Q=Q-(
    INT (Q/360))*360
 35:J=222+32964*T:J=J-(
    INT (J/360))*360
 36:O=101+1934*T:O=O-(
    INT (O/360))*360
 37:L=279.69019+36000.76
    892*T+(1.91945-0.004
    79*T)* SIN (M)
 38:L=L+0.02000* SIN (2*
    M)+0.00029* SIN (3*M
    )+0.00179* COS (261+
    445267*T)
 39:L=L+0.00134* COS (90
    +V)+0.00154* COS (90
    +2*V)+0.00069* COS (
    258+2*V-M)
 40:L=L+0.00043* COS (78
    +3*V-M)+0.00028* COS
    (51+3*V-2*M)+0.00057
    * COS (90-Q)
 41:L=L+0.00049* COS (30
    6+Q-M)+0.00200* COS
    (91+J)+0.00076* COS
    (270+2*J)
 42:L=L+0.00072* COS (17
    5+J-M)+0.00045* COS
    (293+2*J-M)
 43:L=L+0.00479* COS (90
    -O)+0.00035* COS (29
    5+2*M)
 44:L=L-( INT (L/360))*3
    60
 45:E=23.45229-0.01301*T
    +0.00256* COS (O)
 46:F= SIN (L)* COS (E)/
    COS (L):F= ATN F
 47:G= SIN (L)* SIN (E):
    G= ASN G
 48:H=D*24*15+99.69130+3
    6000.76892*T
 49:H=H+0.917*(0.00479*
    COS (90-O)+0.00035*
    COS (295+2*M))-F:H=H
    -( INT (H/360))*360
 50:S=0.26696+0.00447*
    COS (M)
 51:INPUT "LATITUDE +N-S
    ?";A
 52:A= DEG A: DIM B(2):
    FOR I=1 TO 2
```

```
53:INPUT "HORZ CIRCLE T
   O SUN?";D
54:D= DEG D
55:INPUT "HORZ CIRCLE T
   O RO?";E
56:E= DEG E
57:B(I)=D-E
58:IF B(I)<0 THEN LET B
   (I)=B(I)+360
59:NEXT I
60:K=(B(1)+B(2))/2
61:PRINT "WHERE IS ZERO
   ?": WAIT 120: INPUT
   "ZENITH OR NADIR Z/N
   ?";W$
62:IF W$="Z" THEN GOTO
   64
63:IF W$="N" THEN GOTO
   72
64:DIM X(2): FOR J=1 TO
   2
65:INPUT "VERTICAL CIRC
   LE RDG.?";Z
66:Z= DEG Z
67:IF Z>90 THEN LET Z=3
   60-Z
68:X(J)=Z
69:NEXT J
70:Z=(X(1)+X(2))/2
71:GOTO 111
72:DIM X(2)
75:FOR J=1 TO 2
80:INPUT "VERTICAL CIRL
   E RDG.?";Z
85:Z= DEG Z
90:IF Z<180 THEN LET Z=
   180-Z
95:IF Z>180 THEN LET Z=
   Z-180
100:X(J)=Z
105:NEXT J
110:Z=(X(1)+X(2))/2
111:INPUT "PRESSURE OR H
    EIGHT P/H?";C$
112:IF C$="H" THEN GOTO
    115
113:IF C$="P" THEN GOTO
    118
115:INPUT "HEIGHT IN MET
    ERS?";O
116:P=((288.16-0.0019812
    *O)/288.16)^5.2561
117:P=P*1013.2: GOTO 120
118:INPUT "PRESSURE IN M
    ILLIBARS?";P
120:INPUT "TEMPERATURE C
    ELSIUS?";U
129:R=P/1013.25*273.2/(2
    73.2+U)*(60.1* TAN Z
    -0.07* TAN Z/( SIN Z
    )^2)-8
130:R=R/3600
135:Z=Z+R
145:Y=( SIN G- SIN A*
    COS Z)/( COS A* SIN
    Z)
150:Y= ACS Y
155:IF N$="AM" THEN GOTO
    165
160:IF N$="PM" THEN LET
    Y=360-Y
165:IF Y<K THEN LET Y=36
    0+Y
170:V=Y-K:V= DMS V: WAIT
172:PRINT USING "####.##
    ###";"TRUE BEARING="
    ;V
174:END
```

```
YEAR?1976
MONTH?3
DAY?24
AM OR PM?AM
ZONE TIME OF OBS 0-24?7.40
ZONE TIME OF OBS 0-24?7.42
LATITUDE +N-S?-5.3700
HORZ CIRCLE TO SUN?5.2740
HORZ CIRCLE TO RO?0
HORZ CIRCLE TO SUN?185.5740
HORZ CIRCLE TO RO?180.0010
WHERE IS ZERO?
ZENITH OR NADIR Z/N?Z
VERTICAL CIRCLE RDG.?69.5230
VERTICAL CIRCLE RGD.?290.1300
PRESSURE OR HEIGHT P/H?H
HEIGHT IN METERS?200
TEMPERATURE CELSIUS?30
TRUE BEARING=  80.46566
```

Unit of True Bearing is in Degrees.Minutes and Seconds (D.MS)

MEMORY CONTENTS:

F right ascension
H Greenwich Hour Angle (GHA)
G declination
S semi diameter

Units of these 4 quantities are degrees and decimals of a degree

SUN OBSERVATION FOR AZIMUTH AM

Observed by
RO Stn 4.	At Stn 5	Field Book page 10.
Day Wednesday Date 24/3/76.
Barometer or Height 200 m.	Temp 30° c	Refn Corr Factor (f) 0.90.

Obs No	App Posn	Face	Hor Circle on RO	Time	Hor Circle on Sun	Vertical Circle	Bearing RO
1	♀	L	0 00 00	0740	5 27 40	69 52 30	80°46'57"
	♂	R	180 00 10	0742	185 57 40	290 13 00	
2	♀	R	180 00 10	0745	185 17 40	291 26 00	80°46'51"
	♂	L	0 00 00	0745	5 49 55	68 40 00	
3	♀	L	0 00 00	0750	5 08 30	67 22 25	80°47'08"
	♂	R	180 00 10	0752	185 40 35	292 30 00	
4	♀	R	180 00 10	0755	184 57 35	294 01 00	80°47'06"
	♂	L	0 00 05	0756	5 30 00	66 05 30	

Lat 5°37'00 Long 146°19'.50"
Zone 55 Central Meridian 147 00 00
Diff. Longitude 40'10"

Mean True Bearing of RO 80°47'00"
Convergence − 3' 56"
Grid Bearing of RO 80°43'04"

Note *Observation East of Central Meridian Convergence is +, for West −*

BATHYMETRIC ACCURACY IN HEIGHTING AROUND FREMANTLE AREA

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LAE

1.0 INTRODUCTION

In the last decade or so, more concentration and emphasis has been placed on the satellite information regarding the land and its environment. Scientists here and abroad have shown a keen interest on a wide range of applications attainable from the satellite imagery sources. Such applications may include the geology, land use, agriculture, urban and regional planning .... etc.

The purpose of this project is to examine another aspect of application of satellite imagery upon water/sea; that is Bathymetric mapping.

1.1 DEFINITION

Bathymetric maps in short can be summarized, quoting from Frank Young (1982):

"as the topographic maps of a nation´s submerged lands."

Small scale Bathymetric maps 1:250,000 series covering Australia may not necessarily be useful for navigational purposes as important navigational hazards may not appear on the maps, thus overlapping the primary use of the Hydrographic chart. Bathymetric maps are, solely, important additional aids to scientific studies associated with marine environment.

1.2 EXPLORATORY STUDIES

Bathymetric mapping can be done by a variety of traditional methods available depending upon its requirements (refer A.J. Snow & A.J. Hornby). The new area of study in the experimental stages include:

a) Aerial Photogoraphy;

b) Laser Depthing;

c) Sonar Holography; and

d) Satellite Imagery.

The aim of this project is to examine and process the satellite data for accuracy in shallow water mapping.

1.3 USERS OF BATHYMETRIC MAPS

Navigators may not be the sole users in the marine environment, constantly requiring the need to use such a map. Many scientists as (A.E. Collin, D. Monahan & A.J. Kerr) quote:

..."Physical oceanographers study water and physical characteristics include temperature, density, currents ...

Geologists study the shape, structure, erosion, transportation and ocean sediments .....

Biologists´ concern is with distribution of movements of life in the sea, study of various organisms at various depths ....

Fishermen acquire other scientific data to search for free-swimming and bottom-dwelling creatures .....

Engineers build structures on the ocean floor for oil rigs, pipelines, telephones ....."

All are regular users.

Hence, indications of the demand of this map of varying scales are at an increase; considering the implementation of survey by traditional methods may not be economically favourable. Satellite data for mapping can be acceptable according to Frank Young (1982).

"..... concluded that the positional accuracy of LANDSAT approaches that of a 1:250,000 map."

in addition:

"... believes 1:250,000 mapping tolerances could be met if horizontal distortion corrections were applied ...."

So the question of a method alternative to that of the conventional means must be approached; satellite imagery is a possibility if technical improvements can be achieved.

2.0 DEVELOPMENT IN W.A.

In Western Australia, Western Australian Petroleum Pty Ltd requested Bathymetric mapping of the Monte Bello Islands Group off the north-west coast of Australia for planning and execution of a seaborne seismic survey. This led to a combined exercise by means of aerial photography and Landsat imagery. The result of the Landsat accuracy reported by K. Lyons while the survey was carried out by the CSIRO. Relevant developments in Australia were by the Division of National Mapping (DNM 1976), D.K. Warne (1978) and Fleming (1977).

2.1 ACCURACY

Evaluation of the experimental Bathymetric map produced by Landsat data of the Monte Bello Islands by the CSIRO and "WAPET map, K. Lyons (1976):-

"The order of accuracy of the depth produced from the satellite data is 1 to 2 metres out to 10 metres without local calibration of radiance."

From the Division of the Nationall Mapping, Canberra (DNM 1977) collated from results of The Commonwealth Scientific and Industrial Research Organization (CSIRO) and Department of Engineering Physics within the Australian National University (ANU):

"Reports to date indicate that the depth of approximately 2 metres may be achieved down to a limit of 20 metres but these claims have yet to be substantiated in routine mapping operations."

In the Photogrammetric Engineering and Remote Sensing article by D.K. Warne (1978):

".... Other studies (Byrne and Honey 1977); Polcyn 1976) have demonstrated that under favourable conditions, Landsat is able to measure water depths of up to approximately 20 metres within 10% (RMS) of the measured value. Penetration is reduced as water clarity falls."

For the planimetric accuracy test the study by the DNM (1977) concluded that unless horizontal corrections were applied to the image, the accuracy was outside 1:250,000 mapping tolerance but satisfactorily met 1:500,000 standards.

3.0 SATELLITE (LANDSAT)

The first series of the satellite was launched in 1972, the purpose of these being the remote sensing of the earth land resources. In June 1973 and February 1975 Landsat satellites 1 and 2 were launched covering over 80% of the surface of the earth with repetitive coverage in many areas. The second (Landsat 2) satellite launched in 1975. The acquired data from the MSS revealed during investigation of channels 4, 5, 6 and 7 provided good water penetration. This discovery opened up possibility of producing Bathymetric maps from the satellite.

The satellite orbits the earth at a norminal altitude of 913 km and an orbital frequency of 14 per day. The imaging system used by the satellite has been the four channel multispectral scanner (MSS).

Channel	Wavelength	Approx. colour
4	0.5 - 0.6 μ	green-yellow
5	0.6 - 0.7 μ	red
6	0.7 - 0.8 μ	infra-red
7	0.8 - 1.1 μ	infra-red

The twenty four detectors, six per channel are calibrated at the data processing facility to the digital counts; the channels 4, 5 and 6 range from 0 - 127 while channel 7 ranges from 0 - 63. During calibration some interferences due to noise and stripping may be present in data. These sources of errors need to be removed or minimized.

For this project channel 4 and 5 (0.5 - 0.7) which has higher penetration capability will be considered and analysed.

4.0 PROJECT LOCALITY

The area of investigation covered a large area of extending from the Rottnest Island in the north to the Garden Island and Cockburn Sound in the south. This area was chosen because of other investigations had been done in the area around Fremantle and secondly the availability of a recent 19.2.81 Hydrogrphic chart of the approaches to Rottnest Island as the standard for the accuracy determination.

5.0 PROCEDURES

The satellite data on the 17.12.81 tape was analysed on the HP1000 computer at remote sensing centre, Department of Electrical Engineering at WAIT. The Landsat program displayed the precision processed colour image of the area to be investigated.

Precision processing is a process whereby transformations are applied on the Landsat images and the map control points incorporate the least square adjustment for the best fit image. The data from this tape has a positional accuracy of approximately 20 metres as compared to approximately 200 metres for one that has not been precision processed.

The false-colour composite of MSS 4, 5, 6 and 7 Landsat imageries derived fom the Landsat computer compatible tapes (CCT) was displayed on the TV monitor screen. Target areas for analyses were specified to the computer through the electronic cursor display. The result of the digital classification for the four bands was displayed on the TV screen.

The calibration of the satellite data was done by obtaining a statistical result of the mean value in radian measure of about one hundred observations. These observations were graphically plotted and the best fit curve produced as the standard for this working project. The only other correction, the tide correction for the Fremantle area, had to be determined as a supplement to the callibrated value (see Appendix VII).

6.0 **ANALYSIS**

From the Frequency Histogram (VIA), it can be clearly seen that the measured values (satellite) were much higher than the standard. This has resulted in the histogram lying on the right-hand side of the graph indicating large differences in reflectivity recordings as to Bathymetric.

However, the Frequency Histogram (VIB), (VIC) and (VID) generally indicated a systematic trend in that the satellite data, smaller in magnitude are shown to be on the right-hand side of the Histogram. This may be the cause of some phenomena such as a scale factor error; otherwise following situations may explain the causes of these differences:

a) Scaling
- may not be very accurate on the VDU screen due to its curvature
- critical in areas of bathymetric steep grade.

b) Samples
- of mixed proportion like water and land in the case of near the shore sampling
- collected in areas known to be infested with seaweed which could result in false recording
- in bathymetrically steep grade

c) Graph
- the best fit curve for callibration may not be suitable

7.0 **CONCLUSION**

From the foregoing it can be concluded that:

(i) A shift to the left-hand side of the curve indicating a constant relative phenomenon

(ii) Result achieved of less than 10% (RMS) indicated by other authors also valid in this finding.

Remote sensing by Landsat may not supersede the traditional methods of Bathymetric mapping in the near future but it has potential in areas of reconnaissance and small scale mapping. But, being in the age of rapid technological era such a breakthrough may not be so far away as one would imagine.

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APPENDIX (IIA) DATA FROM: BATHYMETRIC MAP, LANDSAT (METRE) EQUIVALENT, TIDE CORRECTION, ERROR + OBS - TRUE

No.	Bathy. Depth	Rad. Depth	Tide Cor.(+.5)	Error	No.	Bathy. Depth	Rad. Depth	Tide Cor. (+.5)	Error
1	1	5.6	6.1	+5.1	21	4.0	9.2	9.7	+5.7
2	1.5	3.7	4.2	+2.7	22	4.0	10.8	11.3	+7.3
3	1.5	1.1	1.6	+0.1	23	4.0	5.6	6.1	+2.1
4	1.0	1.1	1.6	+0.6	24	4.0	5.2	5.7	+1.7
5	1.5	2.2	2.7	+1.2	25	5.0	6.1	6.6	+1.6
6	1.8	8.4	8.9	+7.1	26	5.0	8.4	8.9	+3.9
7	1.8	6.0	6.5	+4.7	27	5.0	13.0	13.5	+8.5
8	2.0	5.9	6.4	+4.4	28	5.0	2.4	2.9	-2.1
9	2.0	6.8	7.3	+5.3	29	5.0	2.2	2.7	-2.3
10	2.5	9.8	10.3	+7.8	30	5.5	4.4	4.9	-0.6
11	2.0	4.4	4.9	+2.9	31	5.0	5.2	5.7	+0.7
12	2.0	5.6	6.1	+4.1	32	6.0	9.8	10.3	+4.3
13	2.0	1.1	1.6	-0.4	33	6.0	8.9	9.4	+3.4
14	2.0	4.4	4.9	+2.9	34	6.0	3.5	4.0	-2.0
15	2.0	1.6	2.1	+0.1	35	6.0	3.7	4.2	-1.8
16	2.5	8.8	9.3	+6.8	36	7.0	8.0	8.5	+1.5
17	3.0	4.4	4.9	+1.9	37	7.5	6.0	6.5	-1.0
18	3.0	6.4	6.9	+3.9	38	7.0	4.4	4.9	-2.1
19	3.0	4.0	4.5	+1.5	39	7.0	5.0	5.5	-1.5
20	3.6	5.2	5.7	+2.1	40	7.0	5.4	5.9	-1.1
41	8	3.5	4.0	-4.0	51	10	5.6	6.1	-3.9
42	8	2.8	3.3	-4.7	52	11	6.8	7.3	-3.7
43	8	3.8	4.3	-3.7	53	11	6.8	7.3	-3.7
44	8	4.4	4.9	-3.1	54	11	8.4	8.9	-2.1
45	9	4.0	4.5	-4.5	55	12	5.4	5.9	-6.1
46	9	6.8	7.3	-1.7	56	12	8.2	8.7	-3.4
47	9	4.0	4.5	-4.5	57	12	12.0	12.5	+0.5
48	9	7.4	7.9	-1.1	58	12	12.1	12.6	+0.6
49	10	6.8	7.3	-2.7	59	12	11.6	12.1	+0.1
50	10	6.8	7.3	-2.7	60	12	10.4	10.7	-1.3

No	Bathy Depth	Rad Depth	Tide Cor.(+.5)	Error	No.	Bathy Depth	Rad Depth	Tide Cor. (+.5)	Error
61	13	10.7	11.2	-1.8	71	16	11.0	11.5	-4.5
62	13	2.1	2.6	-10.4	72	16	9.0	9.5	-6.5
63	14	2.5	3.0	-11.0	73	16	9.2	9.7	-6.3
64	14	10.7	11.2	-2.8	74	16	9.4	9.9	-6.1
65	14	9.8	10.3	-3.7	75	17	22.6	23.1	+6.1
66	15	10.7	11.2	-3.4	76	17	5.2	5.7	-11.3
67	15	8.9	9.4	-5.6	77	17	5.2	5.7	-11.3
68	15	9.8	10.3	-4.7	78	17	13.6	14.1	-2.9
69	15	13.6	14.1	-0.9	79	18	20.4	20.9	+2.9
70	16	9.0	9.5	-6.5	80	18	12.9	13.4	-4.6
81	18	13.1	13.6	-4.4					
82	18	22.6	23.1	+5.1					
83	19	22.6	23.1	+4.1					
84	19	12.9	13.4	-5.6					
85	19	13.1	13.6	-5.4					
86	20	13.4	13.9	-6.1					
87	20	13.1	13.6	-6.4					
88	20	10.8	11.3	-8.7					
89	20	14.8	15.3	-4.7					
90	20	14.8	15.3	-4.7					

DATA GROUPINGS

Error	Depth	(0-5)	(5-10)	(10-15)	(15-20)
-11.35	-9.34			2	2
-9.35	-7.35				1
-7.35	-5.35			2	8
-5.35	-3.35		6	6	5
-3.35	-1.35	2	8	4	1
-1.35	+0.65	5	3	4	
+0.35	+2.65	7	1		
+2.65	+4.65	8	2		2
+4.65	+6.65	4			1
+6.65	+8.65	5			1
		31	20	18	21

APPENDIX (IV) A

DATA FOR FREQUENCY HISTOGRAM

RELATIVE FREQUENCY DISTRIBUTION

(0-5)

Class Interval			Class Boundary			Class Mark	Class Freq	Rel Freq	% Rel Freq
-11.3	-	-9.3	-11.35	-	-9.35	-10.35	-	-	-
-9.3	-	-7.3	-9.35	-	-7.35	-8.35	-	-	-
-7.3	-	-5.3	-7.35	-	-5.35	-6.35	-	-	-
-5.3	-	-3.3	-5.35	-	-3.35	-4.35	-	-	-
-3.3	-	-1.3	-3.35	-	-1.35	-2.35	2	0.06	6
-1.3	-	+0.6	-1.35	-	+0.65	-0.35	5	0.16	16
+0.6	-	+2.6	+0.65	-	+2.65	+1.65	7	0.23	23
+2.6	-	+4.6	+2.65	-	+4.65	+3.65	8	0.26	26
+4.6	-	+6.6	+4.65	-	+6.65	+5.65	4	0.13	13
+6.6	-	+8.6	+6.65	-	+8.65	+7.65	5	0.16	16
							31	1.00	100

APPENDIX (IV) B

DATA FOR FREQUENCY HISTOGRAM

RELATIVE FREQUENCY DISTRIBUTION

(5 - 10)

Class Interval	Class Boundary	Class Mark	Class Freq	Rel Freq	% Rel Freq
-11.3 - -9.3	-11.35 - -9.35	-10.35	-	-	-
-9.3 - -7.3	-9.35 - -7.35	-8.35	-	-	-
-7.3 - -5.3	-7.35 - -5.35	-6.35	-	-	-
-5.3 - -3.3	-5.35 - -3.35	-4.35	6	0.30	30
-3.3 - -1.3	-3.35 - -1.35	-2.35	8	0.40	40
-1.3 - +1.6	-1.35 - +0.65	-0.35	3	0.15	15
+0.6 - +2.6	+0.65 - +2.65	+1.65	1	0.05	5
+2.6 - +4.6	+2.65 - +4.65	+3.65	2	-.10	10
+4.6 - +6.6	+4.65 - +6.65	+5.65	-	-	-
+6.6 - +8.6	+6.65 - +8.65	+7.65	-	-	-
			20	1.00	100

APPENDIX (IV) C

DATA FOR FREQUENCY HISTOGRAM

RELATIVE FREQUENCY DISTRIBUTION

(10 - 15)

Class Interval	Class Boundary	Class Mark	Class Freq	Rel Freq	% Rel Freq
-11.3 - -9.3	-11.35 - -9.35	-10.35	2	.11	11
-9.3 - -7.3	-9.35 - -7.35	-8.35	0	0	0
-7.3 - -5.3	-7.35 - -5.35	-6.35	2	.11	11
-5.3 - -3.3	-5.35 - -3.35	-4.35	6	.34	34
-3.3 - -1.3	-3.35 - -1.35	-2.35	4	.22	22
-1.3 - +0.6	-1.35 - +0.65	-0.35	4	.22	22
+0.6 - +2.6	+0.65 - +2.65	+1.65			
+2.6 - +4.6	+2.65 - +4.65	+3.65			
+4.6 - +6.6	+4.65 - +6.65	+5.65			
+6.6 - +8.6	+6.65 - +8.65	+7.65			
			18	1.00	100

DATA FOR FREQUENCY HISTOGRAM

RELATIVE FREQUENCY DISTRIBUTION

(15 - 20)

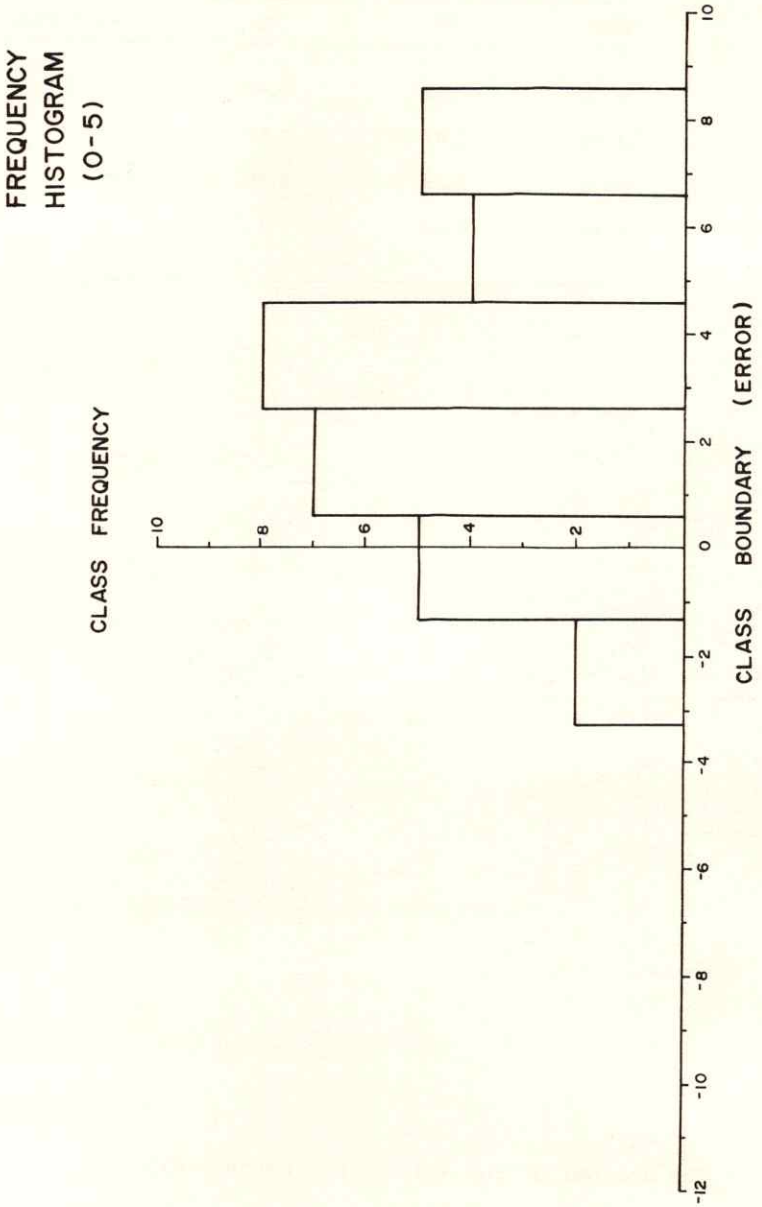
Class Interval			Class Boundary			Class Mark	Class Freq	Rel Freq	% Rel Freq
-11.3	-	-9.3	-11.35	-	-9.35	-10.35	2	.09	9
-9.3	-	-7.3	-9.35	-	-7.35	-8.35	1	.05	5
-7.3	-	-5.3	-7.35	-	-5.35	-6.35	8	.38	38
-5.3	-	-3.3	-5.35	-	-3.35	-4.35	5	.24	24
-3.3	-	-1.3	-3.35	-	-1.35	-2.35	1	.05	5
-1.3	-	+0.6	-1.35	-	+0.65	-0.35	0	0	0
+0.6	-	+2.6	+0.65	-	+2.65	+1.65	0	0	0
+2.6	-	+4.6	+2.65	-	+4.65	+3.65	2	.09	9
+4.6	-	+6.6	+4.65	-	+6.65	+5.65	1	.05	5
+6.6	-	+8.6	+6.65	-	+8.65	+7.65	1	.05	5
							21	1.00	100

APPENDIX (V)

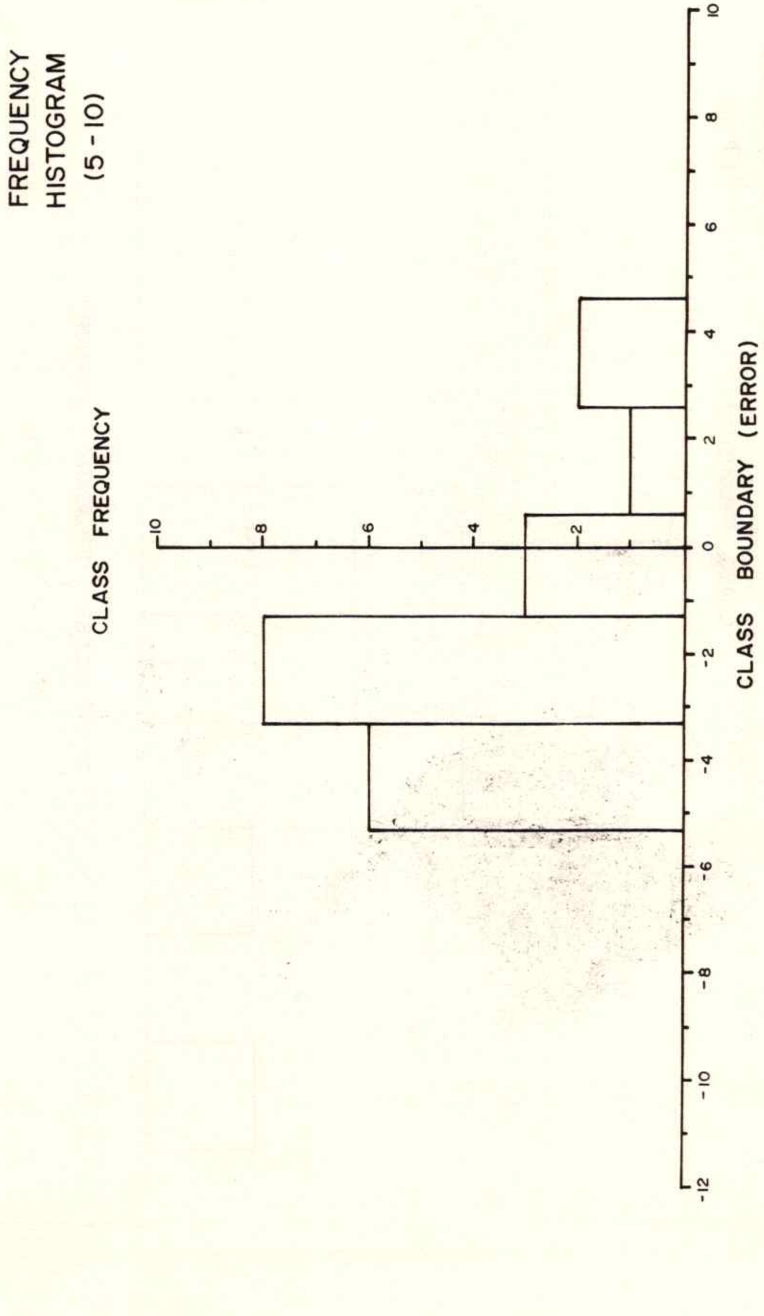
RESULTS

DEPTH	MEAN	STD	MSE	PERCENTAGE
0 - 5	2.95	2.86	0.52	10
5 - 10	-1.82	2.47	0.57	6
10 - 15	-3.52	3.25	0.79	5
15 - 20	-4.18	4.83	1.1	6

APPENDIX (VI) A

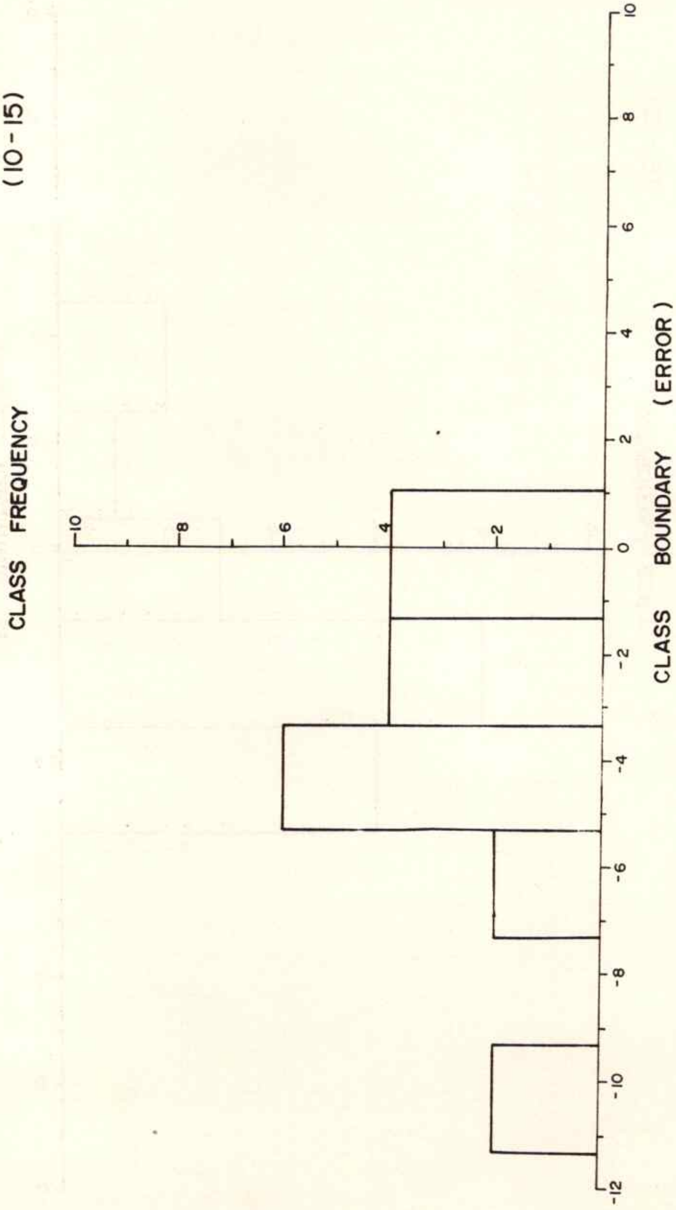


APPENDIX (VI) B



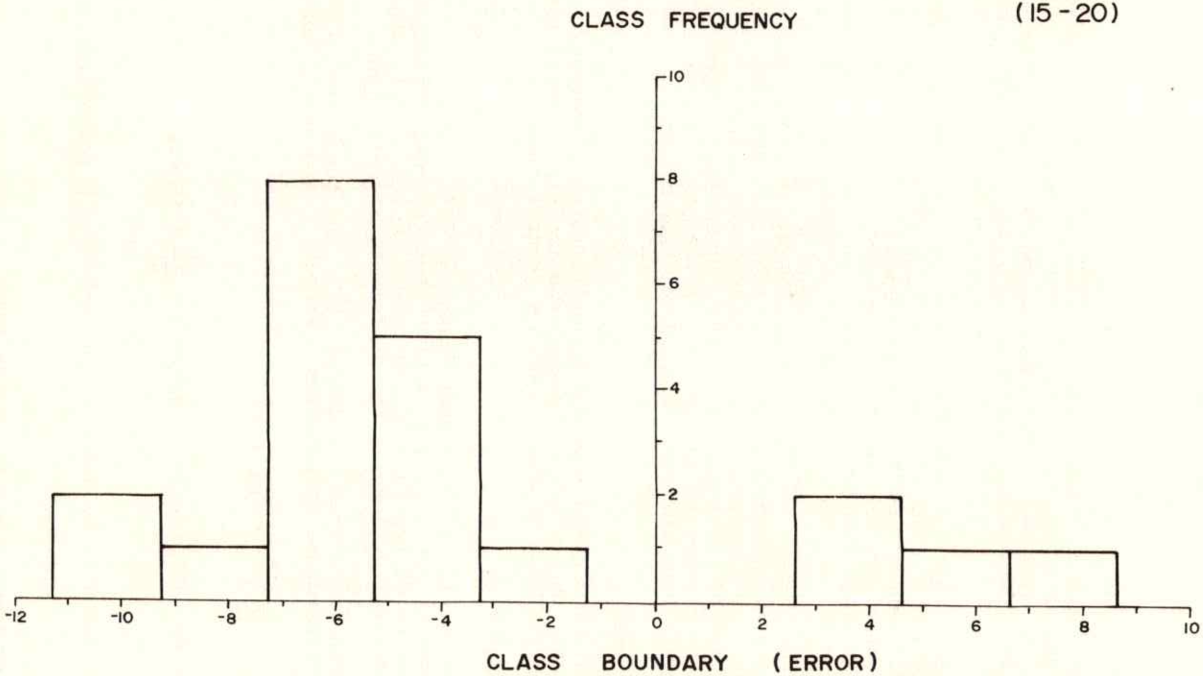
APPENDIX (VI) C

FREQUENCY HISTOGRAM (10-15)



APPENDIX (VI) D

FREQUENCY HISTOGRAM (15 - 20)



MATHEMATICS IN SURVEYING : A RECALL PAPER

By K.N.Toms, MBE, B Surv, B Econ, MUS (Qld), FIS Aust, FRICS and S.H. Pearse, B Econ, MUS (Qld), FIS Aust.

INTRODUCTION

It is likely that the profession of surveying is about to enter an age of continuing professional development. This will involve practitioners in updating their professional knowledge through such avenues as continuing education courses, workshops and self-study.

Surveying technology is solidly based on mathematical and scientific principles. For efficient practice of the profession, surveyors at all levels need to be able to follow, generally at least, new developments as they appear in the technical literature or in short courses. To do this successfully the practitioner needs an understanding of mathematics which, for many, may rest on formal studies undertaken at a considerable distance in the past. In short, many are likely to be "rusty" and to be in need of updating their knowledge of calculus and matrix algebra. This paper briefly recalls some basic concepts and gives examples of their application to surveying. Hopefully it will help to regenerate an interest in mathematics that will be of use to practising surveyors and survey technicians.

SOME BASIC CONCEPTS

Differential calculus gives information about rates of change of variables. When there is a known relationship between the variables x and y it can be expressed in a formula such as:

$$y - ax^3 + bx^2 + cx + d$$

Differentiation merely tells us what change δy will occur in y that corresponds to a change δx in x when these become infinitely small. In other words the ratio $\frac{\delta y}{\delta x}$, becomes, in the limit, the expression $\frac{dy}{dx}$ generally known as the differential coefficient.

Rules have been developed to compute $\frac{dy}{dx}$ and these are to be found in any intermediate mathematics textbook. Applying these to the formula

$$\frac{dy}{dx} = 3ax^2 + 2bx + c$$

This can itself be differentiated giving: $\frac{d^2y}{dx^2} = 6ax + 2b$

All that one needs to be aware of is that when $\frac{dy}{dx}$ (or a similar partial ratio $\frac{\partial y}{\partial x}$) occurs, the reader is merely obtaining information about what change is occurring in y which corresponds to a very small change in x.

Integration reverses this process. It starts with the rate of change, and it works back to the function itself. Thus given

$$\frac{dy}{dx} = 3ax^2 + 2bx + c$$

the rules may be applied to obtain easily

$$y = ax^3 + bx^2 + cx$$

However, this does not say anything at all about the last constant d in the original function known as a "constant of integration". The value of d can be determined by a limiting case, for example, when x = 0 then d = y.

Integration can also be used to give information about the sum of all values of a function y between different values of the function x or whatever variable occurs in the format. Thus the symbol

$$y = \int_{x=0}^{x=2} f(x)\,dx$$

gives the sum of all values of y between x = 0 and x = 2 having in mind the way in which x changes. Thus use if often made of integration when the analyst wants to determine the area under the curve, between certain values of x.

Take an example, let $y = ax^2 + bx + c$. The shape of this curve is shown in Figure 1.

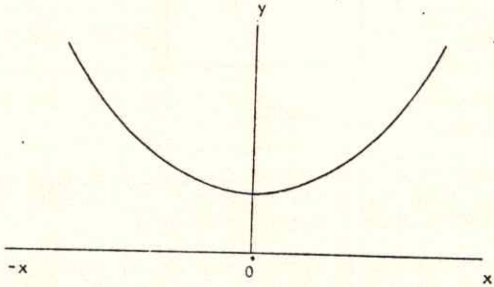


Figure 1.

Integration can tell us the sum of all values of y when x varies from say, -3 to +1, as in Figure 2.

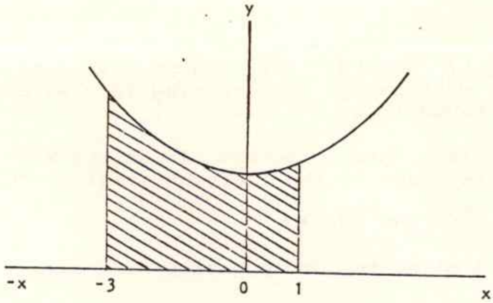


Figure 2.

The notation need not turn one off if one understands what is happening.

Sometimes surveyors take observations of a quantity and are aware that they are changing in unknown ways. One can also plot the values and see how they cange (alternatively how they vary from the average), as illustrated in Figure 3.

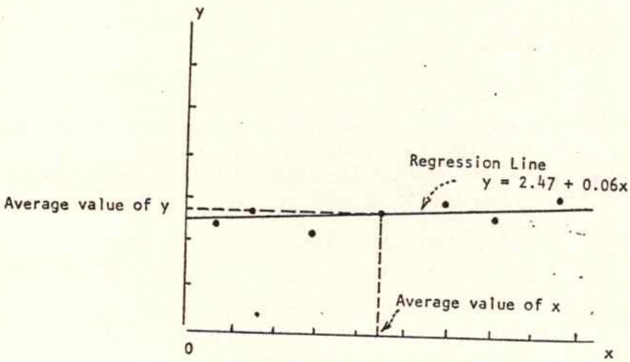


Figure 3.

Statisticians have developed ways of working out the formula that best fits such observed values. An example is the "regression" line $Y = 2.47 + 0.06x$ shown in Figure 3.

All the preceding discussion has dealt with single values x, y, a, b etc. Sometimes we are interested in groups of numbers and how they change in relation with each other - for example, in a network of observations. These can be resolved as systems of simultaneous equations which may be dealt with by the ordinary rules of algebra. The techniques of matrix algebra however, make the manipulation of these systems much easier.

Many of the processes are identical but there are some limitations to the ways in which groups of numbers can be manipulated and this causes some confusion amongst those not familiar with matrices. For example, although matrices can be added, subtracted, multiplied by a scalar (ordinary number) and, subject to certain conditions, multiplied by one another, a matrix cannot be divided into another. But it can be inverted (which involves some processing of the numbers in the matrix) and then multiplied by another matrix.

In ordinary algebra $\frac{x}{y} = x.y^{-1}$ in which y is inverted. So in matrix notation we never show $X.Y^{-1}$ to get around the problem of division. The capital letters represent matrices in this paper. Peculiar looking expressions such as AX = K or $A.^{T}A$ merely refer to groups of numbers (usually the coefficients or constant terms of simultaneous equations) that are being dealt with as units. With a basic understanding of what is going on, the detailed unravelling of the theoretical analysis contained in a technical article or textbook can be followed more easily.

To assist practitioners in gaining a better understanding of the application of calculus and matrix algebra to Surveying, some examples follow in which the mathematical processes have been explained in full detail. None of these is claimed to be original but it is hoped that the explanations may inspire practitioners to develop or re-develop an interest in mathematics and its relationship to Surveying.

TO FIND A SUITABLE FORMULA FOR A VERTICAL CURVE TO JOIN TWO INTERSECTING GRADIENTS

A sudden change of grade encountered at a gradient intersection will cause discomfort to passengers and mechanical stress to a vehicle. It is obvious that the intersection must be eased by a vertical curve which, amongst other things, must ensure a constant rate of change of gradient and be symmetric about the intersection point. The purpose of this example is to illustrate differential and integral calculus in action.

In Figure 4 let the two intersecting gradients (expressed as percentage gradients) be g_1 and g_2. For ease of analysis g_1 and g_2 are positive or rising gradients.

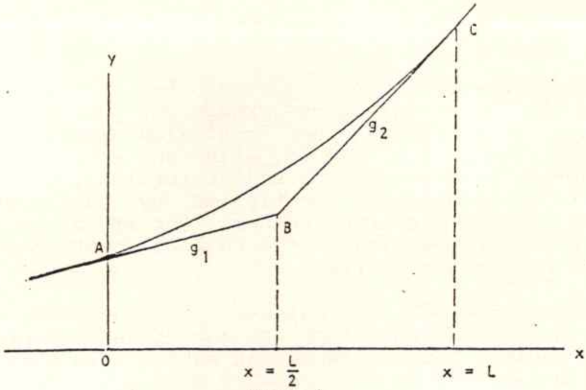


Figure 4.

AC is a curve of horizontal length x = L springing from the first tangent point A. The reduced level of A above datum is H_A.

The basic requirement of the curve is that the rate of change of gradient is constant. Since the gradient (or slope of the tangent) at any point on the curve is given by the first differential coefficient $\frac{dy}{dx}$ the rate of change of gradient at that point is obviously the second differential coefficient $\frac{d^2y}{dx^2}$. To satisfy the comfort requirement we require $\frac{d^2y}{dx^2} = k$ where k is a constant.

The change of gradient between x = 0 and x = L is given by $g_2 - g_1 = g$ the so-called "grade angle". Since the rate of change of gradient is constant it will be given by $\frac{g_2 - g_1}{L} = \frac{g}{L} = k$

We can now set up the second order differential equation

$$\frac{d^2y}{dx^2} = k$$

from which we find $\frac{dy}{dx}$ and then an expression for y.

Integrating,

$$\frac{dy}{dx} = \int \frac{d^2y}{dx^2}\,dx = \int k\,dx = kx + m \qquad \ldots (1)$$

where m is another constant (the constant of integration). At the origin where A is the first tangent point

$$x = 0 \text{ and } \frac{dy}{dx} = m.$$

Since $\frac{dy}{dx}$ is the slope of the tangent at x = 0, at that point $m = g_1$.

Substituting in (1) we have,

$$\frac{dy}{dx} = kx + g_1$$

$$= \frac{gx}{L} + g_1 \qquad \cdots (2)$$

Integrating again, $y = \int \frac{dy}{dx}\,dx = \int(\frac{gx}{L} + g_1)\,dx = \frac{gx^2}{2L} + g_1 x + a \quad \cdots (3)$

where a is another constant of integration.

When x = 0, y = a = H_A = the reduced level of a and (3) becomes

$$y = H_A + g_1\,x + \frac{gx^2}{2L} \qquad \cdots (4)$$

which is a parabola of the general form

$$y = a + bx + cx^2$$

The question now arises, does the curve satisfy the requirement of symmetry about the intersection point B (at $x = \frac{L}{2}$)?

From the two gradients g_1 and g_2

$$\begin{aligned} H_c &= H_A + g_1\frac{L}{2} + g_2\frac{L}{2} \\ &= H_A + g_1\,L + g_2\frac{L}{2} - g_1\frac{L}{2} \\ &= H_A + g_1\,L + (g_2 - g_1)\frac{L}{2} \\ &= H_A + g_1\,L + g\frac{L}{2} \end{aligned} \qquad \cdots (5)$$

But from (4) above, we have for x = L

$$H_c = H_A + g_1\,L + \frac{gL^2}{2L}$$

$$= H_A + g_1\,L + \frac{gL}{2} \qquad \text{(i.e. Equation (5))}$$

Whence the curve must pass through C. It remains only to show that it is tangent to gradient g_2 at C.

Recalling (4)

$y = H_A + g_1\,x + \frac{gx^2}{L}$ and differentiating,

$\frac{dy}{dx} = g_1 + \frac{gx}{L}$, which, because differentiation and integration are reverse processes, has given Equation 2 again.

At x = L

At $x = L$ reverse processes, has given Equation 2 again.

$$\frac{dy}{dx} = g_1 + \frac{gL}{L}$$

$$= g_1 + g \qquad \text{(but } g = g_2 - g_1\text{, the "grade" angle)}$$

$$= g_1 + g_2 - g_1$$

$$= g_2 \text{ the gradient of the tangent BC.}$$

The above analysis shows quite conclusively that the parabola

$$y = H_A + g_1 x + \frac{gx^2}{2L}$$

satisfies the stated conditions for suitability as a vertical curve.

DERIVING SIMPSON´S RULE OF AREAS

All surveyors will be familiar with the application of Simpson´s Rule to the determination of areas betwen a traverse line and a non-right line bounday such as a creek bank. It is instructive to apply the integral calculus to the derivation of Simpson´s Rule which states -

$$A = \frac{L}{3}(y_1 + 4y_2 + 2y_3 + 4y_4 \ldots + 2y_{n-2} + 4y_{n-1} + y_n) \qquad \ldots (6)$$

Consider three equidistant ordinates from the x axis as in Figure 5.

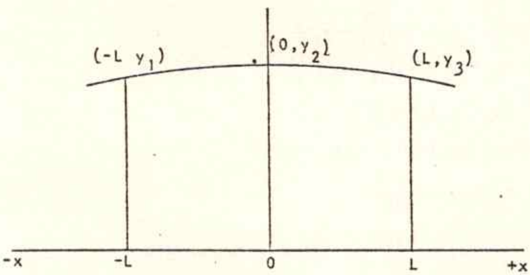


Figure 5.

Pass a parabola of the form $ax^2 + bx + c$ through the extemities of the three ordinates.

The area (A) under this section of parabolic arc is given by summing all values of y between $x = -L$ and $x = L$.

It is stated as:

$$A = \int_{-L}^{L} (ax^2 + bx + c)\ dx$$

$$= \left[\frac{ax^3}{3} + \frac{bx^2}{2} + cx \right]_{-L}^{L} \text{ which, following the rules}$$

$$= \left[\frac{aL^3}{3} + \frac{aL^3}{3} + \frac{bL^2}{2} - \frac{bL^2}{2} + cL + cL \right]$$

$$= \frac{2aL^3}{3} + 2cL \qquad \ldots(7)$$

From the equation to the curve we also have

$$y_1 = aL^2 - bL + c$$
$$y_2 = c \quad (\text{where } x = 0)$$
$$y_3 = aL^2 + bL + c$$

From which, by subtraction, or addition we have

$$c = y_2$$
$$aL^2 - bL = y_1 - y_2$$
$$aL^2 + bL = y_3 - y_1$$
$$2aL^2 = y_1 + y_3 - 2y_2$$

Rearranging (7) by taking $\frac{L}{3}$ outside a bracketed term:

$$A = \frac{L}{3} (2aL^2 + 6c)$$

and substituting for $2aL^2$ and $6c$

we have

$$A = \frac{L}{3} \left[(y_1 + y_3 - 2y_2) + 6y_2 \right]$$

$$= \frac{L}{3} (y_1 + 4y_2 + y_3) \qquad \ldots(8)$$

Now a creek bank or similar boundary will follow, in general, a curve as shown in Figure 6.

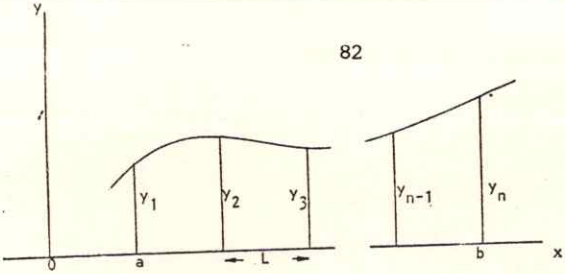


Figure 6.

Each separate piece of the curve covering an x interval of 2L (the unit for integration) is approximated by an arc of a parabola. The area under each parabolic arc is then given by an expression like Equation 9. The results are then summed to give

$$A = \frac{L}{3}\left[y_1 + 4y_2 + 2y_3 + 4y_4 + \ldots + 2y_{n-2} + 4y_{n-1} + y_n\right]$$

which is Simpson's Rule as stated in Equation 6 above. The function requires an odd number of ordinates.

LEAST SQUARES ADJUSTMENT OF A SMALL NETWORK OF LEVELS

Figure 7 shows diagrammatically a network of levels joining bench marks O, A, B and C. The objective of this exercise is to determine the MOST PROBABLE VALUES of the differences in height OA, OB and OC. These "MPV's" are the unknowns, three in number.

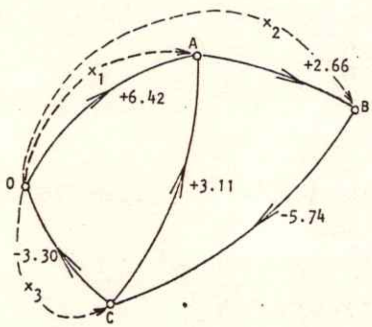


Figure 7.

All observed quantities are considered to be of equal weight. No observed quantity is considered to be more precise than any other. The first step is to allocate symbols to the three unknown height differences as follows:

Unknown Height Difference	Symbol
0 - A	x_1
0 - B	x_2
0 - C	x_3

These can be written in matrix notation as a column matrix (column vector) of order 3x1, that is to say 3 rows "by" 1 column.

$$\text{Matrix } x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

Referring to the observed height differences shows in Figure 7, we note that the reduced levels of A, B and C could be determined (without checks) by simply applying the observed height differences O-A, A-B and O-C to the known RL of O. The additional observed height differences C-A and B-C are redundant measurements BUT PROVIDE A CHECK. The redundant observations show that there are no blunders so that any of the five observations can be used to determine the required height differences x_1, x_2 and x_3. But, by choosing different combinations of 3 out of the 5 observations, slightly different values for x_1, x_2 and x_3 are obtained. These inconsistencies arise not because of any mistake or carelessness on the part of the observer but due to the presence of small random errors which are inherent in the measuring system. To be of any use the data must be consistent so that the same result is obtained no matter which combination of observations is used, and the values finally chosen must be the best, or MOST PROBABLE VALUE. The procedure of doing this will now be traced. It is known to surveyors as "least squares".

The first step is to form "observation equations" to link the unknown quantities x_1, x_2 and x_3 to the observed quantities. For example, the MPV of the difference in height between A and C is given by the algebraic sum x_1 and x_3. Its observed value (from the diagram) is 3.11. Again, the observed value of x_1 is 6.42 and the observation equation is $x_1 - 6.42$. From the diagram we can write the five observation equations, one for each observation, as follows:

$$\begin{aligned}
(1)x_1 + (0)x_2 + (0)x_3 &= 6.42 \\
(1)x_1 + (0)x_2 + (-1)x_3 &= 3.11 \\
(0)x_1 + (0)x_2 + (1)x_3 &= 3.30 \qquad \ldots(9) \\
(-1)x_1 + (1)x_2 + (0)x_3 &= 2.66 \\
(0)x_1 + (1)x_2 + (-1)x_3 &= 5.74
\end{aligned}$$

The figures in brackets are the coefficients of the unknown quantities.

The coefficients of this set of simultaneous equations can be written in matrix form as shown below. It is commonly given the symbol A and is known as the "Coefficient Matrix".

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & 1 & -1 \end{bmatrix}.$$

It is of order 5x3 (5 rows and 3 columns)

Finally, we may write the observed values as a single column matrix:

$$b = \begin{bmatrix} 6.42 \\ 3.11 \\ 3.30 \\ 2.66 \\ 5.74 \end{bmatrix}$$

of order 5x1

Matrices of a single column, such as b, of a single row, are frequently referred to as column or row vectors.

Recalling that

$$x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$

we can now write the observation equations in matrix notation as:

$$\begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & 1 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 6.42 \\ 3.11 \\ 3.30 \\ 2.66 \\ 5.74 \end{bmatrix} \quad \ldots (10)$$

or more simply Ax = b.

This may be verified by multiplying matrix A by matrix x using the normal rules of matrix multiplication, i.e. by multiplying

row elements by column elements and adding the resulting multiplicands. This process will yield the observation equations in their original form.

Now if we put into the Observation Equations (9) and (10) in their original form the MPV's of x_1, x_2 and x_3 the resulting computed values will differ slightly from the observed quantities in the b column matrix. These differences are called the "residuals" and are denoted as v_1, v_2, v_3, v_4 and v_5.

$$
\begin{array}{rrrrcl}
x_1 & & & -6.42 & = & v_1 \\
x_1 & & -x_3 & -3.11 & = & v_2 \\
x_1 & & +x_3 & -3.30 & = & v_3 \\
-x_1 & +x_2 & & -2.66 & = & v_4 \\
 & x_2 & -x_3 & -5.74 & = & v_5
\end{array} \qquad \ldots (11)
$$

In matrix form these are:

$$
\begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & 1 & -1 \end{bmatrix}
\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} -
\begin{bmatrix} -6.42 \\ -3.11 \\ -3.30 \\ -2.66 \\ -5.74 \end{bmatrix} =
\begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \end{bmatrix} \qquad \ldots (12)
$$

$Ax - b = v$

Now that we have set up the five residual equations for the three unknowns x_1, x_2 and x_3 we can go ahead and apply the principle of least squares to obtain the most probable values of the unknowns.

In order to facilitate an understanding of this process it will pay us to apply classical least squares theory to the generalised case of m residual equations in the three unknowns x_1, x_2 and x_3. These equations take the form of:

$$
\begin{array}{l}
a_1 x_1 + b_1 x_2 + c_1 x_3 + k_1 = v_1 \\
a_2 x_1 + b_2 x_2 + c_2 x_3 + k_2 = v_2 \\
\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\
a_m x_1 + b_m x_2 + c_m x_3 + k_m = v_m
\end{array} \qquad \ldots (13)
$$

We can write the ith equation in this general set as:

$$a_i x_1 + b_i x_2 + c_i x_3 + k_i = v_i \qquad \ldots (14)$$

The principle of least squares requires that the sum of the squares of the residuals shall be a minimum, i.e.:

$$S = v_1^2 + v_2^2 + \ldots + v_m^2 = \sum_{i=1}^{m} v_i^2$$

$$= \sum_{i=1}^{m} (a_i x_1 + b_i x_2 + c_i x_3 + k_i)^2 \qquad \ldots (15)$$

= minimum

Now we know from calculus that a variable has a minimum value when the first differential coefficient is equal to zero. For example the simple function $y = x^2 - x$ is minimised when

$$\frac{dy}{dx} = 2x - 1 = 0$$

i.e. when $x = \frac{1}{2}$

If y is a function of two variables such as $y = x^2 + u^2$ we have two "partial" differential coefficients $\frac{\partial y}{\partial x}$ and $\frac{\partial y}{\partial u}$.

$\frac{\partial y}{\partial x}$ is obtained by treating u as a constant and differentiating to get $\frac{\partial y}{\partial x} = 2x$.

Similarly, $\frac{\partial y}{\partial u} = 2u$

For $y = x^2 + u^2$ to be minimised we have the necessary conditions

$$\frac{\partial y}{\partial x} = 2x = 0$$

$$\frac{\partial y}{\partial u} = 2u = 0$$

Restating Equation (15)

$$S = \sum_{i=1}^{m} (a_i^2 x_1^2 + 2a_i x_1 b_i x_2 + 2a_i x_1 c_i x_3 + 2b_i x_2 c_i x_3 + 2a_i k_i x_1$$
$$+ 2b_i k_i x_2 + 2c_i k_i x_3 + b_i^2 x_2^2 + c_i^2 x_3^2) \qquad \ldots (17)$$

Differentiating partially we get:

$$\frac{\partial S}{\partial x_1} = \sum_{i=1}^{m} (2a_i^2 x_1 + 2a_i b_i x_2 + 2a_i c_i x_3 + 2a_i k_i) = 0$$

$$\frac{\partial S}{\partial x_2} = \sum_{i=1}^{m} (2a_i b_i x_1 + 2b_i^2 x_2 + 2b_i c_i x_3 + 2b_i k_i) = 0 \qquad \ldots (18)$$

$$\frac{\partial S}{\partial x_3} = \sum_{i=1}^{m} (2a_i c_i x_1 + 2b_i c_i x_2 + c_i^2 x_3 + 2c_i k_1) = 0$$

Cancelling th 2's and carrying out the summations we have:

$$\frac{\partial S}{\partial x_1} = x_1 \sum_{i=1}^{m} a_i^2 + x_2 \sum_{i=1}^{m} a_i b_i + x_3 \sum_{i=1}^{m} a_i c_i + \Sigma a_i k_i = 0$$

$$\frac{\partial S}{\partial x_2} = x_1 \sum_{i=1}^{m} a_i b_i + x_2 \sum_{i=1}^{m} b_i^2 + x_3 \sum_{i=1}^{m} b_1 c_1 + \Sigma b_i k_i = 0 \qquad \ldots (19)$$

$$\frac{\partial S}{\partial x_3} = x_1 \sum_{i=1}^{m} a_i c_i + x_2 \sum_{i=1}^{m} b_i c_i + x_3 \sum_{i=1}^{m} c_i^2 + \Sigma c_i k_i = 0$$

Equations (19) are the so-called "normal equations" of least squares theory. Their solution yields the most probable values of x_1, x_2 and x_3. They are easily formed from the observation equations by carrying out the squares and cross multiplications of coefficients and appropriate summation. The normal equations derived from the Observation Equations (9) and Residual Equations (11) are:

$$\begin{aligned} 3x_1 - x_2 - x_3 - 6.87 &= 0 \\ -x_1 + 2x_2 - x_3 - 8.40 &= 0 \\ -x_1 - x_2 + 3x_3 + 5.55 &= 0 \end{aligned} \qquad \ldots (20)$$

The normal equations may be solved by algebraic substitution methods one of which is given below:

	x_1	x_2	x_3	Constant Term	
(I)	3	-1	-1	- 6.87	
(2)	-1	2	-1	- 8.40	
(3)	-1	-1	3	5.55	
(2)	-1	2	-1	- 8.400	
(4)	1	- .3333	- .3333	- 2.290	(I) x .3333
(II)	0	1.6667	-1.3333	-10.690	(2) + (4)
(3)	-1	-1	3	5.55	
(5)	1	- .3333	- .3333	- 2.290	(I) x .3333
(6)	0	-1.3333	2.6667	3.260	(5) + (3)
(7)	0	1.3333	-1.0667	- 8.552	(II) x 0.800
(III)	0	0	1.6000	- 5.292	(6) + (7)

whence $x_3 - 3.308 = 0$ and $x_3 = 3.308$

Back substitution yields the values of x_1 and x_2. The MPV's of the three unknowns are:-

$$\begin{aligned} x_1 &= 6.412 \\ x_2 &= 9.060 \\ x_3 &= 3.308 \end{aligned}$$

An alternative solution is available by the use of matrix notation.

Those of you who have "twigged" that matrix multiplication involves the summation of the products of corresponding elements in a row and in a column will probably realise that the coefficients of the Normal Equations (19) can be obtained by premultiplying the matrix of coefficients in the Observation Equations (13) by its transpose. The procedure is demonstrated below.

$$\begin{bmatrix} a_1 & b_1 & c_1 \\ a_2 & b_2 & c_2 \\ \vdots & \vdots & \vdots \\ a_i & b_i & c_i \\ \vdots & \vdots & \vdots \\ a_m & b_m & c_m \end{bmatrix}$$

$$\begin{bmatrix} a_1 & a_2 & \cdots & a_i & \cdots & a_m \\ b_1 & b_2 & \cdots & b_i & \cdots & b_m \\ c_1 & c_2 & \cdots & c_i & \cdots & c_m \end{bmatrix} \text{ to give: } \begin{bmatrix} \sum_{i=1}^{m} a_i^2 & \sum_{i=1}^{m} a_i b_i & \sum_{i=1}^{m} a_i c_i \\ \sum_{i=1}^{m} b_i a_i & \sum_{i=1}^{m} b_i^2 & \sum_{i=1}^{m} b_i c_i \\ \sum_{i=1}^{m} c_i a_i & \sum_{i=1}^{m} c_i b_i & \sum_{i=1}^{m} c_i^2 \end{bmatrix}$$

Re-stating the Residual Equations (12) of the example:

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 1 \\ -1 & 1 & 1 & 0 \\ 0 & 1 & -1 & -1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} - \begin{bmatrix} -6.42 \\ -3.11 \\ -3.30 \\ -2.66 \\ -5.74 \end{bmatrix} = \begin{bmatrix} v_1 \\ v_2 \\ v_3 \\ v_4 \\ v_5 \end{bmatrix}$$

or $Ax - b = v$

Consider now the product A^TA where A^T is the transpose of A, i.e. a column of A becomes a row of A^T. We get from Equation 12:

$$A^TA = \begin{bmatrix} 1 & 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & -1 & 1 & 0 & -1 \end{bmatrix} \times \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 0 & 0 & 1 \\ -1 & 1 & 0 \\ 0 & 1 & -1 \end{bmatrix}$$

These are conformable (the number of columns in A^T equals the number of rows in A) hence they can be multiplied and A^TA is effectively the "square of matrix A". The arithmetic of the multiplication is given below.

$$A^TA = \begin{bmatrix} 1\times1+1\times1+0\times0+(-1)\times(-1)+0\times0 & 1\times0+1\times0+0\times0+(-1)\times1+0\times1 & 1\times0+1\times(-1)+0\times1+(-1)\times0+0\times(-1) \\ 0\times1+0\times1+0\times0+(1)\times(-1)+1\times0 & 0\times0+0\times0+0\times0+1\times+1\times1 & 0\times0+0\times(-1)+0\times1+1\times0+1\times-1 \\ 0\times1+(-1)\times1+1\times0+0\times(-1)+1\times0 & 0\times0+(-1)\times0+1\times0+0\times1+(-1)\times1 & 0\times0+(-1)\times(-1)+1\times1+0\times0+(-1)\times(-1) \end{bmatrix}$$

$$= \begin{bmatrix} 3 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 3 \end{bmatrix}$$

which is the N (or coefficient) matrix of the normal Equations 19

Now multiplying A^T by the column vector b we have

$$A^Tb = \begin{bmatrix} 1 & 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & -1 & 1 & 1 & -1 \end{bmatrix} \times \begin{bmatrix} -6.42 \\ -3.11 \\ -3.30 \\ -2.66 \\ -5.74 \end{bmatrix}$$

$$= \begin{bmatrix} -6.42+(-3.11)+0+(-1)\times(-2.66)+0 \\ 0+0+0+1\times(2.66)+1\times(5.74) \\ 0+(-1)\times(-3.11)+1\times(-3.30)+0+(-1)\times(-5.74) \end{bmatrix}$$

$$= \begin{bmatrix} -6.87 \\ -8.40 \\ 5.55 \end{bmatrix}$$

which is the b matrix of the Normal Equations (20) which can be written in matrix form as Nx - k = 0. From the preceding argument $Nx = A^TA$ and $k = A^Tb$. It follows then as we can write the normal equations directly in matrix form as:

$A^TAx - A^Tb = 0$ Compare this with Equations (19)

$$A^TAx = A^Tb$$

$$\text{and} \quad x = (A^TA)^{-1}A^Tb \quad .$$

where $(A^TA)^{-1}$ is the inverse of A^TA

By the rules of matrix inversion we can find that:

$$(A^TA)^{-1} = 1/8 \begin{bmatrix} 5 & 4 & 3 \\ 4 & 8 & 4 \\ 3 & 4 & 5 \end{bmatrix}$$

We can now solve the normal equations to determine the values of the components of the column vector x.

$$x = (A^TA)^{-1}A^TK$$

$$= 1/8 \begin{bmatrix} 5 & 4 & 3 \\ 4 & 8 & 4 \\ 3 & 4 & 5 \end{bmatrix} \times \begin{bmatrix} -6.87 \\ -8.40 \\ 5.55 \end{bmatrix}$$

which yields $x = \begin{bmatrix} 6.412 \\ 9.060 \\ 3.308 \end{bmatrix}$

i.e.

$$x_1 = 6.412$$
$$x_2 = 9.060$$
$$x_3 = 3.308$$

The arithmetic of the inversion of matrix (A^TA) is not shown. Hopefully the reader will seek the precedure from a text and carry out the inversion himself.

CONCLUSION

It can be seen from the examples above, that the application of calculus and matrix algebra to Surveying problem solving is at once elegant and interesting.

It is recommended to practitioners whose mathematics are rusty that they should purchase and indulge in some self-study of an intermediate mathematics textbook such as Thomas and Finney **Calculus and Analytic Geometry**, published in paperback by Addison and Wesley. This could be a good investment.

SOFT SCIENCES AND HARD REALITIES IN LAND MANAGEMENT IN PAPUA NEW GUINEA

by

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FIJI

When your Association generously invited me to give the keynote address I pointed out that I wouldn't know which end of theodolite to look into. In fact about 25 years ago Diana Howlett taught me the rudiments of chain and compass mapping in relation to some land tenure studies we were then involved in, and I've never got past that stage, but an invitation to return to Papua New Guinea is too hard for me to decline. It remains one of the world's most interesting countries and one with tremendous potential. So when Mick Larmer pointed out that you already know which end of a theodolite to look at, I readily succumbed.

We have a very valuable set of papers before us which I read with great interest and I hope you have too, because the last thing we want to hear is people reading what we should read for ourselves. We are mainly here to discuss options.

The people present embody a wealth of experience, and we hope that you will all participate, for everyone has something of value to contribute. And we hope that everyone, throughout this meeting, will focus on what can be done that is useful, achievable and realistic for Papua New Guinea. I have no doubt that, if your recommendations are positive and constructive, they will be given full consideration by the public, and by the National and Provincial Governments.

Anywhere in the world, human development is a continuing process. Here in particular the surveying profession has an important contribution to make to it. I am sure you will work hard on that contribution this week.

From the wealth of material covered by our agenda this week, I will focus on five topics for discussion:

FIRST: On the registration of customary land: Achievements and potentials, both positive and negative, here and in comparable situations that have relevance for what might be done here.

SECOND: About the land tenure systems that existed in this country in the past, about the customary systems today (which have probably changed more than we realise), and about likely systems tomorrow - and the day after.

THIRD: The related topic of custom and law.

FOURTH: About the land rights of women, so we can be aware if coming changes, and

FIFTH: About training for surveying and related tasks, making sure we focus on the neds of this country at this time.

1. REGISTRATION

Tonga is the only country in the Pacific which never became a colony. It undertook more radical land reform than any colonial power has ever done in the Pacific. Tonga was also the first country in the Pacific to survey and register all its land. It also achieved for a long time, the highest productivity per person and per unit of land in the Pacific. Now over a hundred years after the major reform was introduced, they have a Royal Commission looking into further improvements. I mention the Tonga case because colonial powers have seldom been able to do as much about equipping their public with relevant systems of tenure and registration as independent ones.

Andrew Lakau´s excellent paper really contains enough by itself for us to concentrate on for the whole week. His main focus is appropriately on registration, but he is also concerned with the quite different topic of tenure. Tim Davey´s equally important paper places the emphasis on Tenure.

I will make only three comments before leaving the topic of registration for your deliberations. First, we must not assume that there is such a thing as a "true" owner. Interests in land in all customary systems are everywhere multiple, conditional on a variety of other factors, and adaptable. That flexibility is their greatest advantage. Determining who will have what registered rights calls for wisdom, judgement and understanding - not for science. The Prime Minister of Fiji was probably right when he denied everybody access to the information on which the Fiji Lands Commission made its decisions, for as he said, all customary claims are likely to be challenged and a cooling off period is necessary after the decisions are made. He is talking in terms of two generations.

Second, Papua New Guinea, once among the most egalitarian societies in the world, is rapidly becoming highly stratified. Neither customary tenure nor registration will stop that process, but either could modify it if appropriate legislation was efficiently administered.

Third, people debate endlessly about whether to register groups or individuals. The short answer is not either/or, but both.

Small isolated societies with subsistence economies and without centralised government, anywhere in the world, were usually organised into groups on the basis of closeness of blood relationship, seniority of descent, fragmentation into sub-clans, clans, lineages, tribes etc., on various related principles. Land rights were recognised at each of these levels, and land rights of individuals were of course recognized - you can only sleep at one place at a time and seldom does more than one man plant in the same garden at any one time.

In those Pacific societies where land was first registered by groups, some form of occupation right, lease or license to individuals soon becomes necessary. And in those which registered by individuals, larger group rights often later emerge. The realities of today necessitate a range of levels of rights being recognized, from those of national and local governments, through those of clans, communities and other corporate groups, to those of the component individuals. But registration is only merited where disputes are numerous. Computers can help store information, but the big task is to accumulate to the basic data.

2. TENURE

All of us, Europeans at least as much as Melanesians, suffer from cultural lag. We are all conditioned more by past experiences than present realities. We find security in established patterns and fear the unknown. But in times of change the feeling of security in past models can lead to disaster as we move into a new world, which is incidentally as unknown to Americans or Australians or Japanese or Russians as it is to Papua New Guineans.

We are all feeling our way and Papua New Guineans are likely to adapt better than Europeans, for if we look at the history of empires, the dying empires fossilise, and the growth and adaptation takes place outside them.

How far should a government of Papua New Guinea (which is based on democratic parliamentary elections more than on Melanesian principles) and administered on principles of bureaucratic management (which are quite different from traditional principles) and with a conscious policy of developing the monetarised economy (which is vastly different from a traditional economy) and encouraging use of the most modern technology in the world, and a complex system of formal education, recommend that their people should adhere to traditional principles in relation to land tenure?

The opposite tendency applies to some extent in the case of certain aspects of domestic life, some forms of dance and creative expression, some aspects of language. With land more than with most other aspects of life, people are confused about which way to turn in looking for models. This is to be expected.

With communications it's easy - the transistor radio, the video set, the Honda, Air Niugini and Talair are everybody's choice over the drum, the foot and the canoe.

But with land, some people insist on ancient models. There are serious limits to the extent that the old models apply, because they depended on clan and tribal governments, not provincial and central governments: on total subsistence rather than a money economy: on most people living their whole lives in one small locality rather than the high mobility that is apparent today; and whole range of other factors which have so changed the context that traditional precedents can only be applied to a limited degree.

People often deceive themselves, not only in Papua New Guinea but anywhere in the world, as all parties try to get the best deal for themselves out of a rapidly changing situation. What constitutes custom gets distorted and reinterpreted to accord with the interests of the person or persons making the claim.

Some people consider that the problems will be overcome if the custom is documented and codified and given the power of law. This goal can never be achieved, because once custom is codified it is no longer the same custom and a great deal of the flexibility is gone from it. And once an independent judicial body is set up to apply "custom" it can only be a distortion of the former custom, which was that it was applied by members of the society very vigorously pushing their own self-interest. The final arbitrator in custom was physical power, which today is discouraged as much as possible.

In a rapidly changing situation like that in this country today, there is very good reason to make accurate studies of the existing tenure system in particular places, but trying to make everybody keep to the system that applied at any one point of time can only create more problems than it solves. To study and understand customary tenure is essential. But to fossilise them is disastrous.

Some recommend a return to the "traditional" system - in the sense of the system that operated before national government, before the introduction of steel tools and complex technology, before the introduction of international markets for the supply of goods and the sale of local products, and before rapid mobility and fast population increase. That option is out - at least as a total option.

Both impossible to apply, and totally unacceptable to the people of the country today if it was applied. But selected traditional principles will nevertheless remain important. The principle of "evolution from a customary base" expounded by the committee of enquiry on land matter in 1974, remains important.

A second approach is to adopt a foreign model in total, whether from Australia, Japan, China, Fiji, Russia, USA, Israel or elsewhere. Likewise, no other system would be publicly acceptable - although specific ideas from various systems may be very useful.

Another option is to leave the situation to deteriorate. The comment one sometimes hears, to the effect that the system has worked for thousands of years, so why not leave it a bit longer, is simply not true. The system that worked for thousands of years is no longer working as it worked for those thousands of years, and the context within which it operates is totally different.

It leaves us with a fourth option: to get down to some hard work to sort out which traditional precedents are still feasible and acceptable, which foreign precedents might be useful wherever they come from, and which new adaptations might be made here in Papua New Guinea to suit the unique local conditions of particualr land tenures.

Of course the final decisions in these matters rest with the political leaders, but political leaders anywhere - especially in a democracy - respond to informed public opinion and workable ideas. The surveying profession has a major contribution to make in this and should not be afraid to make it. But in the long-term interests of the nation, not in the short-term of surveyors.

Some tenure changes are perceptible in a wide range of societies. For example, in most Pacific Isalnd societies, older relatives had superior rights to the juniors in matters of land allocation, but there has been a perceptible shift in this across much of the Pacific (and beyond) as seniority of descent becomes a less important criterion of the allocation of rights and privileges.

And there are changing patterns of acquisition. In pure subsistence societies a great majority of people acquired access to their land rights primarily through a few dominant principles such as that of inheriting from the father´s relatives in patrilineal societies, inheriting mainly in one particular locality and son on. High mobility, occupational specialization and differential access to factors of production are leading to significant changes in this.

People marry much more widely than they used to, people move much more, and the actual processes of acquisition change. Last week I was in Malaita in Solomon Islands with a Malaita man who was just coming back by Solair from another marketing trip to Bougainville, selling "Traditional" shell necklaces. He did the trip regularly and said the necklaces were bought by people from various parts of Papua New Guinea for two purposes: to acquire wives and to acquire land.

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Taking work as a migrant labourer, to dig copper, to use the wages to buy Solomon Islands beads flown in by jet-prop, in order to buy land is custom in a sense, but a very different sense from that of the ancient custom.

3. CUSTOM AND LAW:

Custom is always in process of change, and codifying custom fossilises it and, particularly in countries where customary patterns are many, generally creates more problems than it solves.

But to some extent custom gets codified when literacy is introduced. Codification simply means turning a series of customary practices and principles which are conveyed orally, into written rules made more or less binding on independent courts. For good or ill, Pacific countries, like all countries of the world, are increasingly handling land matters in terms of formal law. That is inevitably associated with a usually slow process of making the diverse practices in various parts of the country less diverse and moving towards more uniform nationally recognized patterns. This is not because it is necessarily good, or the best way of doing it: it is because it is an inevitable by-product of national government and centralized bureaucracy.

But we should not be too intimidated by law. Much of it doesn´t work anyway, and much of it that does work, works in a very different way from what was intended. To take a few examples Fiji law has provided, for about 80 years, for persons leaving their home communities for a period of 2 years or more, to be deprived of their rights to the land in those communities.

In a country of a quarter of a million Fijians, over a period of 80 years, the law has never been applied once. I think it is still the law. In French Polynesia, the colonial government provided that the only adoptions that would have any effect in relation to land rights were those made in accordance with the law and confirmed by the courts. But after approximately 100 years of application of this law (and it still applies), the actual rights of adopted rural Tahitians have more to do with Tahitian custom than with law. The Cook Islands government in 1975 introduced a law to provide for short term leasing which it was confident would overcome the problems associated with the very frequent "customary" pattern of borrowing and temporary use of land. But the legislation has hardly ever been used, despite the continuing problem. One could go on very extensively citing cases of land legislation which simply have not worked.

One can also cite many cases of legislation which has had a very different effect from that which was intended. As Tim Davey´s paper points out, Fijian land is controlled today by legislation which was brought in by the colonial government several generations ago as a temporary expedient. It was not in any realistic sense based on Fijian custom, but like so many temporary expedients, it has now gone on for so long that Fijians assume it was their custom and are resistant to changing it. The Tongan law that provides for nobles to be consulted before government allocates land in their area, and allows for land to be allocated to commoners informally for a period to ensure that they are really going to work the land, has not had that desirable effect, but rather provided an avenue for exploitation of commoners by unscrupulous nobles. And Vanuatu has found it necessary to change quite recent law rapidly because of unintended effects.

Tim Davey´s paper refers to the need for lawyers who are not only specialists in Land law, but have close and continuing working experience with various aspects of Land Management so that the laws they draft can achieve the goals they intended. Your association might consider having its next annual meeting jointly with lawyers concerned with land, valuers, planners, administrators and politicians. That could achieve a great deal for all parties.

In the same way that it is necessary for lawyers, planners and administrators to learn more about, and to get more closely involved, the work of surveyors and other land managers - so it is important for surveyors to get a fuller appreciation of the law and the government, of what can and cannot be done, and not to be afraid to press for appropriate evolution of the legal and administrative system.

4. THE RIGHTS OF WOMEN

The land rights of women in all Pacific Island land tenure systems were minimal. That situation is likely to change faster than we think. In Tahiti and the Cook Islands, the rights of women used to be as minimal as they are in most of Papua New Guinea today, but today in these places, the rights are equal to those of men and, with all the land registered, women are landowners to the same extent as men. Recent studies in the Cook Islands have shown that in the last generation a reversal of roles has taken place. Whereas a generation ago land matters were almost entirely handled by men, today they are handled by women in more than half the cases. One reason is that the land is registered and land matters require studies of records, attendance at hearings and so on.

With men being more frequently away at work, more and more of this has been left to women. Moreover, whereas a generation ago it would be rare to see a woman speak at a meeting involving land matters, today in Rarotonga women participate more than men in such meetings. There seem to be two reasons: one is that women seem to be more concerned than men to ensure that they get land for their children (now that they have the same rights as men in land) and the second is that many men now prefer to leave the debates to the women because land issues are sensitive and likely to provoke aggression, which seems to be considerably less when the matters are handled by women.

The main point I´d like to bring out is that when I first went to the Cook Islands, both male and female would have thought it inconceivable that women could become as important in land matters as men, land still being regarded as a "male" preserve. But within a generation more effectively women´s land rights have likewise increased markedly in Kiribati, Niue and even Samoa in the last generation. I realise that most people in Papua New Guinea will be of the view, as were most Cook Islanders, that "it can never happen here". Get ready, it´s going to.

5. TRAINING SURVEYORS FOR WHAT SURVEYORS WILL BE DOING:

Surveying, at least the older conventional form of surveying, was based very much on hard science assumptions. The key aims were for precision measurement, readily identifiable and easily reconstructable.

Nobody doubts the continuing importance of accurate records, but technological advances have made many of these functions much easier.

As I see it, the so-called "hard" sciences are rather soft - or at least easy, purely because they are precise, measureable, absolute. I would like to add indisputable, but with land even the most indisputable facts get disputed! The important things in real life are never precise or measurable or absolute. The more important the issue, the more it is likely to depend on the "soft" sciences: on understanding psychological, cultural, social, economic and political systems and processes - which are in reality much "harder" to deal with. It is in these so-called "soft" areas that all the critical arise and the crunch decisions have to be made: issues relating to cultural values, to apparently "illogical" reactions, struggles for power and property and prestige. Some of these occur in rural villages, but there is just as much tribal rivalry between government departments (whether in Waigani or Canberra or Tokyo or Washington) as in any village, and even more between political parties. Cultural systems and political processes are vital determinants of the way any system of land tenure and use actually works, and learning their dynamics is as important as measuring and marking the land.

Ken Toms´ most interesting paper shows that partly because students come in with less mathematical and scientific background they cannot take the elective subjects which allow some broadening in other countries. And I´d like to highlight his sentence that emphasises the importance of keeping up with technical <u>and social</u> change.

The technical change is likely to be kept up with better than the social. It´s social change that you will perhaps need to give higher priority in the future. As Ken Toms´s paper points out, learning is today a life-long process - an exciting worthwhile and fulfilling process if we do it well.

In a country like Papua New Guinea, where land development is so vital to the achievement of the country's goals, surveyors have much more to contribute than their counterparts in countries where most of the income is generated by Commerce and Industry in urban areas. To carry out your role most effectively you need not only the high quality technical training that you have had, but the widest possible expansion of your horizons to better understand and deal with the cultural, social, economic and political context within which you work. That necessitates first being aware of its importance, and second, making a conscious effort to understand it better. Short courses in particular of Management, Psychology, Anthropology, Accounts or Economics will be as important as advanced courses in Surveying. If we each resolve to read a little more widely in fields which impinge on our own specialization, to listen more carefully to those in fields which relate to our own, to attend Courses in fields outside our own, to think through realistic improvements and to put serious effort into seeing if some reasonable part of those improvements can actually be brought about, then Surveyors will make an even greater contribution to the development of this nation.

And while there is a strong case for more training for some, there may also be a case for less training for others. When Tonga decided in the 1950's to survey every plot of land in the nation, it hired a professional surveyor (the former Surveyor General of Malaysia) to do the job, using a team of Tongans with no surveying background, whom he trained in three to six months to do the great bulk of the surveying. He taught them only what they needed to know to do that job, under minimal professional supervision, in the minimum time, with appropriate levels of accuracy. There were only two or three professional surveyors on the job at any one time, and the whole nation was surveyed in about four years at a total cost of about K50,000. I realise that Tonga is small (about 105,000 people today), that the terrain is easy, and that the pattern of land holding was simple. But nevertheless, in those same conditions, a conventional approach to surveying would have cost vastly more. Likewise in PNG you have no doubt given careful thought to the minimum requirements, in both training and techniques, needed to record the boundaries of customary land where this is desired.

CONCLUSION:

When land development gets held up by personal jealousies or departmental rivalries or posturing by political parties, we sometimes wish we were in a benevolent dictatorship, where wisdom would come from the top and all would do as they were told. But dictatorships never are benevolent, at least never for long. And they are never efficient for long - and usually hopelessly inefficient, involving waste and coercion on a massive scale. And there is seldom much in the way of wisdom at the top of dictatorships anyway.

If we look at some of the real alternatives around the world, the people of Melanesia have much to be grateful for in the working democracies that run their countries. Of course we are all aware of the defects, serious defects in many cases, and we should do anything within our power to minimise the defects. But we should also be aware of the benefits of the present systems of relatively open, elected governments.

And while we regret what has not been achieved, we should also remember the tremendous amount that has. I first lived in this country more than twenty years ago, and every time I come back I am amazed at the developments - most of them positive. The government set up the Commission of Enquiry on land matters and adopted a broad policy. The next stage is implementation. Immediately after independence land does not get top priority. That is natural, but now that the national government is well established, any body of clear workable proposals from your organization is likely to receive serious consideration. I congratulate the Papua New Guinea Association of Surveyors for facing this complex problem, and recommend you to set up a working committee to help evolve a rolling programme of action to facilitate the progressive use of the land as the basis for the development of this wonderful country.

SOME NOTES ON THE STATE OF THE ART AND CURRENT TRENDS

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Abstract

The author has attempted a review of some aspects of the current ´state of play´ in land and hydrographic surveying, and wishes to emphasise its personal, subjective nature. However, a fairly comprehensive bibliography is given, so that any individual can draw his own conclusions.

1. Geodetic surveying is the term used to describe any form of surveying which involves work either to a high order (eg. first order levelling with change-over points of the order of tens of metres apart) or which incorporates comparatively long distances between control points, thus necessitating computations which account for the curvature of the earth (eg. planimetric surveys with leg lengths of tens of kilometres) - or both. The natural reference surface for heights (the Z coordinate), is the geoid, or mean sea level, whereas that for planimetry (X, Y) is the theoretical ellipsoid. If the two, historically separate, systems are subsequently to be combined, then a knowledge of the geoid - ellipsoid separation (N) over the area concerned should be well known. This is not generally the case.

2. The advent of satellite surveying has led to a new position-fixing strategy. Three dimensional (X, Y, Z or , , h) coordinates are determined directly with accuracy and convenience, without the need for line-of-sight between control stations. The best technique in terms of accuracy, logistic feasibility and for the provision of a solution in real time from the TRANSIT Doppler system would appear to be that of translocation, which has proved very successful in Papua New Guinea and elsewhere. This is a relative positioning technique whereby (ideally the same) satellite passes are observed from both a station of known coordinates and from a station to be fixed. Provided that the satellite orbits do not pass between the two stations, fixing errors such as those due to an imperfect knowledge of the geopotential model, which lead to errors in the broadcast ephemeris are substantially common to both, and the relative interstation vector is comparatively unaffected.

3. At present it is probably true to say that there now obtains a period of world-wide transition between use of the classical geodetic methods, giving results on different reference surfaces, and use of satellite-based methods with results in three dimensions, and especially conveniently expressed with respect to geocentric ellipsoids - i.e. geocentric datums. As a result some countries have decided to base their future surveys, mapping, and national coordinate systems on the latter type, but this is by no means a universal trend. The implications, complications and unavoidable transitional pains are such as to have convinced several that no such change should be made. Perhaps to the logically minded the ideal solution would be for all countries to adopt the same geocentric datum. Equally, it would be logical and convenient for all mankind to speak exactly the same universal language, without any national or local dialects or inflections. Will either international development ever take place?

4. The latest entrant to the space surveying field is the Global Positioning System (GPS), and in particular the use of its coded signals merely as strong, pseudo-random noise so as to generate results from application of the interferometric methods previously restricted to Very Long Base Line Interferometry (VLBI). Small, portable units are available, performing relative fixing to accuracies of the order of centimetres. The further refinement and increasingly more widespread use of this development is certain to accelerate.

5. Much research in recent years has been directed towards quantification of the cumulative, systematic effects of refraction in first order levelling. This has been carried out with some success; retrospective corrections have been applied to some historical data in America, where current first order levelling procedures now include measurements of vertical temperature gradients for use in the appropriate correction algorithm. However there are known to be other systematic influences, notably geomagnetism and crustal movement, and work is continuing on this aspect. A significant improvement in conventional differential levelling can be expected before long - the laser level, having comparative immunity from refraction effects and lines of sight of the order of a kilometre. This will make levelling faster, cheaper and substantially more accurate.

6. The development of inertial surveying techniques is described elsewhere in this issue. This branch of surveying endeavour should not be seen as being in competition with Doppler - essentially, inertial surveying is an interpolative technique ideally to be used for densification and infill. The two separate methods are nicely complementary; Doppler should provide the primary control and I.S.S. that of lower order. At present it seems that research effort is mostly directed at

improvements in the soft-ware, especially those concerning post-mission adjustment and the separation of systematic errors in the error budget. Currently work volume of at least four weeks is usually required to make hire operations economical; given that, the most impressive advantages of I.S.S. over conventional surveying are the time saving (80 to 90 percent) and reduction in costs (50 to 65 percent). Accuracies of 1 in 250 000 are attainable now, provided that the system is used to best advantage - viz. in the area mode, with constraining cross-over points used in the final adjustment. Progress rates have reached 60 to 80 stations daily using helicopter, 190 - 150 using vehicles. It is considered that I.S.S. has a great future in Australia; effective utilization however requires the carefully planned pre-positioning of large numbers of points, provision of peripheral geodetic control, good logistical support and an efficient operating team.

7. In the hydrographic field, the trend is increasingly towards microcomputerized, integrated and automated survey systems for charting. In these sophisticated developments, the fix is generated through a least squares solution from more than one Navaid (if such be available) with appropriate weighting, and continuously updated in real time. Digital and graphical displays of position, ship's track, off-line distances, distances to datum points such as end of line, and depth data are available. Bathymetry is reduced in and by the system (using a mathematical tidal model) at every fix, and reduced soundings plotted automatically, often in colour-coded form so as to make the task of hand contouring easier.

8. The problem of accurate marine positioning is acute - the oil industry, for example, requires well head and drill rig positioning to 3 - 5 metres in real time and oil and gas pipelies to 1 - 8 metres. Bearing in mind that marine lease bids have reached approximately US$35,000 per hectare it is obvious that delineation of Exclusive Economic Zones and deep-sea mining concessions requires accuracies of geodetic order. Such surface positioning should present no problems as GPS Navstar develops, but there will be a clear requirement for ocean bottom control stations (OBCS) or beacons. Acoustic beacons have been used for example by the oil industry for some time and the most versatile are of the transponder type, although passive reflector types have also been used. For example, a 'network' of three or four such bottom mounted devices may be fixed by successive passes of a surface vessel, using satellite or inertial techniques to fix its own position. When the network has been so fixed, it may itself then be used as a means of position fixing with high relative accuracy. The problem with such acoustic systems is that they are subject to the vagaries of the path taken by the sound waves through columns of water often of a complex and unknown thermohaline structure. These problems obviously attain greater significance for greater depths.

9. An anchored control buoy, fixed by GPS satellite observation, in turn can be used to fix a transponder array on the ocean bottom to provide further control: it is possible to envisage an array of OBCS's covering the world's oceans, comparable to conventional first order geodetic networks on land. Once established and adjusted, such an array could serve several applications, inter alia surveying and mapping (perhaps using submerged photogrammetric techniques), marine geoid and sea surface topography determinations, studies of tectonics and ocean floor spreading, together with, of course, marine positioning and navigation.

It is a truism that the oceans are inadequately mapped: even the shallow seas are largely unexplored. As exploration of the oceans for food, fuel and minerals continues, geodetic control will have to be extended to the oceans both for the precise positioning required for boundary demarcation and as the necessary basis for the measurement and representation of the seafloor topography, about which so little is known.

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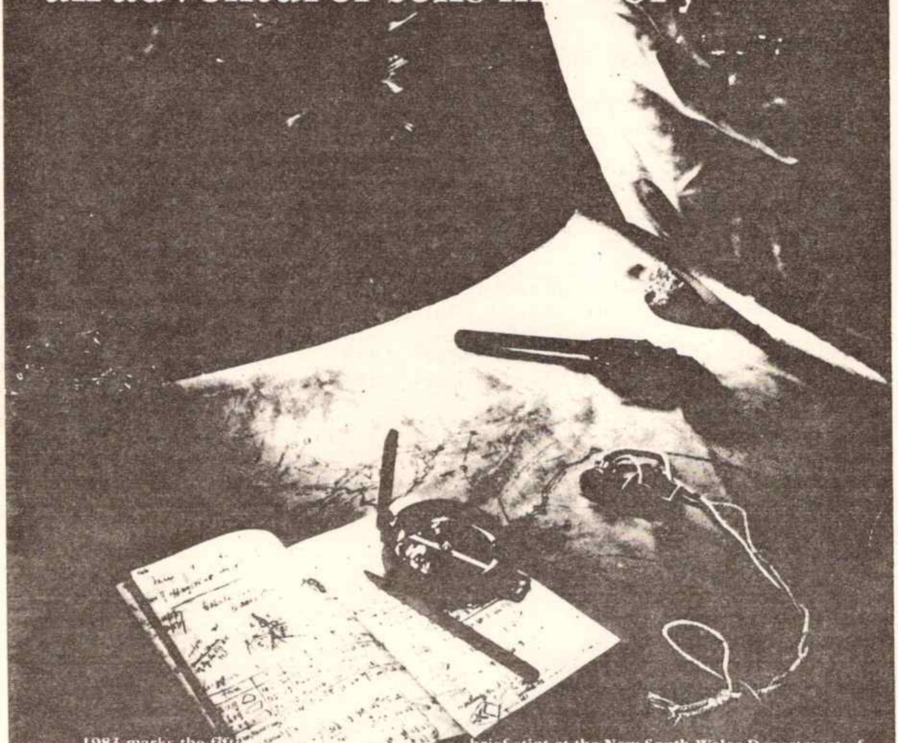
The Chimbu Expedition

New Guinea — February 1933

by Charles Marshall

an adventurer tells hi[illegible]tory



1983 marks the fift[illegible] European man's first sigh[illegible] — a vast, heavily populated h[illegible] between the main mountain [illegible] running up the centre of Papua New Guinea. Called the Wahgi Valley, this magnificent vista of great open valleys surrounded by towering peaks was unknown to the outside world until February 15, 1933. Its discovery, by Charles Marshall, Mick and Danny Leahy, had a profound effect on subsequent exploration of the Central and Western Highlands of Papua New Guinea.

Charles Marshall in all spent 12 years in New Guinea working for mining companies. After a brief stint at the New South Wales Department of Main Roads, then the Joint Coal Board as an open cut expert, he formed his own engineering and mining consultancy in 1958. Charles Marshall is an Officer of the Order of Australia and holds the prestigious Medal of the Australasian Institute of Mining and Metallurgy.

With the documentary film, *First Contact* — which makes effective use of original film footage taken in the valley only weeks after that first expedition took place — still showing in cinemas throughout Australia, this article: by Charles Marshall is particularly timely.

This story concerns the first exploratory activities on the Central Highlands of the Territory of New Guinea ranging from the Bena Bena River, Garfuka River and the Chimbu to Mt Hagen and beyond. Until 1933 this was a blank area, unseen, unknown and unmapped. Written from first hand knowledge it contains some of the matters I was concerned with but the complete tale is too long to cover in this article. It is an endeavour to record facts and some fun as well as being an antidote to the sloppy research written and published in the press about these events. I write as a professionally trained explorer, engaged in a modest way in exploration six years before the events, related below, happened. Until now I have always followed the dictum of my mentor in exploration, Henry George Foxall. "Surveyors, mining engineers, geologists and certain seafaring types are trained in exploration but are paid not to talk about it. Explorers are often ill trained for exploration but get paid to write about it".

The first question we ask is — Why did it take place? What is the origin of this exploratory activity which stretched from the Bena Bena Valley out to the west of Mount Hagen and beyond, over towards the head of the Sepik and Fly Rivers and the Dutch Border.

Kainantu in the Upper Ramu, on the edge of the Central Highlands, was opened up by Edward (Ned) Rowlands, an experienced prospector in 1929. Subsequently, Mick Leahy and Mick Dwyer, both prospectors, passed through on their epic expedition down the Purari River in mid 1930. They did not quite know where they were until they arrived on the south side of the Papua/Mandated Territory Border and were addressed as 'Taubada' — the Papuan form of address instead of 'Master'.

In late October 1930, Leahy and Dwyer re-entered the Bena Bena country.

In 1932 the Morobe District Mining Warden, concerned for the safety of miners, in the area requested the Administration take steps to protect them. As a result a police post was established by Assistant District Officer, Jim Taylor and a patrol officer.

The goldfields around Wau, the Bulolo, Edie Creek and many other places in New Guinea had been established on what were originally rich alluvial gold areas. By 1930, however, they were being rapidly exhausted. Costs of production in New Guinea, whether for an individual prospector or big mining company operations, were excessive and often prohibitive. The main costs were transport, facilities, communications and stores, since much of New Guinea, with the exception of the highlands and some of the coastal areas, was sparsely populated. Except for small sporadic native gardens there were few sources of good food supplies available in the then known hinterland. So it was essential that new areas be discovered, to prolong economic mining life.

It was quite obvious, even after the first few years of testing that the established goldfields of Edie and Namie Creek were not going to be 'new Mount Isas'. Thought needed to be given as to where and when companies should move their activities. Of the scores of finds reported, few if any, were not investigated by New Guinea Goldfield's Limited's (NGGL) geologists, surveyors and their prospectors.

The question of what minerals lay in the high mountain spine of New Guinea and what sort of topography might be hidden under the great cloud banks seen from around the distant perimeters, often came under discussions by the company's senior staff.

All sightings of the great highland ranges, stretching across the middle of the country indicated very heavily timbered country.

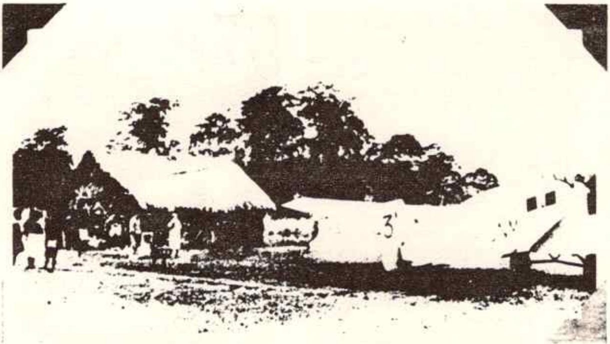
H. M. Kingsbury of NGGL, a top class geologist of his time, forecast the general direction of the ranges and valleys, but their exact nature was still not known. Whether they were rugged, densely forested mountains or open grassed valley was still a mystery.

Although aeroplanes came to New Guinea in 1926 very little or no aerial reconnaissance was carried out apart from the occasional flight over known valleys. This was mainly because planes lacked modern instrumentation and were only equipped with an altitude indicator and magnetic compass. No plane, until the late 1930's carried a radio, and none had homing beacons. Any plane trip over the mountains quickly involved flying through any available gaps in the clouds. No pilot dared to deviate his course because it was time consuming and dangerous.

The limiting altitude of planes available in New Guinea was well under 3500 metres while many of the known gaps between the mountains, as between Wau and Salamaua, were about 2600 metres. Further to the west mountain gaps were often higher than that, so exploring was usually a case of shank's pony, blind travelling mostly, and living off the land as much as one could. Aeroplane supply drops were, at that time, unknown in New Guinea. From German days right up to, and including the 1930's, there had been many brave exploratory ventures in search of wealth. Ever since the establishment of NGGL in Wau, in 1929, staff and prospectors were employed to search the country still unknown to Europeans.

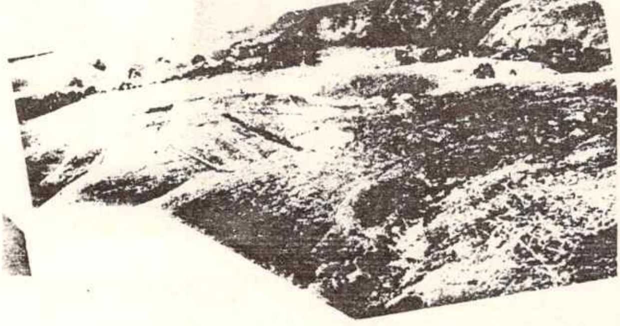
After one of my trips from Bena Bena to Wau, I had long discussions with Harrison, general manager of NGGL, and Kingsbury, in regard to the potential of country further to the west.

Charles Marshall at Bena Bena base camp.



A valuable supply drop at Kiantu Airstrip.

Bena Bena River Flat.



Kingsbury felt we should find other great valleys due to the geo-folding systems, and I advanced my long-held theory that areas of clear sky visible to the west of Bena Bena could indicate open grasslands. Mick Leahy, by that stage a well-known prospector and previous employee of NGGL, agreed with me. I urged that we should go into this country before any other people, and take up areas if warranted. Harrison and Kingsbury had reports of other groups preparing expeditions and we also knew that the Leahys were talking with local mining companies which were in opposition to us.

With this in mind, Kingsbury made a special flight to Bena Bena in January/February 1933, to sign the Leahys on contract to NGGL. Following discussions on my brief visit to Wau, Kingsbury agreed with recommendations that the company should acquire any suitable areas in unknown regions. He wrote to Mick Leahy, instructing him to penetrate the ranges to the west and search for parallel valleys. It was part of NGGL's intention and plan that further westward penetration should take place.

I flew out in January 1933 to look at Bena Bena River and the Garfuka areas. With more in this than just a 'look-and-see'. I was later able to peg areas that could possibly be dredging claims. This allowed me, on the company's behalf, to have a general lookaround and get the feel of the topography, inhabitants and to note the geological and geographical features.

This year, 1983, marks the anniversary of the expedition when, on February 15, 1933, I, together with Mick and Dan Leahy first saw 'The Long View'. — We had climbed to the top of Mt. Irimbadi, at about 2,700 metres and saw this magnificent 'Vista' of great open valleys, surrounded by towering peaks, many in excess of 3,500 metres, with the Great Mt Wilhelm over 4,500 metres to the northwest, spread out before our eyes. This was the highlight of a trip which confirmed the existence of country that was potentially suitable for future dredging areas. Looking out to the west from Bena Bena one saw clear sky indicating open country, predicted earlier by H. M. Kingsbury, Chief Geologist of NGGL.

Three men, myself, Chief Surveyor for NGGL, Mick Leahy with his line of highly trained natives and younger brother Danny, comprised the field walking party. This expedition was to have a profound effect on subsequent exploration of the Central and Western Highlands.

The background to this trip which first penetrated the Chimbu Highlands and found what is now known as the Wahgi Valley follows below. This was the expedition that triggered off the rash of exploration westwards, which was only interrupted by the 1939-45 war.

It was a project planned by NGGL's senior staff. The Leahy's came very little into the long term planning, but they were very useful with their well trained native line, efficiently carrying out the immediate objective in the field.

In 1932, Mick Leahy approached NGGL to look at the Bena Bena area. The company thought it was appropriate to use Mick Leahy because he knew how to handle new people, explore new country and had a trained line of natives experienced in this activity. NGGL employed Leahy to do further work in October 1932 in the Bena Bena areas.

In November 1932, Kingsbury, the geologist and Whyte, surveyor's assistant of NGGL, flew to the Larumpa airstrip near Kainantu. They walked into the Upper Bena Bena, looking at the Valley and came out again. Kingsbury instructed the Leahys to make an airstrip at Bena Bena. It was completed in December 1932.

All this activity was completed with the minimum of publicity. Ian Grabowsky, pilot, and I flew up the Markham River at 2500 metres altitude. Eventually, after a very rough trip through the clouds we crossed into the Ramu, came down low through Ramu Gap and landed at the airstrip at Larumpa, near Kainantu. There Assistant District Officer, James Taylor and a patrol officer were at the new police post constructing the new Kainantu airstrip.

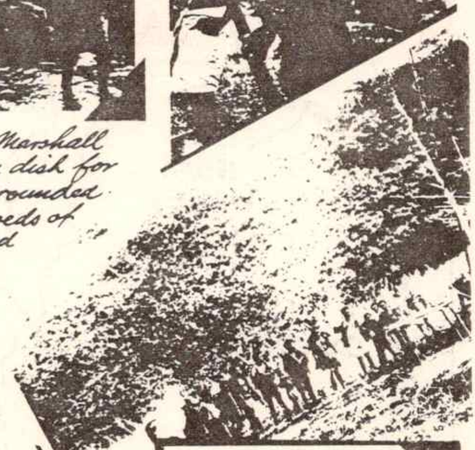
After the clouds lifted we just got off the ground at the old Larumpa strip, eventually arriving at Bena Bena. The plane at this altitude with its heavy load only cleared the trees at the end of the strip by two metres. I arrived at Leahy's camp on January 19, 1933, did some test dishes of workings, as well as surveying and measuring angles between some of the dominant hill tops.

The next morning, I set out with Mick Leahy and seven natives to inspect the junction of the Bena Bena and Garfuka Rivers returning to base camp later in the day. We walked 32 kilometres surveying and testing. Mick for some curious reason made the pace a cracker. Some of his natives commented on my performance saying I was a "dri bone finish" which is pidgin for being in very good physical condition.

Before leaving head office in Wau, Harrison had given me a blank cheque on the company to cover any possible expenses. He also gave me a letter, authorising hire of an aeroplane, seaplane, or motor boat, to obtain stores etc. These documents were wrapped in oiled silk and fastened with a big safety pin. He said at the time, "When I was in Russia, Marshall, I found this was a useful way of keeping valuables safely in the legs of ones trousers". On being asked for any other instructions, the only answer was — "Don't let those damn Yanks beat you in". We didn't!!

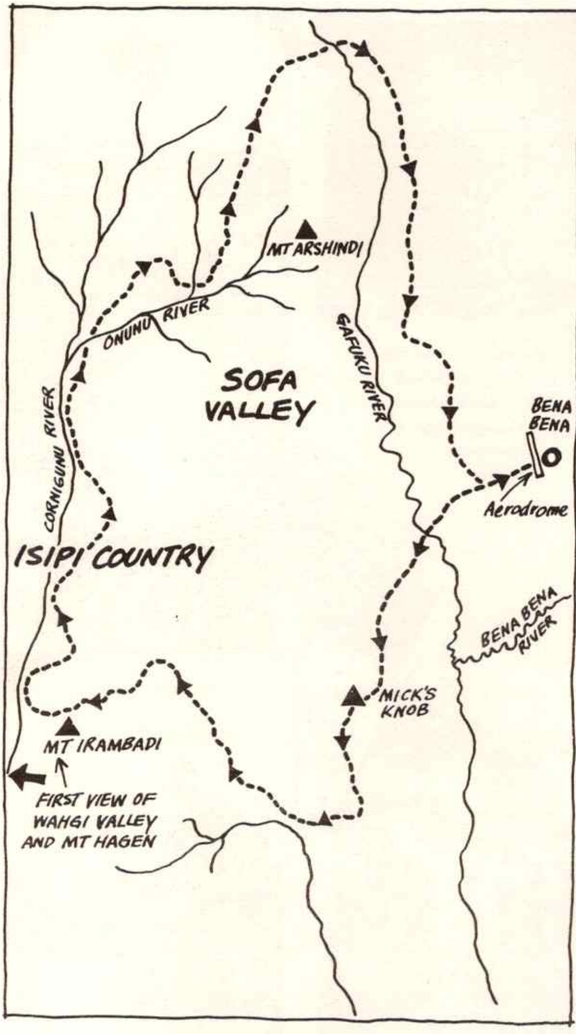
On January 26, I returned to Wau to

Charles Marshall washing a dish for gold surrounded by hundreds of armed natives



Charles Marshall by the camp's rope barrier.

Ken Spinks, surveyor.



A map showing the route the expedition took from Bena Bena to Mt. Irambadi and back.

make my report, not returning to our camp until January 29. On January 31, Mick Leahy and I walked to the Garfuka River upstream to the Asaro Villages, near the now famous 'mud' men's villages.

Over the last couple of days in January and first few days in February, we were in more or less unknown territory, although Mick Leahy and Mick Dwyer had been near the area.

I was especially keen to find where they had been so I could record the topography. Mick was very vague about where he had actually been on his trips and this proved to be one of his main weaknesses. He was a very good and courageous man on the march but somewhat dependent on his natives for any exac. information on location.

This was a good trip for our party as daily routine could be tested. The Leahys had never worked with a professional surveyor before, and I had to break them into the routine of stopping for mapping, testing and surveying as we went along.

I wrote up my work diary every night or on the following morning. It was brief and technical and an essential aid to making my reports.

February 2, the diary entry: *"Had a very big day. Looked like a fight at 11am from Kamiufa Village on north side of Bearded Mountain. Natives came down with wooden shields from village on west bank but we managed to make friends".*

After passing Kamiufa Village we pushed on to the Ashinoni villages where we estimated the population to be about 2,000. I washed many dishes of alluvial gravel whenever we paused.

It was a peculiar feeling having to turn your back on a seething mass of excited bowmen — some visible and many hundreds of others hidden in the pit-pit, or bamboo-like reeds. I had to close my mind to all of this and concentrate on washing a dish of gravel, examining the very fine minerals and estimating their value with only the doughty Mick Leahy and a handful of faithful natives to protect my back. This was all achieved bearing in mind that only a few hours before, first contact had been made. It was much easier to face the seething mob with your hands free and with all senses alert, assessing moods and movements of the natives prowling around.

February 4. *"Left Kabisup (near where the present Goroka stands) at 7am and reached our base camp at Goritufa (Bena Bena) by 11.30am after passing through Mahometo Village where we had a great reception. Passed a war party from there on the way to fight Kawisup — they threw down their bows and arrows when they met us. Joe, one of Mick Leahy's boys, was speared by Krou villager late this afternoon (Kropu was about three kilometres east of Bena Bena strip)".*

February 5. *"Left camp at 5.30am*

a native from the Purari Country. The cord in front is the barrier we put around the camp.

to interview Kropu Village — they came out to greet us with shields and bows, etc. — Fight took place — Barononoa, (one of Mick's boys) was wounded in head with arrow — We called fight off at 9am on receiving surrender from them, with exception of bowmen still hidden in pit-pit cane in the gully. Five pronged attack — we were on a ridge. We descended on three spurs to within 50 metres of their village when they broke off fight which was hectic while it lasted. They are not as good bowmen as the Kuru men (Oriomo River — Western Papua). Two pigs were fetched over to camp when we got back as a peace offering on Sunday night".

I had sent in a request for our company medical officer — Dr Ian Dickson, to come out to give the statutory TAB (typhoid) injections, as insisted by the Assistant District Officer. As a result Dr Dickson was flown out by Pilot Orme Denny. Jim Leahy also came out to build up our strength. It was an Administration requirement that all persons entering uncontrolled Territory must have current TAB injections and the local administration officers allowed the NGGL's field staff little latitude at all while we were in the area. Dr Ian Dickson gave us all the injections and attended the two boys who received arrow wounds.

He also left me a hypodermic syringe, needles and morphine tablets, carefully explaining the strength of the dose required in case it should be needed. He has seen some of the terrible two-way barbed arrows used by the natives in these parts.

February 9. *"Still awaiting plane. Rained all night. These moonlight nights are a bloody nuisance — nice for making love at Manly maybe, but good for a hate from the kanakas' point of view. Saw three natives swallow 22 inch doubled ⅜ inch Kunda (lawyer) vine, they pushed it down their gullet. It is a secret ceremony as all piccaninnies and women are chased away before it can be done. They seem to always carry their swallowing kunda cane with them. Wish the plane would hurry up".*

February 10. *"Rained all night and we all slept better. Dogs quiet. Saw a dead enemy's finger hanging in a fellow's hair. Quite hardened to the pig-greased old buck natives mauling me — or having a nice pig-greased hand (very ancient pig grease) chucking me under the chin. Will go to drome (to await plane with the guns etc, tomorrow and leave for the Western trip as planned) whether or not the plane comes — am afraid I cannot afford to wait any longer".*

Up to January 1933, Mick Leahy was employed on a letter type agreement by NGGL. In the course of negotiations for his further employment, he indicated he was prepared to work for rival mining interests unless we met his increased demands. We were uneasy about his attitude, so Kingsbury flew out to the Bena Bena No. 1 camp on a secret flight to sign him up formally in January/February 1933 before committing our plans to him.

These expeditions were fairly costly exercises and all information gained was to be held in strict confidence.

Pilot Ray Parer flew Kingsbury in on a day when there were threatening black clouds over the Gap. Ray indicated that he wanted to get away as soon as possible. Kingsbury quickly disembarked, handed me urgent mail to be dealt with, and collared Mick to sign him up — We both went quickly to our separate grass huts nearby to complete our business in haste — as the weather was closing in over the Gap. Then the unexpected happened!

Kingsbury's wife was hidden in the tiny cabin of the little plane and in our hurry had not been noticed. Stowing away with instructions from Kingsbury to keep out of sight, she was illegally in a proclaimed Uncontrolled Area and in breach of Administration Regulations. Nevertheless, her desire to be the first white woman to set foot in the new Bena Bena area was really too much for her to resist. So out she stepped among a large crowd of curious natives. She was dressed in a white silk blouse — New York cut — pale yellow riding trousers, and her long black hair in a plait down to her waist, standing tall in her shiny riding boots. This of course amazed the locals as they had never seen such an apparition before.

Now the local ceremonial form of greeting was shoulder in groin, hand through the fork of the legs and an enthusiastic pinch in the lower regions accompanied by certain customary words of rude meaning.

At this cool altitude, the natives cover themselves in a thick layer of pig-grease and soot. To say the least, she really did get a sudden and very enthusiastic welcome from the elders of the tribe. We white men were about our own urgent business dealings nearby, out of sight of the plane. Suddenly, the silence was split by piercing series of shrieks and calls for King! King!!(her husband) and Charlie! Charlie!! to rescue her. We all rushed over with guns at the ready to see this lady marked all over her bosom, belly and backside with sooty hand marks and in a bearlike hug of greeting from a Bena Bena native VIP. We made the mistake of laughing instead of an immediate rescue of a damsel in distress! I was in consequence treated with considerable coolness for some time afterwards when I returned to Wau.

The official business was quickly completed and without giving her a chance to remove the black grease marks, the lady was strapped into a cramped plane seat as Ray Parer raced for the Gap in the mountains before the clouds closed in.

The first stop was at Wau airstrip

where she arrived, all the greasy marks on her clothes still plainly showing. She had to walk up the one in ten grade strip, past the crowded pub verandah in full sight of the groups of white miners assembled for their late Saturday afternoon booze-up.

I paid the penalty for my unseemly mirth and received no invitations for dinner for many months after I returned to Wau — Mrs. Kingsbury was a splendid cook!

However, she achieved her ambition of being the first white woman to set foot on land in the Bena Bena/Goroka Valley. The Americans had done it again!

On February 7, 1933, after seventeen days of continuous activity, we declared a holiday. I had sent for more shotguns and was waiting for these to arrive from Wau. By February 8, it was time to think about the next step in our operations. We had a good base camp, one tent completely enclosed with pit sawn timber, bought from the locals, and the other, my tent, enclosed with plaited pit-pit cane six feet high all round, which does give a sort of barricade from arrows.

On February 11, the shotguns arrived by plane. These were left at the base camp with Jim Leahy and Ken Spinks, my assistant surveyor. Then Mick, Danny Leahy and myself, with our native carriers set out for the unknown country to the west of the Garfuka River. This expedition was to trigger off many later major expeditions westward to the Dutch border. Now we were a well organised unit, and the impatient Mick Leahy became used to the needs of a scientific exploration party who knew where they were geographically. Kingsbury had given Mick Leahy written instructions to cross the river and mountains to the west.

Each man, black or white, knew his job and the programme followed a tight, well disciplined plan. I had learnt this from Newbury who was the geologist in Western Papua with me in 1927 and 1929, and also from Stephen Maclean, surveyor who was out on the Fly River in 1912. Newbury, who was at Edie Creek in 1929 had passed some of his exploration 'lore', gained in Africa, central Australia and Papua to Mick Leahy who had a high regard for him.

First contact with people who had not seen whites before, always made both sides equally cautious and nervous of the other's capabilities. On second contact, the young bucks and/or locals, seeing the treasure in our hands often became ambitious to possess it. On the third meeting one had to be on guard against an unexpected attack, unless a psychological and physical superiority had been established.

In the eastern Highlands, intruders were always outnumbered by the warriors. It was quite common in Bena Bena, Goroka and the Chimbu to have 300 to 500 warriors following, walking

A mean looking Bena Bena warrior.

Bena Bena locals.

beside or meeting us. The only way to deal with this situation was to put on a demonstration showing the superiority of European weapons.

Early rising was an essential ingredient for exploration in a new country. The locals, knowing every inch of the countryside, came in from their village before sunrise to establish their positions. So the camp had to be fully awake in this pre-dawn period, their favourite time to attack.

Secondly, stopping places for rest or campsite were selected to gain the best topographical advantage in case of trouble. Sites outside villages were chosen to allow for trading and slightly upstream so that the water would not be polluted.

At those altitudes, both the coolness of night and rain came down quite early. As soon as the camp site was selected, a barrier was constructed of heavy cord, or something similar around the perimeter of the camp. It was a system often used by explorers in Papua and other parts of the world, using either saplings, fences, ropes, (Kunda) cane or simply by clearing or cutting down the long grass around the perimeter. A definite boundary was established and it was an unwritten law that no-one, other than a member of the party was allowed inside the barrier.

On trips with the Leahy's, their dogs would stop anyone coming inside the ropes who didn't have the cloth (lap-lap) around their body. Those inside the boundary could spot any movement and better observe the faces and attitudes of people outside the barrier.

Camp was always made by three o'clock in the afternoon, because it was a very busy time between then and dark purchasing food and other essential stores. In the Bena Bena area every stick of wood had to be bought. Timber was needed for tent poles, making fires to cook food and drying clothes.

Even under good conditions, without being able to obtain native food, or game, it was well known that the maximum period of one month was the limit before carried food was exhausted. The compulsory ration was a pound and a half of rice per day per man. One would extend this by supplementing the diet with native food one bought. There was an abundance of sweet potato, corn, apple cucumbers, beans, yams, bamboo shoots and in some places, bananas were generally obtainable. Sugar cane was also a great trading item. Pigs were scarce and expensive but a valuable source of protein. Shooting a pig also demonstrated the efficiency of our weapons.

All trading was completed early and intelligence obtained from the locals of the country ahead as to the lie of the land, rivers and streams.

All members of the expedition had picked up the essential 'lingua franca' for travelling and trading. The first phrases were "we come in peace", "we want to trade", "unstring you bows", "have you any sweet potatoes"? and essentials to make contact, such as, "can we camp here"? We tried to gain permission wherever we could, otherwise we risked giving offence.

The 'Long View' and the great valleys ahead from about 7500 feet

Charles Marshall crossing the Garfuka River.

The team knew exactly what to do, where and how to erect our tents. We bartered for firewood, food and obtained our water supply while it was daylight to keep our men under cover from interference.

It would usually take until about four or five o'clock to trade. Food had to be cooked and tents erected well before dark. As soon as the tents were erected, we would close the flaps and stack our stores and cargo carefully. It was unwise to let the crowds of curious natives see how or where we slept.

Usually the European slept with his pack roll not far from his head, between himself and the wall. We often went to bed fully dressed. Meantime the lights, kerosene or carbide, were lit so we could write up our notes in the shelter of the tent. My job was to record the topography, geology and geography of the areas we passed through as well as descriptions of the people and natural resources.

As soon as camp was established, one of the party with our medical kit would dress any wounds, cuts, bruises and attend the sick. This was an early procedure, for the sooner any wounds or cuts were dressed and the sick given attention, the chances were better for them to be ready for the journey next day.

Rarely did we set guards, and then, only in an emergency because our day's trip was always very strenuous both physically and mentally. The strain of meeting new people whose friendliness was unknown was constant. Even the most faithful of guards could easily fall asleep.

The morning routine started with lighting fires, eating a good breakfast, checking all the gear, reading the aneroid barometers and instruments and checking the carriers' packs. All the carriers fell into single line and were often joined by hundreds of followers. After the first kilometre we checked all the carriers' packs again.

On this Chimbu trip, as well as in the Bena Bena and Goroka areas, we were never less than 1,600 metres above sea level, and, at times we camped at over 3,000 metres. Needless to say it could be very cold at night. The natives were all quite curious, women usually kept well in the background but in the Chimbu, they came right out with the men to meet us at close quarters.

The Bena Bena Highland women were as great traders as their men. More than once they claimed us as some of their dead ancestors.

Sometimes it was so hot in the daytime we had to wear shorts. Often pig-greased tribal volunteers would carry us across the streams — we agreed because it was essential to keep our boots dry.

As the natives carried us across the streams, they would sometimes pull the hairs from our legs and swallow them — or wrap them up in leaves and hang them around their necks.

There was always the possibility of having to defend ourselves when heading into new country. The carriers accounted for the pack loads but nevertheless, the three white men looked like Christmas trees. Each of us carried a revolver, the standard Winchester 32-20 rifle with a ten magazine. My own revolver fired a full sized 32-20 rifle cartridge. We carried a full belt of rifle cartridges, twenty rounds for a revolver, as well as a pouch with a hundred more rounds and spare revolver cartridges.

Ever since arriving in Bena Bena on January 19, I, nor any of us, was ever out of reach of a weapon. Whether having a bath or in bed, our guns were always with us.

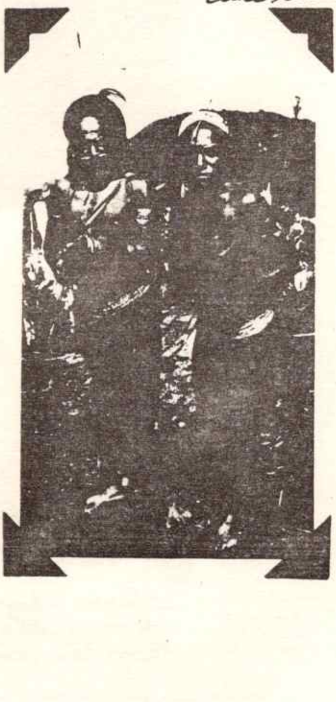
New Guinea in 1933 was a mandated country under the League of Nations so the only people allowed to carry arms of a military nature, such as 303 rifles, were government men and native police. No white person could import a '303'. Some of the native shields were made of a very heavy type of ironwood and ordinary light sporting ammunition would not penetrate it. Even a nickel jacketted '32-20' would seldom go right through these timber shields.

We always shared a tent and if one of us happened to get a call of nature or anything else in the night, he would never move out of the tent without first waking the others. We all slept very lightly and could almost 'hear a mosquito walk', as the saying goes.

Each man carried a long bladed sheath knife, camera, and watch in a pouch. I carried compass, barometer, abney level, magnifying glasses etc, a small bag full of necessities to identify rocks, acid, field books, maps and prospecting pick. Most of us wore khaki woollen shirts and our sandshoes or slippers were dyed brown. Even our pyjamas were brown so if one got up in the night he would not stand out against the sky and make an easy target.

The maximum load a carrier was permitted to carry, under New Guinea regulations, was 20 kilos but natives would normally carry no more than 14 kilos due to the high altitude, rough terrain and strenuous nature of the trips. In addition, they carried their eating utensils, blanket, spare pullover and a dry lap-lap. This brought the pack to about 16 kilos. The government required expeditions into Uncontrolled Territory to have a prescribed number of fire arms. As well as the normal food load etc, there was tentage for Europeans and natives. Sometimes it would be necessary to carry tent poles because timber was scarce and natives were reluctant to sell any. Cooking utensils,

Rather shy and suspicious 'cane swallowers'.



food for Europeans, medical supplies and a large quantity of trade goods to buy native food also had to be carried. The trade was mainly knives, plane blades, looking glasses, pearl shell, beads and cowrie shells.

For a carrier line of thirty, at least twenty would be carrying very little in the way of foodstuffs except that bought casually on the march.

The first thing I did of a morning was to look at the weather, then see if I could notice any natives. Invariably at the first light of dawn they would be around the camp looking for trade, or simply being curious.

Old meat tins and packages were valued, as they had never seen these things before. They would place paper and other discarded rubbish in their hair. As the sun dried the tents they would be shaken out and rolled up as wet tents made heavy carrying.

After breakfast packs were inspected and the boys all fell into line. The 'boss' boy checked them and we would set out again. The three white men would take it in turns as leader, middle man or 'tail end Charlie', changing places at intervals. 'Tail end Charlie' was always the most vulnerable position.

The carrier line would often grow from thirty to sixty or more, with the volunteer locals. They would carry cane bought for our boys, native foods and firewood for all of us.

I had already made maps of the Bena Bena and Garfuka Valleys and this open grass country of high peaks lent itself to rough triangulation methods.

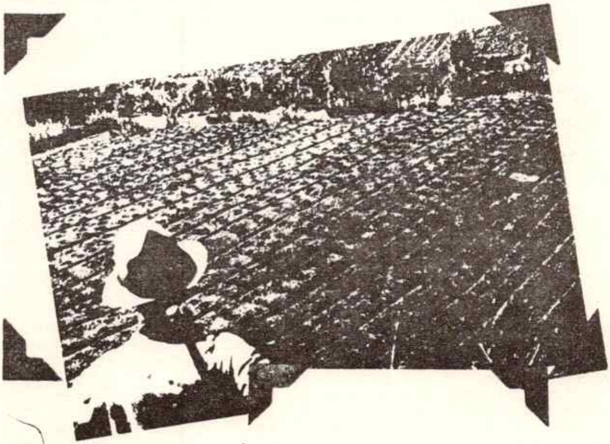
Everytime we came to the top of a hill I took a round of compass bearings to all peaks in sight and sketched the silhouette of the horizon ahead. My base for triangulation was the full length of the small airstrip at Bena Bena. Meanwhile, the two Leahy brothers and our faithful carrier line kept their eyes and ears open eliciting information from the locals, sometimes through many interpreters.

It is a peculiar feeling sitting on a mountain peak at 1,000 to 3,000 metres surrounded by hundreds of warriors and camp followers. It was difficult to concentrate on the task of taking bearings, notes, describing the country and recording possible types of rock formation. This work had to be done fast and accurately.

The keynote for all of our party was constant vigilance, using all our natural senses — sight, hearing, taste and smell.

INTO THE CHIMBU

Mick, Danny Leahy and myself left Bena Bena base camp on February 11, 1933 and made camp due west at Mohometo Village. This was country we already knew. Nevertheless, from the time we left camp everyone was on full alert, because we passed through Korafagu Territory and these people had attacked the Leahys, Kingsbury and



Native gardens in the upper Bena Bena.

Whyte at the end of 1932.

We crossed the Garfuka River on February 12, 1933 and camped on a narrow ridge. At first it looked as though there could be passive resistance to trading. However, some other natives from above the 2,000 metre altitude line brought down food and firewood. These natives were apparently seeing whites for the first time and taking off our hats caused quite a stir.

The ranges all around, were echoing with natives shouting across ridges to villages with the message that 'poonpoona' or white men were coming into their area. 'Poonpoona' was the original name given to white men by the locals in this area. I think it was derived from the sound made by guns, which had a deeper and echoing sound effect at this altitude.

We didn't understand all of the message but we could pick out the emphasis on the word 'poonpoona'. A word which preceded us throughout this trip.

Just before dark, men, women and children from a village only about a hundred metres away, came and brought food for trade. While they were doing this, another tribe, about 400 metres from the food village attacked them, causing several fatalities.

When there is a fatality in the village the ornamental barbed arrow, a dreadful weapon, mostly used to finish off a victim, is broken. We saw a number of these. We also saw them covering wounds with a large leaf and clay, then binding them with strands of bark.

That night, February 13, we all slept badly. Our senses were sharpened, probably as a result of having seen the fight. Even the dogs picked up the tension in the air.

I remember in the pre-dawn of February 14, going out to the edge of camp, which was on a very narrow, long, grassed ridge with steep sides, to attend to a call of nature. In the middle of it, I looked up and saw, in the long grass, scores of male and female natives watching the process. The women were all giggling and chattering like parrots. This sort of thing does tend to cause constipation!

About midday we reached a grass knoll at 2,400 metres which I had used as one of my survey points from way back in the Bena Bena base area.

There appeared to be very heavy population ahead. That was good for food provided the villagers were amicable.

We saw first sign here of the famous green stone axes as well as a Kunai grass valley in the distance, which was especially heartening. The high wet rain forest was depressing. That night we made camp at 2,500 metres. It was cold, wet and miserable.

At every creek we crossed, rock formations were inspected for mineralisation and a dish of gravel washed for gold. It kept me very busy recording it all.

On February 14, we dropped down from 2,500 metres then up again to 2,200 metres making camp in a beautiful glade. The mountains echoed with the news of our arrival.

The next day, February 15, was a great day for us because from a height of 2,200 metres we had first glimpse of the great, wide, grassed Wahgi Valley. Surrounded by tremendous peaks, one well over 4,500 metres and with Mount Hagen in the distance this valley became known as the 'Long View'. It inspired the later rush of exploratory trips to the centre of the Western Highlands.

All the time we were on the move, I was mapping and obtaining the native names of creeks, rivers and mountains. If I had been ten kilometres to the north, south, east or west of a particular place, it would probably have had a different native name and this is what some of our new map makers forget. All the names on my maps, after much cross examination of the locals, were agreed upon by Mick, Danny and myself.

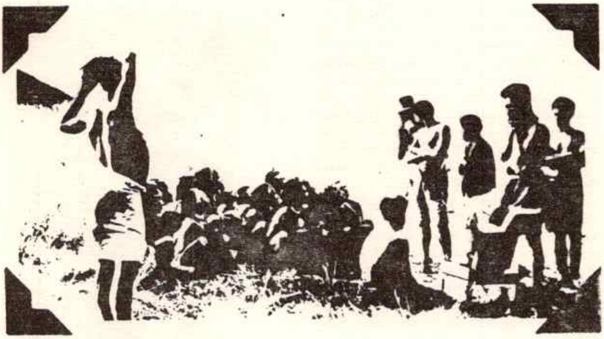
February 15, 1933 was really a day to remember for us. We continued up a mountain, down the other side to the valleys and then climbed Mount Irambadi (now called Elimbari) which is over 2,750 metres. The view was inspiring to all our weary party. We had come through cold, wet, dense forest all morning. The strain of heavy climbing, being surrounded by hundreds of excited natives and the delicate task of making friends with them as we moved along was beginning to tell. We made the pace as fast as possible.

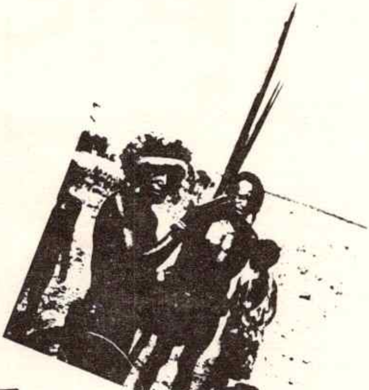
To pass quickly through a country for the first time was a matter of safety, as it doesn't allow time for the locals to overcome their awe, nor allow them sufficient time to plan an attack.

As we came down from Mt. Irambadi, at 2,750 metres, a seething mass of natives surrounded us. One dear old soul broke the barriers we had set up, to claim me as a lost husband and kept closely embracing me. She was covered with pig grease, soot and mourning pigments which came off on my face and clothes. This happened because I removed my hat and as I was quite white-headed even then she indicated I was her husband back from the dead. This caused great amusement among our carriers, until the younger women of the village started to claim them as brothers and so on, which, strangely enough, they did not object to despite the pig grease.

February 16 *"Here had over 300 followers all day with crowds of up to 500 including women when we stopped. I was taken by the hand and led along by virgins many times this morning — offered many wives, temporary or otherwise. (One old woman claimed me as her husband returned from death — poor old thing — was most embarrassing as she persisted in trying to hold*

All firewood and tent poles had to be bought from native traders.





Danny Leahy with "Bully".

me — and she made the hills echo with her howling)".

We continued mak.ng friends where we could but sometimes they almost wore out our patience. On February 16, after a very stiff climb from 1,700 to 2,200 metres, we had to sit down for over an hour to be harangued by the local village speaker. Apparently, this was the custom, so we conformed. When crossing to another tribal boundary, the politicians always get up and tell you how good they are, so following the custom, Mick, Danny and I on this occasion talked nonsense in our loudest voices, much to the amusement of our carriers. After that we gave presents and went on our way until crossing another tribal boundary.

On February 16 and 17, we first saw the great fighting spears used from the Chimbu, right out to Mount Hagen. Their bows were still made of black palm and some carried the green stone axe, apparently the insignia of an important person. These axes are now known as the 'Wahgi Axes'. By this time we were all fairly tired but the routine of making camp, marching and breaking camp, was continued on exactly the same lines, without fail.

On February 18, we struck one of the most severe tests of the trip. We had crossed the divide from the Chimbu country back into the Garfuka River headwaters at about 2,900 metres. On the way down we traversed a long, narrow, cleared ridge at about 2,200 metres. There were long lines of native huts on either side. In the centre of this village were hundreds of armed warriors, decorated, befeathered and splashed with pigs' blood. The women were also in war paint. All were dancing and chanting. It was a full moon and they appeared to be very worked up. Things looked threatening. They would charge up to our party with arrows in their bows in a menacing manner and then retreat at the last moment.

We moved on steadily, realising it was a case of 'you hit me, and I'll hit you'. They could have heard of the white men but they had not seen one. We immediately gave our carrier line the usual instructions to close ranks and pull axes and knives from back packs and make ready. Bush knives were usually put down the sides of their packs, inside the lashing, so as to free hands for climbing.

There was complete silence in our ranks. We clapped on the pace from steady to fast walking. The villagers were taunting and trying to disrupt the line and the air was electric. We had two dogs, Bully, a white bulldog and Bluey, a blue Queensland cattle dog. Bluey was on a tight lead. We stopped for a moment to tighten the packs and check all was ready in case of trouble.

It seemed inevitable. Then husbanding our wind and strength, we quietly moved on. We were still at 2,200 metres. The women had disappeared.

The warriors seemed to be getting even more daring, pulling hair from Bully's back. He was used to having loose hairs pulled from his back — the warriors used to wrap them up in leaves and hang them around their necks — to give strength. Bully didn't normally mind, but one of the cheekiest and noisiest of the warriors then made a grave mistake. He pulled a hair from near Bully's privates, a tender spot even for a bulldog. Now, Bully roared and being an angry English bulldog, roared as the natives had never heard before. The threatening mob disappeared in a flash, and the hitherto cheeky warriors dived into houses and onto roofs hotly pursued by a very insulted and angry, white bulldog.

This was the anticlimax we all needed. There was a roar of laughter from our boys but we did not hang around to see if anyone was bitten. We saw more than one painted, yelling and very worried warrior on top of a hut, but we just kept walking.

It was just as well that we had Bluey, the cattle dog, on short leash as he was very fierce. It had been a very long walk through this village of 600 to 800 metres. Bully eventually fell back into line as trained to do, intently listening to hear if there was a noise in the long grass or huts beside the track. If so, Bully would sniff, snort, then rush and we would see a warrior rocket up to the top of his house with Bully after him. Bully would fall in again with a mouthful of warrior's finery from somebody's rump. Short as we were of food, there was no one who could not spare a mouthful for Bully at camp that night.

We made camp near a group of villages on the Upper Garfuka River where Mick and I had been on January 27. We knew they had a tremendous strength of warriors. This was also a particularly bad night. We were quite worried because it was a full moon, a time when the villagers have their sing sing and can whip themselves into a dangerous, hysterical state. They brought their mongrel bitches on heat to the edge of the camp trying to lure our dogs away.

February 19 — my birthday — we had camped on the river that night, among the Ashinoi people (as we called them). They became cheekier and cheekier. We decided to hasten downstream at first light, as we were low in tucker and things were looking bad. The moment we crossed the river, they threw their missiles beside us. There were over 500 warriors on top of a four metre bank — and we had to walk along a track below the bank.

On the narrow track amid a maze of pit-pit, just over 400 metres from our camp, some natives started throwing sweet potatoes which grew very large in that country. I was walking as 'tail end Charlie' with an ex-sergeant of the German native police behind me. One of the female natives threw a four kilo sweet potato from the bank above which knocked me to the ground.

It was a tense moment. There was a sudden silence from the shrieking natives. Our line of natives only paused for a moment and then walked on holding the dogs tightly. We didn't stop to pick up the large sweet potato. Mick and I estimated on our first trip a month before this group of villages could muster 800 bowmen.

We eventually passed out of the dense pit-pit, which was several kilometres long, past the other Ashinoi settlements to a clear grass knoll which was at least 100 metres in all directions from the dense pit-pit as well as being a good defensive position.

We reckoned that discretion was the better part of valour, and after breakfast streaked back to the old camp site Mick and I used the previous January. This was near the present town of Goroka. There were three villages near here, all close together. We camped on a narrow grass spur, in open country just wide enough to erect our tents and immediately cleared the long grass around the tent site.

It was full moon but with heavy clouds. The dogs were restless, and so were our boys. We sensed that something was afoot and everything and everybody was uptight. It was silent except for the dogs who were growling in their stomachs. We let our boys arm themselves with axes and knives as usual and Mick, Danny and I had our powerful torches ready and waiting.

We knew the natives were on the slopes all around us because occasionally there would be a shine of polished arrows and bows. Movement at night was very unusual, except for the Kuku Kuku tribes from the mountain ranges in the Upper Watut River area.

We waited until they were about 15 metres from us, then we simultaneously put on the bright beams of our powerful torches. The bedecked warriors were momentarily frozen in their tracks. It was like a scene from Dante's Inferno. Blood curdling screams, flashing lights, then the dogs broke loose and pandemonium broke out. These natives had never seen torch lights, hence, we got out of another awkward situation. We were glad when it passed with no casualties except for a few excited warriors with bitten backsides.

They outnumbered us by ten to one. We were glad when dawn came.

We returned to base camp next day to draw up the maps and plan the next expedition.

One of the greatest thrills of my life after this rough trip to the Chimbu and back was to find the Assistant District Officer had erected a flag pole at the old Bena Bena Camp. The Australian flag was flying and I noted in one of my diaries that night, *"This day the Kings writ ran"*.

My report, which was accepted by

Charles Marshall with 'Bill', a local Korafuguan native, who adopted the party.

Harrison and Kingsbury, recommended further penetration to look at the Wahgi Valley and out to Mount Hagen. A joint expedition by NGGL's party consisting of Mick Leahy, Danny Leahy and Ken Spinks, (one of my assistant surveyors) with Assistant District Officer Taylor and police from the Administration to the Wahgi Valley and Mt Hagen area resulted from the Chimbu trip.

The expedition was the last without aerial reconnaissance, not serviced by radios, and the last that was not re-supplied from the air. It was a case of 'go into the blue', not knowing what we might find. Kingsbury's predictions as to the general topography were fulfilled. The belief by some of us that where large spaces of clear sky occur, one finds open country, was justified.

This was the expedition that probably brought half a million or more natives under the Crown and spurred on the mass of later great expeditions in as far as the Dutch border.

PRESIDENT´S ADDRESS: 4 July 1984

PARTICIPATION OF THE SURVEYORS

This week we are holding the Association´s 19th Survey Congress with the theme, Man and His Land - the Surveyor´s challenge.

This means that we are concerned with Land and what it means to us.

Land and its availability are critical for any development to take place.

One major issue Papua New Guinea is considering under its 5 year development plan is the creation of productive work opportunities; I would interpret this to mean, what a piece of land can offer in terms of economic development.

The general emphasis on economic development is to achieve growth in economic production and extend benefits widely to all citizens of the country, and prevent inequalities in the distribution of incomes and provide economic production opportunities to all.

Some of the issues which must be looked at more closely are:

- Customary Land Tenure
- What affects development of Alienated Land
- Review of Land Legislation
- The administrative procedure to be adopted.

What is Papua New Guinea´s concern in terms of Land Development should also be our concern, and we must provide the necessary technical support, as we are already doing.

While we continue to persue our objectives, we must also extend our interests on matters concerning the people we aim to serve. This means that we must share the same responsibility with those having concern for Papua New Guinea land development problems.

In the past, the Association has been more concerned with protection of its members´ interests.

Let´s come out of our particular world and take the liberty to talk with other people about their land problems.

Let us study the interest of the people we live with and share their problem and if necessary, we offer our advice.

We have had 18 survey congresses already where we have generated discussion over various experiences we have had.

Some of the major issues most relevant to us include promotion of the professional and the concern for graduates not being able to register quickly.

Our Government doesn't know that we are contributing our views to the education system in our particular field.

We are doing this at will as we feel that surveyors must gain a high quality of academic knowledge.

A year or two ago we gave support to the proposed amendment to the Survey Act to allow for Certified Measurers. This is the forethought, initiated by Surveyors, following the understanding that sooner or later we will be required to register customary land.

As many other people have said, the surveyor must continue to observe what is happening around him, study the interest of other people and offer his expertise where necessary.

At this point in time, the Department of Lands and Surveys, National Planning Office, Finance and the Department of Primary Industry are looking at Land Policy generally, and how it affects development.

The issues mentioned earlier are being discussed. These of course are of interest to Surveyors. The persons involved are Surveyors, Valuers and Economists. But an Economist does not know much about land; we do and somehow we have to have our say, particularly as an association.

Andrew Lakau has put his foot and mind in the right direction and we will also have to do the same. We must praise him for a very thought-provoking paper and let's not make this day, the burial day of his long months of work.

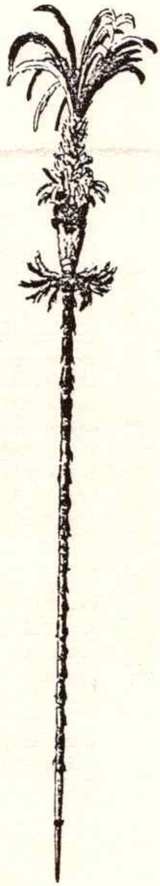
In summary, I have tried to emphasise that we take the liberty to expand our ideas. We must take interest in making our view clear to those having concern for land and its development policy. It is hoped that at the end of this meeting we have developed something out of the week's deliberations to the Government and those directly affected.

P. Salaiau
PRESIDENT FOR 1983 - 1984

No.

THE ASSOCIATION OF SURVEYORS

OF PAPUA NEW GUINEA



This is to Certify that

was elected a

of

The Association of Surveyors
of Papua New Guinea
on the

19 ... .

Witness our hand and the
Seal of the Association, this

in the year of our Lord 19 .. ..

PRESIDENT

HON. SECRETARY

COUNCILLOR

The Association of Surveyors of Papua and New Guinea

AUBARANA

The staff which appears on the right hand side of the certificate is an Aubarana or Tolai clan leader's staff. It was chosen because of its symbolic connection with Surveying.

Each clan possesses an Aubarana which is passed on from one clan leader to the next. Apart from being a symbol of leadership, the Aubarana is used in settling disputes over ownership of land. In the event of an intra-clan land dispute, the clan leader almost invariably acts as arbitrator and, having made a decision, makes it known by thrusting the Aubarana into the ground at each of the corners which define the disputed boundaries. Each corner is then marked by a stake which is subsequently respected as if the corner were still marked by the Aubarana itself. There is no other native custom which so closely parallels the practices of the modern surveyor.

The staff used for the certificate was the one presented to Mr. J.K. McCarthy, the Director of District Administration, by Mr. Vin Tobaining at Kokopo on the 25th July, 1963, on behalf of all the Tolai people. Mr. McCarthy is the only European ever to have been honoured in this way. It was, in fact, his suggestion which led to our use of the Aubarana.

The Aubarana itself is a carved wooden pole about 5 feet long wrapped in fine bark fibre bound with bark string. The upper portion is embellished with cockatoo feathers glued and bound in place.

Ed. This particular item found in 1973-74 addition to Congress Paper. Further information is due to wonderful memories of J.M. and C.M. Page 140.

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1985 SURVEY CONGRESS

RABAUL JULY 1 - JULY 5

SEEKING STABILITY IN A VOLATILE ENVIRONMENT

PROVISIONAL PROGRAMME

MONDAY JULY 1:

1.00 p.m.	Registration of delegates.
7.00 p.m.	Official Opening followed by President's Cocktail Party.

TUESDAY JULY 2:

9.00 a.m.	Technical sessions at Kulau Lodge all day.
10.00 a.m.	Morning Tea for Ladies.
Evening	Free

WEDNESDAY JULY 3:

5.00 a.m.	Annual General Meeting A.S.P.N.G.
	Tours for interested delegates and their wives.
1.30 - 3.30 p.m.	Equipment displays and workshop - Sokkisha and Wild
7.00 p.m.	Annual Dinner

THURSDAY JULY 4:

9.00	Technical Sessions at Kulau Lodge all day.
Evening	Free

FRIDAY JULY 5:

9.00 a.m.	Technical sessions at Kulau Lodge
1.00 p.m.	Forum and closing ceremony at Kulau Lodge
7.00 p.m.	Farewell Barbecue.

1985 SURVEY CONGRESS

RABAUL JULY 1 - JULY 5

SEEKING STABILITY IN A VOLATILE ENVIRONMENT

NOTICE TO OVERSEAS MEMBERS AND PROSPECTIVE DELEGATES

This is an invitation for you to attend the twentieth Survey Congress of the Association of Surveyors which will be held in Rabaul from July 1 to 5 1985.

Planning is well advanced and we already have more confirmed papers than we can use. A copy of the provisional programme is attached for your information.

We are attempting to encourage ex-P.N.G. Surveyors to attend this Congress. The last Rabaul Congress was held in 1971 at the Kulau Lodge. We are using the same venue for this Congress. Rabaul is still the best town in P.N.G. having changed little over the last 15 years.

Air Niugini are offering group discounts for travel and accommodation. For South East Queensland Surveyors, former Air Niugini Chief Pilot John Kessey of Everton Travel Agency is organising group travel.

Rabaul accommodation rates are quite reasonable compared to other P.N.G. centres.

Approximate rates are as follows:-

KULAU LODGE	Single	K24	Twin	K31
TRAVEL LODGE	Single	K49	Twin	K49
KAIVUNA	Single	K40	Twin	K50
HAMAMAS (Former Ascot)	Single	K35	Twin	K50
NEW GUINEA CLUB	Single	K18	Twin	K25

More detailed information can be obtained from Tom Jackson, Sydney 2642076 or Clive Bassett, Brisbane 3554899.

Clive Bassett
for Congress Committee.

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27 February 1984

The President,
Association of Surveyors of Papua New Guinea,
P.O. Box 1422,
BOROKO.

Dear Sir,

I was requested recently to prepare some notes for the 50th Anniversary of the finding of the Chimbu-Waghi Valley. Please find attached a copy of the Australian Natural History Vol. 21 No. 3 which includes my notes.

Amongst those concerned were myself, a surveyor of New Guinea, and one of my assistants, Ken Spinks. You may care to place this in your records as evidence that the surveyors did play a primary part in finding and opening up these areas.

Last Sunday I had my 80th birthday and am still running my consultancy practice at the above address.

I hope in the coming year to write an article in which a number of surveyors were concerned, including S.M. McLean, H.G. Foxall and myself between the years 1925-1929, in the areas east and west of the lower and middle Fly River.

Wishing your association all the best for the future.

Yours faithfully,

Charles Marshall

Charles Marshall

Ed. An abstract from the Australian Natural History Vol. 21 No. 3 of the Chimbu Expedition on Page 110.

J. C. Macartney
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17th August, 1984.

The Hon. Secretary,
The Association of Surveyors of
Papau New Guinea,
P.O. Box 201,
MOUNT HAGEN. WHP.,
PAPUA NEW GUINEA.

Dear Doug,

I refer to your letter dated 22nd July, 1984 in which you requested the background to the logo of A.S.P.N.G.. Sorry to have been so long in replying to your letter but I have been trying to track down some of the other members whose memories may have withstood the endurance of time better than mine. Finally Graham Matheson and myself discussed the matter over lunch and the following is the best we could recall.

Sometime in the mid 1960s a competition was held for the design of a logo for the Association. The winning design was submitted by Miss. Denise Dent who was at that time secretary to Surveyor-General Graham Matheson. Miss Dent's design was fair drawn by Bernie Duncan, a senior draughtsman of the Survey Division of the Department of Lands, Surveys and Mines. The Logo was as portrayed on The Journal Vol.1 No.1 i.e. no stippling or horizontal arrow. Filling of the land masses by stippling or blocking was added for cosmetic effect to make them stand out. The addition of the horizontal arrow to the logo and the certificates was also added for cosmetic effects, we think by the printer, to give a balanced effect to those documents and was not intended to be formally part of the logo. Notions that it portrays the shape and speed of Macartney returning from the Border Survey are not true!! Nor was it intended to signify any threat to PNG from the west!

You are correct in assuming that the staff on the certificates is of Tolai origin. We think it is called an Aborana and was used by the Tolai headman when he indicated the boundaries of land to be used by the various clan members. Alan Bale should be able to give you the correct spelling and more details of its usage. Graham thinks that it was he that approached Mr. Keith McCarthy who was the Director of the then Department of Native Affairs for a suggestion for a suitable emblem for the certificates. Mr. McCarthy suggested the Aborana and as he either had one or had donated one to the museum we were able to get the configuration and the colours. A brief description of the staff was printed and used to be given with each certificate on presentation. I would suggest that someone check with the musuem to see if there is an Aborana there. I also suggest that you may find all the information on the logo and the staff in the Association minutes if they are all still to be found.

Another item of interest re the logo was that it was used on a PNG stamp about July/august 1967. The Post Office issued four stamps called 'Higher Education'

(over) (

and the 3 cent stamp featured surveying and used the Association logo. There was an error in the reproduction and the logo only had eight divisions to the quadrant causing much confusion in the surveying world.

I hope the above information is of some help in solving your queries and I will attempt to get more definite history on the logo and staff but I am sure the minutes are your source.

Kind regards,

John.

J.C. MACARTNEY.

[illegible]

C.W. MARSHALL AND ASSOCIATES

MINING & CIVIL ENGINEERS, GEOLOGISTS & SURVEYORS

PRINCIPAL

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27 February 1984

The President,
Association of Surveyors of Papua New Guinea,
P.O. Box 1422,
BOROKO.

Dear Sir,

I was requested recently to prepare some notes for the 50th Anniversary of the finding of the Chimbu-Waghi Valley. Please find attached a copy of the Australian Natural History Vol. 21 No. 3 which includes my notes. Gold fields

Amongst those concerned were myself, a surveyor of New Guinea, and one of my assistants, Ken Spinks. You may care to place this in your records as evidence that the surveyors did play a primary part in finding and opening up these areas.

Last Sunday I had my 80th birthday and am still running my consultancy practice at the above address.

I hope in the coming year to write an article in which a number of surveyors were concerned, including S.M. McLean, H.G. Foxall and myself between the years 1925-1929, in the areas east and west of the lower and middle Fly River.

Wishing your association all the best for the future.

Yours faithfully,

Charles Marshall

Charles Marshall

Ed. An abstract from the Australian Natural History Vol. 21 No. 3 of the Chimbu Expedition on Page 110.

J. C. Macartney
B. Surv., M.I.S. (AUST)., F.A.S. (PNG).
LICENSED SURVEYOR

**P.O. BOX 1,
MOUNT NEBO, QLD. 4520.**
**"LISSANOURE"
BENSON ROAD,
MOUNT NEBO, QLD. 4520.**
Telephone: (07) 289 8157

17th August, 1984.

The Hon. Secretary,
The Association of Surveyors of
Papau New Guinea,
P.O. Box 201,
MOUNT HAGEN. WHP.,
PAPUA NEW GUINEA.

Dear Doug,

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