DEPARTMENT OF MINERALS AND ENERGY
Secretary: Sir Lenox Hewitt O.B.E.

DIVISION OF NATIONAL MAPPING
Director: B.P. Lambert O.B.E.

TECHNICAL REPORT 18

CRUSTAL MOVEMENT SURVEY
MARKHAM VALLEY - PAPUA NEW GUINEA
1973

by

D.P. Cook and B.A. Murphy

CANBERRA, AUSTRALIA.
1974

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PAPUA NEW GUINEA 1973

CONTENTS

<u>Annexes</u> Continued

CRUSTAL MOVEMENT SURVEY - MARKHAM VALLEY

PAPUA NEW GUINEA 1973

1. INTRODUCTION

With the advent of the laser Geodimeter bringing accuracies of about one part per million into the field of everyday geodetic survey, geologists in the Bureau of Mineral Resources investigated three areas in Papua New Guinea where there was great interest in measuring the rate of movements of the earth's crust across fault zones: the lower Markham valley near Lae; the west Markham valley; and the St Georges Channel, between New Britain and New Ireland. The latter two were chosen for survey.

This report described the methods and special equipment and sets out the results of the initial survey of the west Markham scheme in August and September 1973. It is essentially a survey report and, apart from the geological notes below, contains little information of direct interest to a geologist. It is intended to publish a report on each of the successive re-surveys. The first re-survey is scheduled for 1975.

2. GEOLOGICAL BACKGROUND by Mr D. Dow, Bureau of Mineral Resources

Recent geophysical and geological research has shown that the earth's crust is composed of large rigid plates, many thousands of square kilometres in area, which are moving with relation to each other. Most of these plate boundaries are beneath the oceans and it is in only a very few places in the world that the boundaries cross land, thus enabling direct measurement of the movement between plates.

Papua New Guinea is one country where a major plate boundary is exposed on land. The remarkable Markham-Ramu Valley, a straight alluvium-floored valley which extends over 300 km from the Huon Gulf to the Sepik Plains, is underlain by a major fault zone. This fault zone separates the South Bismarck oceanic plate from the Australian continental plate which underlies the highlands of PNG.

Geophysical and geological evidence indicates that the fault zone is still active, and that the oceanic (northern) plate is moving south-eastwards with relation to the rest of the PNG mainland. It is thought likely that the oceanic plate is also overriding the continental plate, but there is little direct evidence of this. The rate of movement is unknown, but if it conforms with movement postulated for the Pacific Ocean as a whole, a horizontal displacement of about 2 cm per year is likely.

It is also thought that the Huon Peninsula may have risen by as much as 4000 metres in the last million years. This corresponds to a vertical displacement of 4 mm a year and a large proportion of this movement is probably still taking place across the Markham-Ramu Fault Zone.

If such displacements can be directly measured, a major contribution will have been made to the understanding of the processes forming the earth as we know it today.

3. GENERAL INFORMATION

3.1 Area Description

There is a stereo pair of air photographs on the next page.

The survey area straddles the valley of the upper Markham River where it has split into tributaries, of which the largest is the Umi.

The valley floor is flat although it is criss-crossed by many old shallow watercourses. It consists of deep alluvial gravel, covered with shallow soil, usually thickly grassed with kunai up to two metres high, and with a high water table only a metre or two below the surface in many parts. Underground caverns have been found in excavations for bridge sites and the ground trembles markedly if heavy trucks pass by thirty metres away.

The foothills lining the valley, where mountains rise to some 4000 metres to the north and south, are bare of timber and have many outcrops of solid rock.

Constant burning of the kunai for hunting, and also it seems for weekend recreation, caused some problems in visibility. On the other hand, survey operations in grass growing as high as a man stands are not possible, and the cooperation of the landowners was sought early to burn the grass around the stations.

3.2 Local Departments

Assistance by government departments was excellent and much appreciated. Five motor vehicles were hired from two departments and two vacant buildings at Mutsing Agricultural Station were made available. The assistance received at Mutsing included facilities for battery charging, handling of radio traffic, arrangement of fuel supplies and workshop facilities.

3.3 Selection of Survey Stations

The sites were chosen by BMR geologist Mr P. Hohnen in 1972. All stations were intervisible, with lines of sight well above the intervening plain. At each station there was vehicle access to within a few minutes walk and people in the nearby villages were happy to accept employment as light-keepers, staff men for levelling, and as general assistants.

3.4 Marking

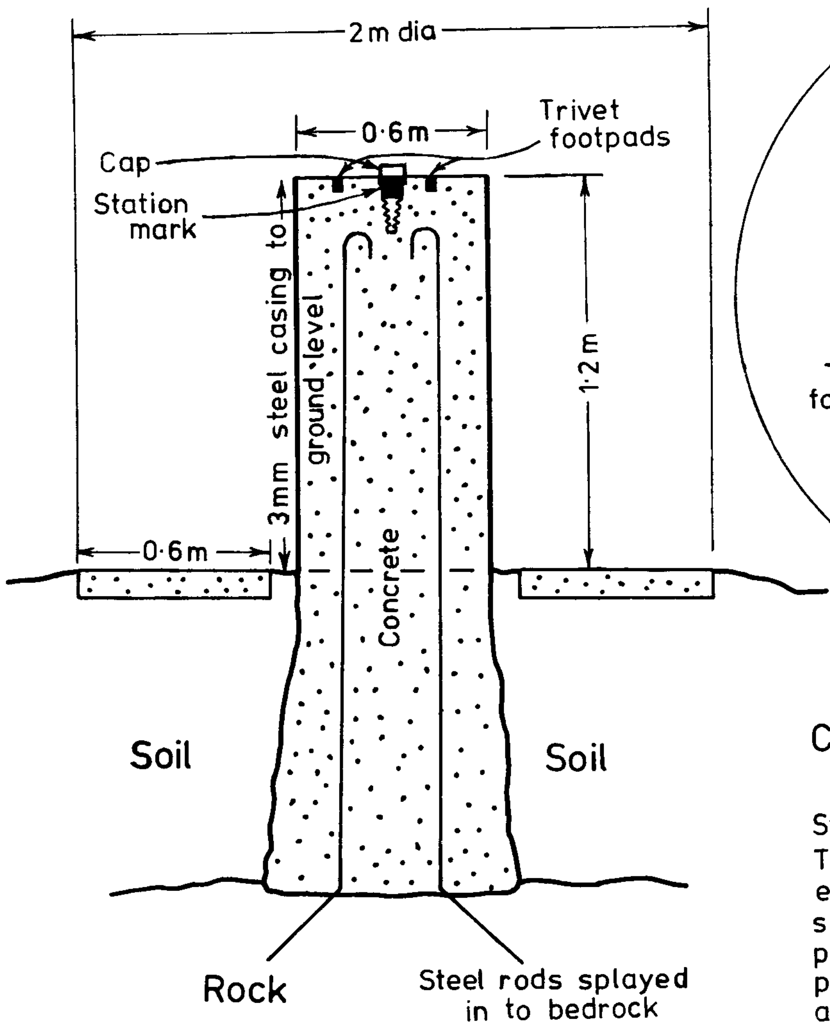
A pillar and three recovery marks were built at each of the six stations to the designs on the following page. They were all fastened to bedrock, which was close to the surface. The construction was carried out by the Commonwealth Department of Works in late 1972.

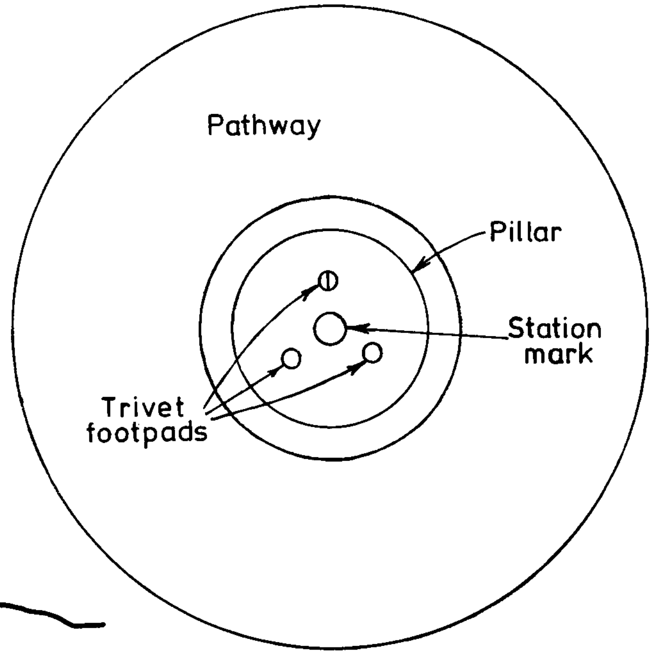
Bench marks were placed by the survey team, as described in chapter 10.

3.5 Land Tenure

During a visit by a surveyor in August 1972 to check the sites from the survey point of view, the Assistant District Commissioner in the Kaiapit Sub-District negotiated an annual rental to be paid to the landowners at each of the stations for use of the small areas involved.

The people in the villages were actively involved in the construction of marks and in the initial survey. It was explained to them why the marks were there and they were quite clear that there was no threat to their title to or use of the land, a matter of very serious concern to Papua New Guinea peoples.



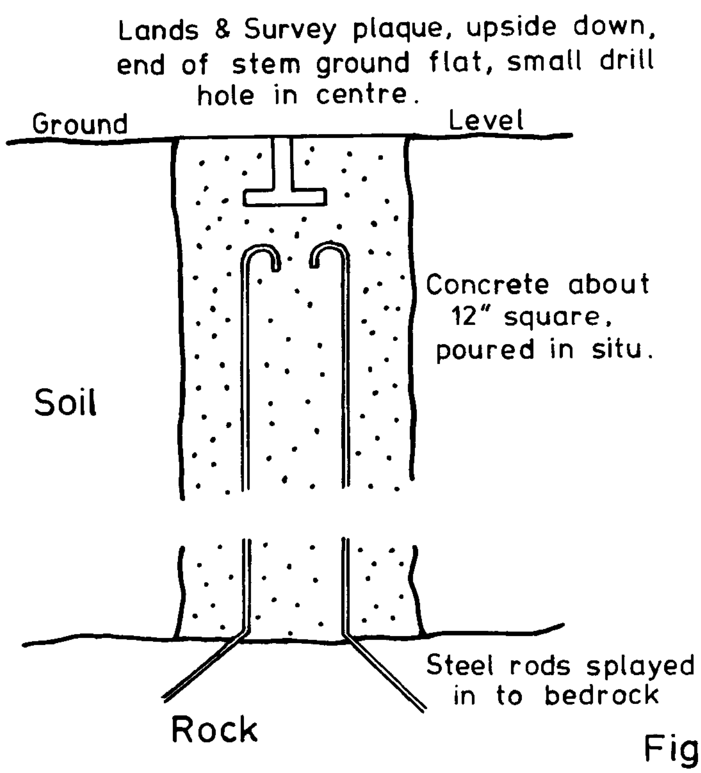


Crustal Movement Survey Station Pillar

Station Mark :- Kern centering plug.
Trivet Footpads :- Brass plugs set equilaterally (120° apart) around the station mark; 0·1m from centre of each plug to centre of station mark. One plug to have a "V" notch 2 mm deep cut across the head. Notch is to be set radial to station mark.

Fig. 3

Recovery Marks



General Layout

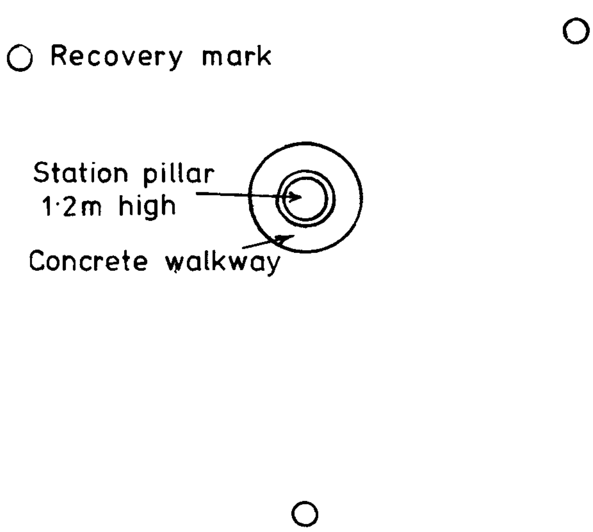


Fig 4

4. DISTANCE MEASUREMENT

4.1 Geodimeters

All distance measurements were made between pillar centres using an AGA Geodimeter Model 8, Serial 80053. A second Geodimeter, Serial 80028, was used initially but was withdrawn from further measurement when large irregular fluctuations were observed when monitoring the U3 reference oscillator with a frequency counter. This crystal was subsequently replaced by AGA Sydney when the Geodimeter was returned to Australia.

4.2 Equipment

Geodimeter Station:

1. AGA Geodimeter Model 8, fitted with coaxial outlet for monitoring of modulation frequencies
2. Geodimeter alignment head
3. Waterproofed canvas observing screen with aluminium supporting frame
4. Kern Type 426 trivet
5. Takeda Riken Model TR5578D universal frequency counter with coaxial connecting lead
6. Valradio Model B12/150T transverter for Takeda Riken
7. Mechanism Type M1991A precision aneroid barometer
8. Bendix Model 566-3 psychrometer
9. NEC Type ATR-400P1-1A/1B UHF/FM transceiver
10. Three 12 V accumulators, plus hydrometer
11. 30 metre tape
12. Special spanner and Allen keys required for removal of protecting cap from Kern 17153A pillar plug
13. Field books and pens
14. Booking light

Reflector Station:

1. Standard AGA seven prism housing and prisms
2. AGA adapter Part 571.900.008 - from $\frac{5}{8}$" thread to trivet
3. Mechanism M1991A precision aneroid barometer
4. Bendix 566-3 psychrometer
5. NEC Type ATR-400P1-1A/1B UHF/FM transceiver
6. 30 metre tape
7. Special spanner and Allen keys for removal of protecting cap from the Kern 17153A pillar plug
8. Kern 426 trivet
9. Field book and pens
10. Booking light

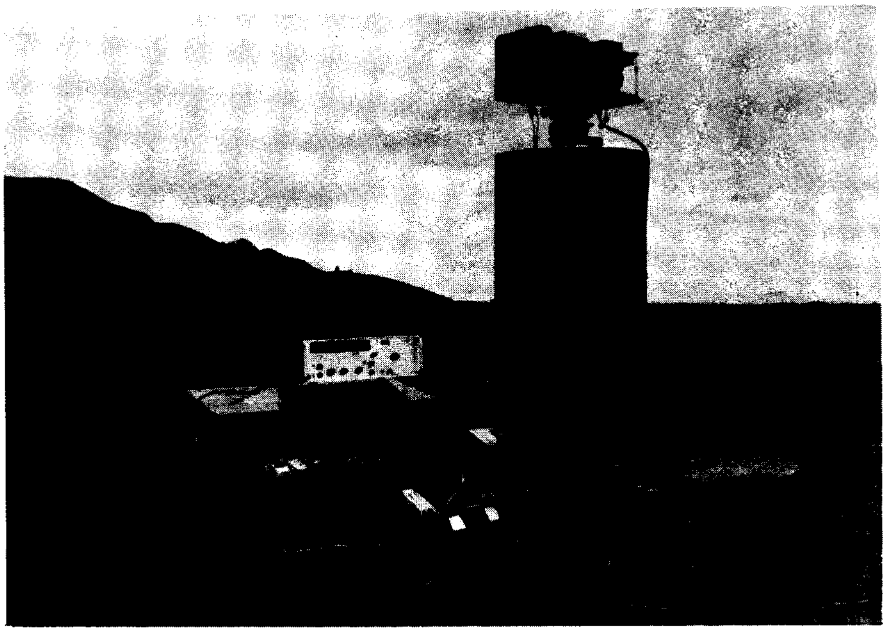
4.3 EDM Measurement Procedure - General

A total of eighteen lines, fifteen internal and three external, were measured, as shown on the map at 3.1. All internal measurements were made in two sets on each of two days, a set consisting of two consecutive measurements. Sets were measured two hours apart, with the first set about one hour before sunset.

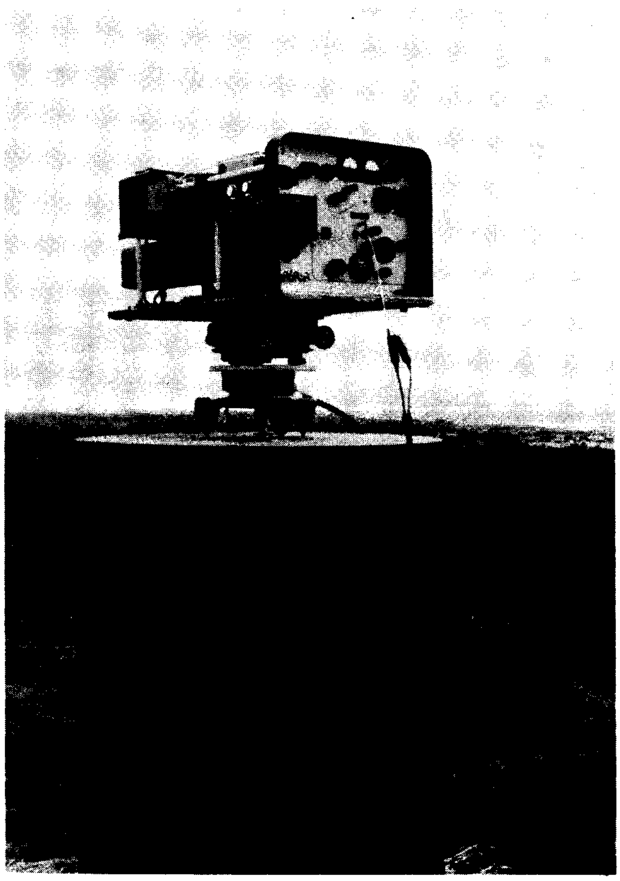
Six of the internal lines were measured on a third day. Three of these lines were re-measured in an attempt to detect any possible movement which may have occurred as a result of severe earth tremors experienced at 1830 hours on 13 August (see Chapter 13). At this stage only five of the internal lines had been measured. The other three lines were re-measured because of either technical difficulties with the Geodimeter or abnormally large ranges between L_1, L_{2K} and L_{3K}.

The three external lines were measured to connect the crustal movement network to the local first order traverse. These lines were measured to the same specification but were not measured over sunset.

The upper temperature limitations given by the makers for operation of the Geodimeter and frequency counter were respectively +35°C and +40°C. During the measuring programme air temperature inside the observing screen was monitored to check that the limitations were not exceeded. The highest temperature recorded was +30°C.

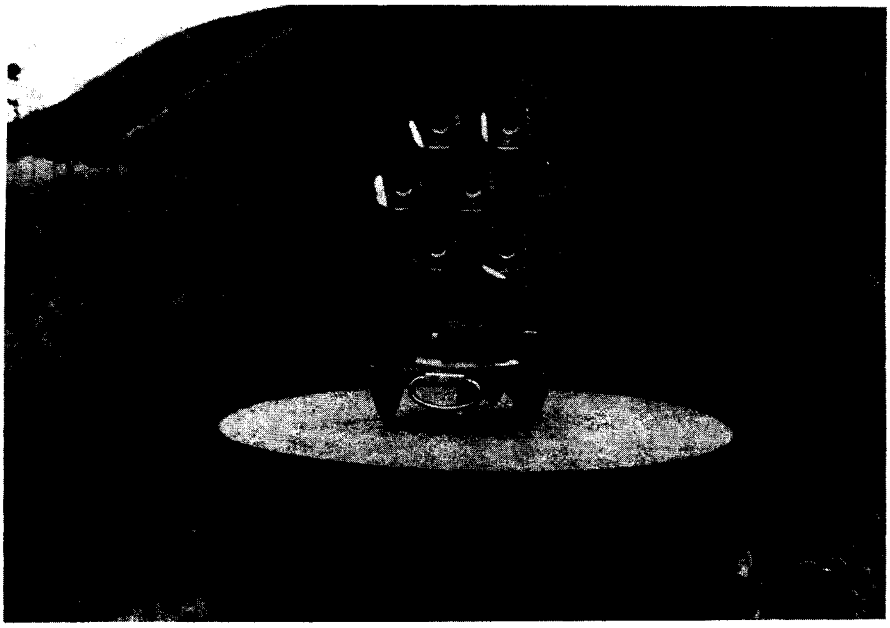


Geodimeter and Ancillary Equipment

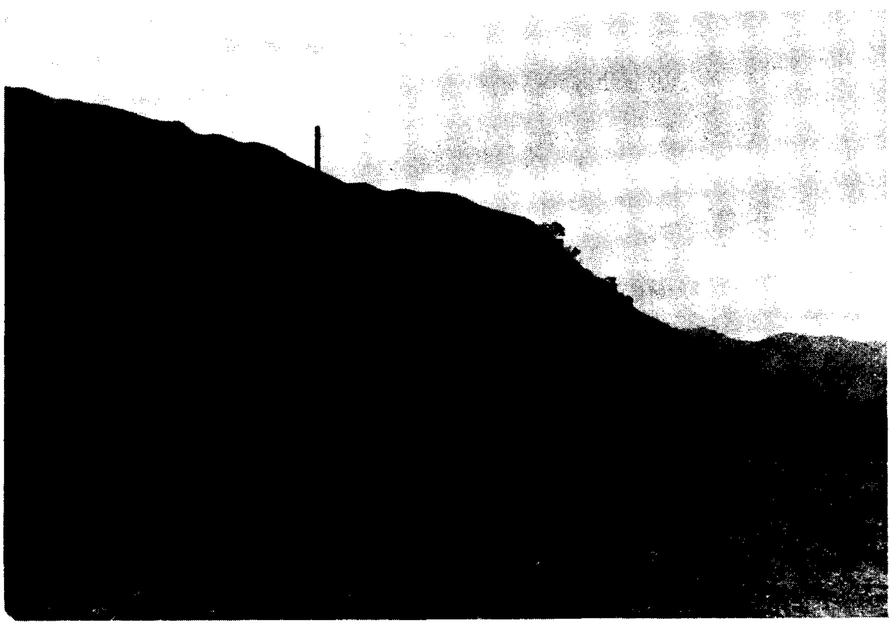


Crystal Frequency Monitoring Lead

Figure 6



AGA 7 Prism Housing on Kern Trivet



NM/J/32 Zaklak

4.4 Wind

Because of the strong south-easterly winds prevailing it was always necessary to erect an observing screen at the Geodimeter station before making any measurements. These stout canvas screens with aluminium supporting frames comfortably housed the observer and recorder and all the equipment, and protected the Geodimeter from wind vibration.

Observing screens were not necessary at the reflector stations as the reflectors and targets proved to be stable in strong wind.

4.5 Meteorological Observations and Topographic Influence

Meteorological conditions were recorded simultaneously at both Geodimeter and reflector stations before and after the measurements in each set, i.e., three sets of observations were recorded for each set of measurements. The UHF transceivers mentioned above were used for coordination of measurements and for relay of meteorological and other information to the Geodimeter station.

Psychrometer readings were observed after carefully moistening the wet bulb wick with distilled water, switching on the fan motor and then watching the wet bulb until the reading stabilized. Both bulbs were then read.

All psychrometer readings were made about two metres above the ground with the instrument completely shaded from the late afternoon sun, with both bulbs fully exposed to the wind.

The psychrometer and its transit case were kept out of direct sunlight when not in use.

Meteorological conditions remained extremely stable throughout the whole measuring programme and no doubt this greatly contributed to the consistently good results obtained. The atmosphere was always very well mixed as a result of the strong prevailing south easterly wind.

A record of the dry bulb temperatures, showing the day to day uniformity, is included in the schedule of distance comparisons at Annex B.

The topography in the immediate vicinity of each pillar station generally consisted of black soil holding a good cover of low kunai grass re-growth the high grass having been burnt off before the survey. All stations were devoid of rocky outcrops and both of these factors combined with the consistently strong winds would have significantly decreased ground radiation anomalies in psychrometer bulb readings.

All stations were between 40 and 85 metres above the valley floor. At each station the terrain fell away rapidly in the direction of all other stations and there were no problems with low ground clearances along any of the lines measured.

4.6 EDM Measuring Procedure - Detail

The method used for measurement of all of the fifteen internal lines of the network is now described in detail. All events are referred to a time M, the start of a set.

(1) M-45 minutes to M-30 minutes

(i) Lock Kern trivet into centre mark on top of pillar, checking adjustment of circular bubble attached to trivet before centering and clamping - see Note 1.

(ii) Carefully attach Geodimeter alignment head to trivet - see Note 2.

(iii) Carefully attach Geodimeter - with cover removed - to alignment head - see Note 3.

(iv) Attach power cable to Geodimeter and then to the 12-volt accumulator.

(v) Set up frequency counter and transverter. Connect transverter to frequency counter and to 12-volt accumulators - see Note 4. Connect frequency counter to Geodimeter.

(vi) Commence pre-operating checks on Geodimeter.

(2) M-30 minutes

(i) Switch Geodimeter to "ON"

(ii) Switch transverter to "ON" - see Note 5.

(3) M-30 to M-15 minutes

(i) Carry out self-checking operation on frequency counter.

(ii) Continue with pre-operating checks on Geodimeter.

(4) M-15 minutes Switch laser to "ON"

(5) M-15 minutes Continue with pre-operating checks on Geodimeter.

to M-8 minutes Align laser on reflectors.

(6) <u>M-8 minutes to M-3 minutes</u>

(i) Check modulation frequencies U1, U2 and U3 with frequency counter. If not within ± 10Hz of nominal value, adjust.

(ii) Check the low frequencies on U1, U2 and U3 by connecting the frequency counter to the detector unit on the Geodimeter. The low frequencies (difference transmitter-receiver frequencies) should be 1.5 kHz. If not within ± 3Hz of this value, adjust.

(iii) Repeat steps (i) and (ii) above until modulation and low frequencies U1, U2 and U3 are within the limits specified.

(7) <u>M-3 minutes</u>. Call up reflector station on transceiver and request measurement and recording of meteorological data. Measure and record meteorological data at Geodimeter station.

(8) <u>M to M + 8 Minutes</u>

(i) Carry out normal Geodimeter measuring routine with the following additional procedure:-

Read and record frequency counter display at the following instants during each measurement:

(a) immediately after adjustment of tuning control for maximum control meter deflection.

and

(b) immediately before changing frequency.

(ii) Upon completion of the first measurement call up the reflector station and request measurement and recording of meteorological data. Measure and record meteorological data at Geodimeter station - see Note 6.

(9) M + 8 to

M + 16 minutes

(i) Complete second measurement of the set in the same manner, reading and recording meteorological data at both stations upon completion of the set.

(ii) Measure and record height of Geodimeter and optical centre of standard AGA seven prism housing above respective pillar marks. These heights were found to vary not more than a few millimetres from 0.310 metres and 0.275 metres respectively and these values were adopted as standard for slope and sea level reduction computations.

4.7 Notes on Measuring Procedures

(1) The circular bubble on the trivet is checked for adjustment by a separate circular bubble which is included in the trivet transit case. This bubble can be mounted in the hollow vertical axis of the trivet assembly where it can be rotated through 360° whereas the trivet bubble is fixed and cannot be rotated.

(2) Care is required when mounting the alignment head and Geodimeter on the trivet as the trivet bubble is partly obscured by the base plate of the alignment head once this has been positioned, thereby making any subsequent accurate checking of the bubble impossible.

(3) The cover of the Geodimeter was removed to keep the internal operating temperature of the instrument below 350° Celsius. Once the temperature reached this level the internal cooling fan was thermostatically actuated. This created operational problems early in the measuring programme due to excessive vibration caused by a faulty fan motor. Removal of the cover allowed the Geodimeter to operate below 35° Celsius, without the fan running, and also facilitated checking of the low frequencies by allowing ready access to the detector unit.

(4) The Valradio transverter should not be operated within one metre of any sensitive electronic devices as an AC magnetic field exists around the unit while it is in operation. Input and output wiring should also be placed well clear of any other wiring and equipment.

Two 12-volt accumulators, connected in parallel, were always used to power the transverter and frequency counter.

(5) Switching on the Valradio transverter simultaneously switches on the crystal ovens of the Takeda Riken frequency counter. Tests conducted during calibration of the frequency counters disclosed that their crystals stabilised to an accuracy of 1 part in 10^{-7} within 12 minutes.

(6) On all the lines measured one set of measurements included readings taken on frequency U4 (for both measurements in the set). Measurements on this frequency determined the number of 2000 metre intervals in the line.

4.8 Reduction of EDM Observations

All Geodimeter measurements, except those between AA047 and AA048, were initially reduced on the Hewlett Packard 9100B using program Geodimet 4. This program calculates the slope distance corrected for atmospherics and Geodimeter and reflector constants. Calibration corrections to observed barometer and dry and wet bulb thermometer readings were checked before computation of each measurement. A program listing is at Annex A.

Beam curvature corrections were ignored for field comparisons. Where the coefficient of refraction, or relative ray curvature, k,

$$= \frac{\text{radius of spheroid}}{\text{radius of lightpath}}$$

an average value of k, say 0.15, gave a correction of only 1 mm on the longest internal line of the network, 16.5 km.

For the determination of k, it is standard Division of National Mapping procedure to observe simultaneous reciprocal vertical angles immediately after any Geodimeter measurement of a line longer than 30 km. The vertical angles are corrected for heights of targets and instruments and k is calculated from the difference in the reciprocal zenith distances.

The measured distance is then corrected for curvature of the lightpath and variation in the velocity of propagation along the line, due to the beam dipping into layers of atmosphere with a higher refractive index, from Professor Hopcke's[(1)] formulae:

$$K1 = k^2 \frac{D^3}{24\ R^2} \qquad \text{Hopcke's equation} \quad (7)$$

$$\text{and } K'' = -(k - k^2)\ \frac{D^3}{12R^2} \qquad \text{"} \quad \text{"} \quad (16)$$

(1) W. Hopcke: Curvature of Electromagnetic Waves and Its Effect on Measurement of Distance. Zeitschrift fur Vermessungsweson VI, No. 89 (1964), pp 183-200.

where:

K1 is the correction for curvature of lightpath

K" is the 'second velocity correction' for dip of the beam into denser layers of the atmosphere.

D is the measured distance

R is the radius of the spheroid

These corrections may be combined into

$$K1 + K'' = -(2k - k^2) \frac{D^3}{24R^2}$$

The correction chord-to-arc, Hopcke's K4, equal to

$$+ \frac{D^3}{24 R^2}$$

was applied separately. It attained a value of 5 mm on the 16.5 km line.

Some trouble was experienced with the HP 9100B on several occasions due to unstable output voltage from the 240-volt generating equipment installed at Mutsing. This caused the calculator to blow fuses and soon exhausted the small stock of spares. Attempts were made to operate the calculator from a 12-volt accumulator through a square wave inverter without much success, the cathode ray tube display becoming distorted when the power was switched on.

While awaiting the arrival of replacement fuses from Australia all reductions were performed on Facit hand calculators.

Slope and sea level corrections were calculated as in paragraph 4.9.

4.9 Preliminary Heights by Non-Reciprocal Vertical Angles

Slope and sea level corrections could not be applied to measured distances until the first order level traverse and height connections to the six pillar stations had been completed. To expedite field computation of the network, preliminary heights for each of the six stations were obtained by non-reciprocal vertical angle observations.

The heights of NM/J/33, 34 and 36 were obtained by observing vertical angles to the tops of the respective pillars from NM/J/35 between the observation of two sets of simultaneous reciprocal vertical angles between the latter station and AA048. Values for k were calculated from the simultaneous reciprocal observations, and then interpolated and substituted into the non-reciprocal vertical angle calculations. The preliminary height of NM/J/32 was similarly determined during simultaneous reciprocal vertical angle observations between the latter station and AA047.

4.10 Results

The agreement on each line was generally better than one part per million (ppm) between days except on the six short lines at the western end, of which the longest was 4.3 km and the shortest 1.1 km. The maximum disagreement was 2.3 ppm over 2.7 km, about 6 mm. The average between days on the short lines was 1.4 ppm.

A schedule of distance comparisons:

between single measurements
between sets
between days

is at Annex B. The dry bulb temperatures are included, to show their unusual uniformity.

All measurements were recomputed by the GEODIMET program on the CYBER 76 computer operated by the CSIRO Division of Computing Research on return to Canberra. A summary of the measurements on each line and the adopted length is at Annex C.

5. CALIBRATIONS AND ADJUSTMENTS

5.1 Geodimeter Constant

Instrumental constants, or index corrections, were determined by measuring three sections of the Telopea Park field standard base line in Canberra. This baseline, of total length about 300 metres, was established by the Survey Branch of the Department of Services and Property for field calibration of measuring bands.

Each Geodimeter was centered over Station 00 by means of a theodolite set at right angles to the base line. A set of measurements was then made to a small piece of reflecting tape centered, by an offset theodolite, over Stations 3, 6 and 10. Meteorological observations were made at the Geodimeter station before and after each set.

A diagrammatic comparison between the standard baseline (marked DSP) and Geodimeter 80053 measurements (marked DNM) is on the following page. A value of +0.214 m was adopted as the constant for this instrument.

Previous determinations of the constant for Geodimeter 80053, using similar methods are:

+0.208 m	October 1969
+0.205	October 1970
+0.207	November 1970
+0.215	May 1972

On arrival in the Markham Valley a check baseline about 200 metres long, in two parts, was established to check the constant before and after completion of the measuring programme. No significant variation from +0.214 m was found.

5.2 Crystal Frequency

As mentioned previously, the modulation frequencies U1, U2 and U3 were continuously monitored during the measuring, even though each crystal was reset, as was occasionally necessary, to within ± 10 Hz of its nominal value prior to commencement of measurement. The actual frequency was observed before and after each change of frequency.

The low frequencies were likewise checked prior to measurement and it was occasionally necessary to re-set them to within ± 3 Hz of their nominal values.

A frequency correction was calculated for every measurement using the formulae:

Crystal Correction (Hz) = F (nominal) - F (measured) crystal frequency where F1, F2 and F3 are the modulation frequencies

Frequency Correction in ppm of the distance

$$F_c\,ppm = \frac{\text{Correction F1 + Corrn F2 + Corrn F3}}{3 \times 30}\ (\text{Hz})$$

Corrected Distance = $D_p\ (1 + F_c)$
where D_p = preliminary distance

The correction was usually zero. The largest correction was 6 mm on the line from NM/J/31 to NM/J/35.

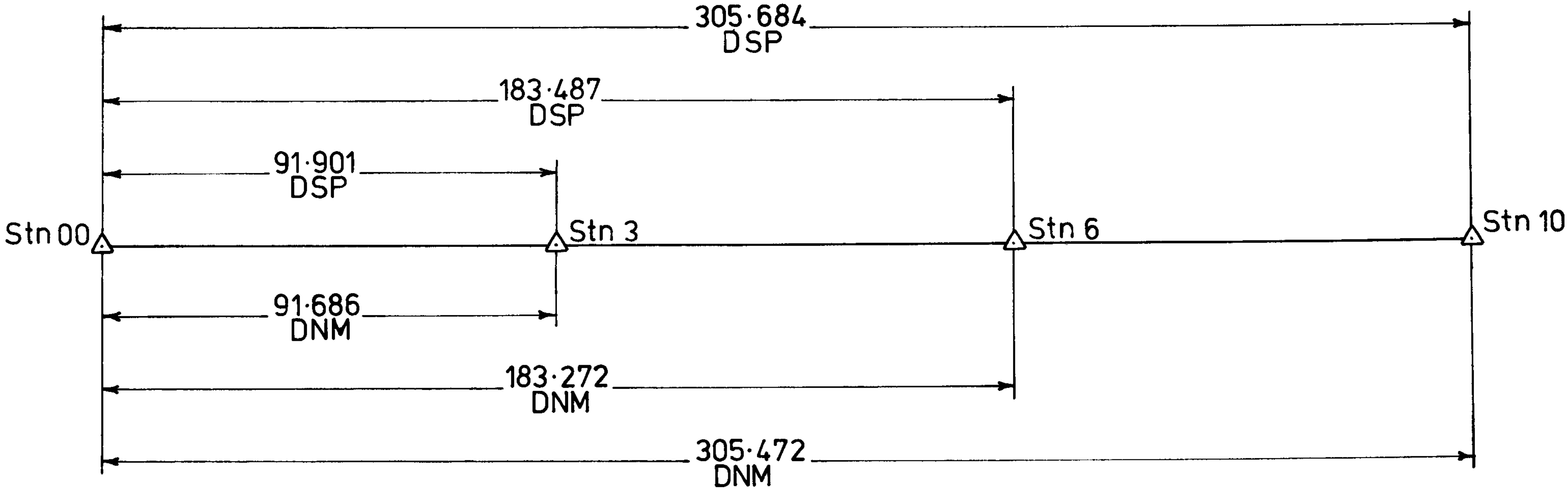
5.3 Laser Output Strength

A small simple radiometer designed and constructed by the Weapons Research Establishment, Department of Supply, during the development of the Airborne Laser Terrain Profiler was periodically used to check the output strength of the laser beam.

For Geodimeter 80053 the output of the laser consistently registered 1.7 milliwatts on the radiometer scale although earlier calibration tests had shown that this reading should be corrected to 1.5 milliwatts.

AGA advise that modulated laser output should register between 1.2 and 1.5 milliwatts.

GEODIMETER N° 80053 CONSTANT CALIBRATION AT TELOPEA PARK BASELINE ON 19 JULY 1973



91·901	183·487	305·684
−91·686	−183·272	−305·472
+ 0·215	+ 0·215	+ 0·212

Adopt + 0·214

GEODIMETER N° 80053

FIGURE 7

Each barometer was compared with a laboratory standard instrument at 800, 860, 920 and 1050 millibars. An average correction was adopted for each instrument, as the maximum range in corrections for any one instrument was only 0.34 mb (4 mb ≙ 1 ppm). The results are in the Geodetic Branch calibrations file.

5.8 Circular Bubbles

The circular bubbles on the Zeiss optical plummets, the omni-directional target lights and modified Zeiss target lights were checked for adjustment by simple rotation about their vertical axes before any observations were made. Some of the bubbles on the target lights needed considerable adjustment.

5.9 Omni-Directional Target Lights

The single vertical filament bulbs fitted to the omni-directional lights were centered over the vertical axis by rotating the light and checking for lateral movement with a theodolite. The bulb sockets are secured by two mounting screws, and can be moved laterally.

5.10 Zeiss Koni Levels

A field collimation check was carried out and entered in the field book every morning before levelling started.

5.11 Invar Levelling Staves

Because of the small range of heights involved in the differential levelling, 362 m to 417 m above sea level, the makers' calibrations of the staves were accepted as correct and no temperature corrections were applied.

5.12 Theodolites

Two Wild T3 double reading theodolites, numbers 29970 and 83450, were used for all of the primary horizontal angle observations. A Wild T2 was used for all the reference mark observations.

All three theodolites were cleaned, overhauled and adjusted by Wild (Australia) Pty Ltd prior to departure for New Guinea.

5.13 Steel Measuring Bands

The 100-metre steel measuring bands used for measuring to the reference marks at each station were standardized by the Survey Coordination Branch, Department of Lands, Sydney. The certificates are held in the Geodetic Branch calibrations file.

5.4 Reflector Constant

The reflector constant for AGA prisms mounted in a standard AGA housing is quoted in the Geodimeter Model 8 operating manual as -0.030 metres. This value was accepted.

All the AGA seven-prism housings used on this survey were checked by an instrument maker for any warping or eccentricity which may have accidentally occurred on previous surveys. Most of the housings received small adjustments in this respect.

5.5 Frequency Counters

A Takeda Riken Model TR5578D universal frequency counter was used to continuously monitor Geodimeter modulation frequencies during the measuring programme.

Two frequency counters were calibrated before leaving Canberra by the Positional Astronomy Section of the Division of National Mapping. The frequency ratio method of calibration was used to compare each counter with caesium beam frequency standard Cs 205, the frequency error of which was known to be less than one part in 10^{-11}.

One of the counters was shown to have an error of 4 parts in 10^{-8} and the other was less than 1 part in 10^{-8}.

5.6 Psychrometers

All the Celsius thermometers used in the Bendix 566-3 electrically aspirated psychrometers were calibrated by the Research School of Physical Sciences of the Australian National University in Canberra.

Each bulb was compared with a platinum resistance thermometer immersed in a constant temperature bath, over the range from +5 to +40°C. The platinum resistance thermometer had been calibrated by the National Standards Laboratory.

Correction graphs were drawn up for each thermometer, the maximum correction being 0.3°C. The graphs are in the calibrations file in Geodetic Branch, Division of National Mapping.

The muslin wicks attached to the wet bulbs were replaced twice during the survey and the dry cell batteries (three size D) powering the fan motors, were also replaced on several occasions before their voltage fell.

5.7 Barometers

The Mechanism precision aneroid barometers used to measure atmospheric pressure were calibrated by the Defence Standards Laboratory, Maribyrnong, Victoria.

6. HORIZONTAL ANGLES

6.1 Equipment

Wild T3 Theodolites. Power for lighting at four volts was tapped from vehicle batteries.

Observing Tents were four-sided canvas on tubular aluminium frame, with rock flap for weighting the tent down in strong winds, designed in National Mapping and sewn in Canberra.

Targets Commercial targets to suit the trivets already in hand were found to be expensive. A Canberra firm, C. and A. Zelman, made several items and modified others to rough drawings supplied by National Mapping at a considerable saving in cost.

Omni-Directional Target Lights were adapted from a design by the Department of Services and Property in Canberra by adding a circular bubble, a forced-centering device and improved electrical connections. Originally intended for simultaneous observation from a number of stations on short lines, it was found to be satisfactory up to 16 km. It was fitted with a single vertical filament 36 W, 12 V bulb which was laterally adjustable for exact centering.

Zeiss Sighting Target - modified by enlargement of the translucent aperture from 5 mm to 37 mm, fitting of 12 V 36 W globe and socket, aluminium reflector, spring terminals for external power supply and a sliding central rod for centering. The above two lights were both powered by 12 V vehicle batteries. They were fitted into Zeiss 60 tribrachs which had the double base plate removed to expose the feet of the levelling screws. Their inverted cone shape sat satisfactorily on the pillar.

Venner Clockwork Time Switches Lights not attended by party members were automatically switched off and left overnight in the care of the local light-keepers.

Rheostats - Berco 150 W, 7.5 ohm. These were mounted in small boxes; they satisfactorily ran the 36 W lights mentioned above, 12 V 50 W Lucas automotive lamps called 'Flamethrowers' and 10 V Lucas lights used on a subsequent project and, with a 4 V tapping from a vehicle battery, also served for instrument lighting.

6.2 Methods

Observations were made according to the standard instructions for first order angles:

One zero of observations should consist of a face left double pointing to each station in turn, proceeding clockwise, reversing on the last station; and a face right double pointing on each station in turn proceeding anti-clockwise. The directions for each pointing should then be deduced. The closing of the horizon is optional.

One set of horizontal observations should consist of 3 zeroes on 3 different circle settings so chosen as to divide the circle and the micrometer drum into equal parts.

Circle settings for the double reading WILD T3 theodolite should be:

1st set			3rd set			5th set		
*FL 00°	00'	05"	* 10°	00'	05"	* 20°	00'	05"
FR 180	00	05	190	00	05	200	00	05
*FR 240	00	25	*250	00	25	*260	00	25
FL 60	00	25	70	00	25	80	00	25
*FL 120	00	45	*130	00	45	*140	00	45
FR 300	00	45	310	00	45	320	00	45

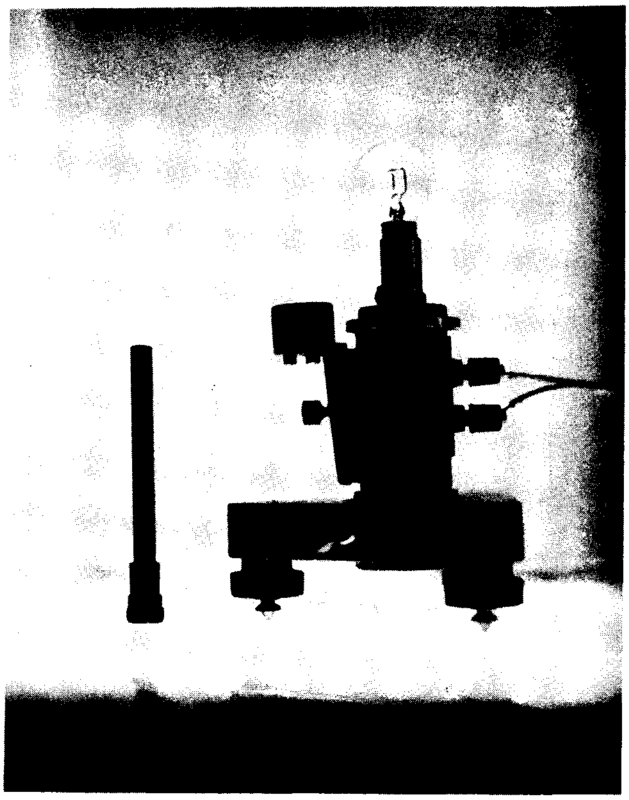
2nd set			4th set			6th set		
*FR 210	02	15	*220	02	15	*230	02	15
FL 30	02	15	40	02	15	50	02	15
*FL 90	02	35	*100	02	35	*110	02	35
FR 270	02	35	280	02	35	290	02	35
*FR 330	02	55	*340	02	55	*350	02	55
FL 150	02	55	160	02	55	170	02	55

* Circle and micrometer initial settings for each new zero.

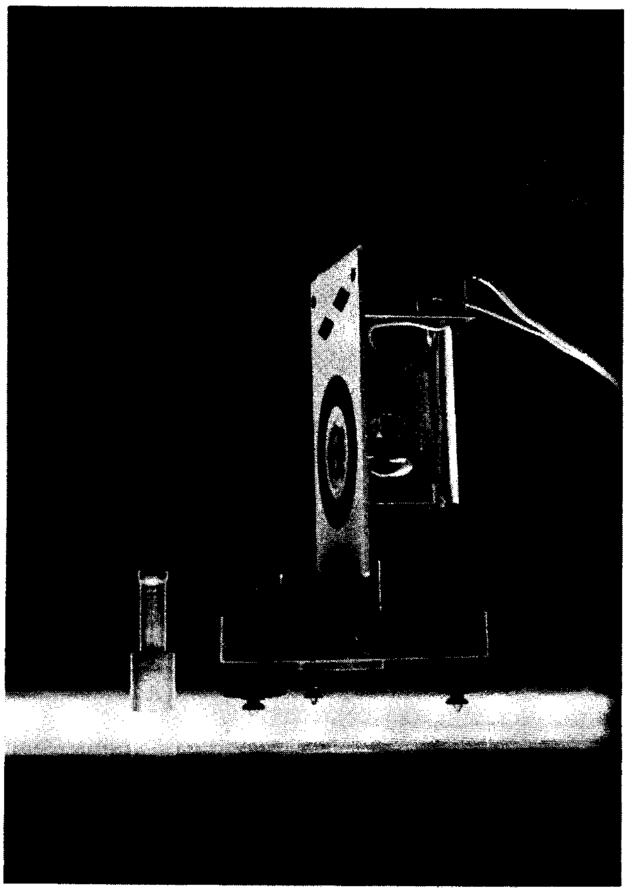
6.3 Number of Zeroes

In the Division of National Mapping a zero is taken to include all observations performed at one setting of the horizontal circle; three zeroes make up a set.

The number of sets to be observed was determined in the field. On the first two nights observations, the standard error of the running mean after each set, up to six sets, was calculated, using a program written for the HP9100B calculator, 'Running Mean and Standard Error'. The result was plotted and in each case the graph levelled off markedly after four sets at about 0.25" standard error for each direction. A listing of the program is at Annex D.



Omni-Directional Target Light with Centering Rod



Modified Zeiss Target Light with Centering Rod

7.2 Measuring Equipment

Wild T2 theodolite

Kern trivet

Adapter (trivet to theodolite)

100 metre steel band (Band No. "C")

2 Zeiss optical plummets

2 Zeiss tribrachs

2 Wild tripods (with telescopic legs)

Tension balance (graduated in Newtons)

Celsius thermometer

30 metre tape

Automatic level

Staff

Staff bubble

2 plumbobs

2 chaingrips

Compass

Camera

Number and letter punching sets

Fieldbook and pens.

7.3 Measuring Procedure

All recovery mark measurements were initially observed from the pillar mark. A second set of measurements was later observed from one of the recovery marks as a check for gross errors.

At the pillar station the horizontal directions of the three recovery marks were observed adopting one of the adjacent pillar stations as RO. A direction was also observed to the nearby bench mark located on the valley floor.

Where possible all directions and measurements were observed directly from the trunnion axis of the theodolite to the recovery mark. Where uneven terrain prevented direct observation, a Wild telescopic tripod was erected over the mark and a Zeiss tribrach attached to the tripod head. A Zeiss optical plummet was then used to centre the vertical axis of the tribrach over the recovery mark. All measurements were then made to the top of the conical centre stud located on the optical plummet. The elevation of the top of the centre stud above the recovery mark was determined by differential levelling - as was the height of the T2 trunnion axis above the top of the pillar mark.

The same 100 metre band (band C) was used at 70 Newtons tension for all recovery mark measurements and field temperatures during measurement were recorded in degrees Celsius. Sag and temperature corrections were applied.

There was evidently little point in continuing observations beyond four sets on one night; a second lot of four sets on another night was more likely to give a better result.

So, thereafter, four sets were observed on each of two nights, starting as soon as the targets were clearly visible, usually half an hour before sunset except for directions towards the setting sun. In contrast to central Australia, targets remained clear and steady well into the night, probably because the constant overcast prevented rapid radiation of heat from the ground. On one night when there was clear sky the quality of the targets did deteriorate more in the usual fashion.

6.4 Computations

Observations were checked to see that they conformed with the specifications:

- Residual from the mean of any direction within a set not to exceed 3 seconds

- Range between sets should seldom exceed 2 seconds

The observed directions were then meaned and entered directly into the horizontal adjustment of the network.

Some observations did not meet the specifications and additional sets were observed. However, unless a gross error was evident, no readings were rejected.

An analysis of angles is at Annex E.

7. RECOVERY MARKS

7.1 General

Three recovery marks, constructed as in the diagram at 3.4, were placed adjacent to each of the pillar stations. These marks were located so that any local movement relative to the pillar mark or adjacent recovery marks would be detectable but close enough to enable easy and accurate measurement. They were within 50 metres of the pillar and where possible at about the same elevation:

Strong winds caused problems on some of the longer lines and it was found better to measure early in the morning before the wind strengthened.

The recovery marks at each pillar station were differentially levelled with an automatic level to determine their elevation in relation to the top of the pillar mark.

The brass cap protecting the pillar mark was stamped with the station identifying number. This number was also stamped on one of the trivet footpads. Each recovery mark was identified by stamping it "RMI", "RM2" or "RM3". All station and recovery marks were photographed and a photographic panorama was taken at all six stations.

At each station a compass bearing was observed along one of the lines from pillar mark to recovery mark.

7.4 Computations

The heights obtained by level and staff were adopted after checking them for errors against the heights obtained by vertical angles and slope distances.

Using a system of rectangular coordinates with its origin at the pillar the radiations from the pillar were checked for errors against the measurements from one of the recovery marks; the radiations from the pillar were then adopted.

Orientation of the recovery marks at each station is based on the true meridian; the azimuth for the direction observed to the RO in each case was extracted from the horizontal adjustment of the network.

Final computation of all recovery mark measurements was completed using program RMCOORD.

7.5 Station Summaries

The recovery mark measurements, together with access and other information for each station are recorded on the trig station summaries. The originals are kept in the Division of National Mapping, Canberra and copies are lodged with the Department of Lands, Port Moresby.

Coordinates shown on the summaries are on the Australian Geodetic Datum and have been adjusted to the existing AGD coordinates of AA047 and AA048, as described in chapter 15. The coordinates for determination of crustal movement based on NM/J/35 are in Annex N.

8. CENTERING

With lines as short as one kilometre centering was important.

8.1 Pillar Plugs

Kern trivets and pillar plugs were used. The plugs with their three footpads, one radially grooved, were set in the pillars during construction as shown on the diagram of the pillar at paragraph 3.4. The tops of the plugs were set to be flush with the pillar top when the cap was removed.

The plug caps were modified by the addition of a locking screw in the top which had to be slackened off with an Allen key before the cap could be screwed off with a two-pin spanner.

8.2 Trivet

The trivet fastened directly into the plug by the radially expanding central rod.

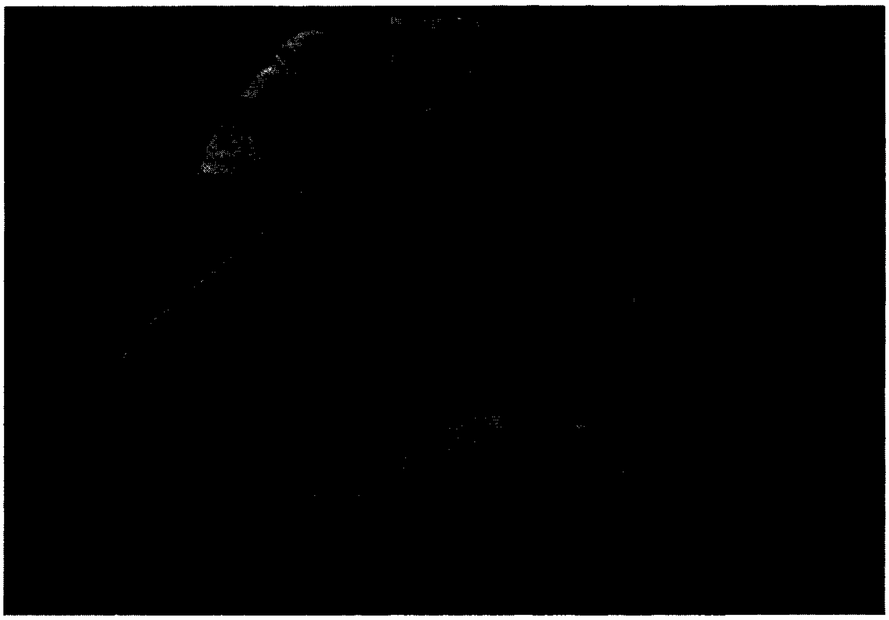
8.3 Target Lights

The centering of the target lights was achieved by the coaxial sliding rods which were a neat fit inside the 16.5 mm pillar plugs. Their light weight, due to aluminium construction, required that a little plaster of Paris be placed around the feet of the tribrach to secure it to the top of the pillar when the short centering plug was used in high winds. Verticality of the rod was obtained by centering the attached bubble, which had the effect of locating the target or light vertically above the pillar plug. All target lights were free to rotate on their vertical axes, which enabled the bubble adjustment to be checked.

8.4 Theodolites

The theodolites, Wild T3 for the primary angles and Wild T2 for recovery marks, were fastened to the Kern trivets by a 'stub plate', a flat circular aluminium disc having the Kern triangular hole on the underside and Wild threaded spigot on the top. Geodimeter parties had used these stub plates for some years, to avoid frequent changes of tripods, but for first order angular work this arrangement was less than satisfactory. Some source of rotational looseness was present and occasionally the theodolite would rotate slightly causing a set of angles to be lost. This system will be improved.

Wild T3 with Stub Plate Fitting for Kern Trivet



Modified Zeiss Target with Short Centering Rod

8.5 Chaining Points

For chaining to recovery marks the Zeiss tribrachs, with the base plates still attached, were used on tripods and centered over the marks by a Zeiss optical plummet, which was free to rotate in the tribrach to check its adjustment. The optical plummet could then be replaced if desired by a small aluminium plug with a conical top, fitting neatly into the tribrach.

8.6 Geodimeter

For mounting the Geodimeter on a pillar the standard AGA tilting head fitted directly onto the Kern trivet. However great care had to be taken, when placing the heavy Geodimeter onto the tilting head, not to dislevel the trivet head. The tilting head obscured the bubble on the trivet, and it could not be checked again until the Geodimeter was removed.

This aspect and checking of the bubbles are dealt with further at paragraphs 4.6 section 1 and 4.7 note 1.

9. LEVEL DATUM

The levelling network is shown on the map following paragraph 3.1.

The levelling along the Highlands Highway from sea level at Lae, 150 km east, was carried out for construction of the highway and its standard was not known. The new levelling was connected to three bench marks, CDW 151, CDW 155, and CDW 160 but reliable values for them had not been found at the time of writing.

Heights were therefore based on the geodetic survey, the height of AA 048 RAGITSARI being held at 492.2 m as shown on the 1974 geodetic station summary for that point. Height differences were carried through the new work without adjustment by various means:

Station	Method	Δ h	h
AA 048 RAGITSARI			492.2 m
	Geodimeter distance Simultaneous Reciprocal Verticals (SRV)	-25.519	
NM/J/35 ATSUNAS			466.681
	DI 10 distance and SRV (adopted) checked by one way levelling	-59.173	
MCM 16			407.508
	First order levelling	-41.766	
MCM 21			365.742

Station	Method	Δ h	h
MCM 21			365.742
	DI 10 distance and SRV	+79.541	
NM/J/32			445.283
	Geodimeter distance and SRV	+139.889	
AA 047 KAIAPIT			584.172 (584.4 PO)
	Geodimeter distance and SRV	-92.714	
AA 048 RAGITSARI			492.458
		(misclose	0.258)

10. BENCH MARKS

10.1 Description

Along the Highlands Highway, which runs through the centre of the survey area, two separate level runs had been made at different times, each with bench marks a mile apart, one on either side of the road. The marks were conventional concrete blocks.

In view of the unstable ground it was decided to put in a network of deep bench marks. These are mild steel electrodes about 2 m long and 14 mm diameter, coated with stainless steel. The first rod is fitted with a driving point. Successive rods are joined to the first by a steel tubular coupling about 6 cm long; prolonged percussion forces the tapered ends of the rods together inside the coupling to form a permanent joint. The rods are driven by a petrol-driven power hammer.

When the rods will go no further the last rod is sawn off at ground level and a stainless steel dome-topped cap is driven on to form the bench mark. A loose concrete collar 25 cm diameter and 30 cm high, with a 6 cm central hole, is set over the rod and the bench mark number is punched into a brass strip set in the concrete. A bench mark is shown at figure 12, para.12.3.

The twenty bench marks placed were set about ten metres back from the roadside. No witness posts were placed, in an effort to protect the marks from vandalism. However later advice was that the risk of destruction by road maintenance and realignment was almost as great, and concrete guard posts are to be placed adjacent to each mark.

10.2 Marking Materials and Equipment

These consisted of:

(a) steel electrodes, stainless steel covered, 1.8 m long, supplied by Tubemakers of Australia, with couplings driving points and caps.

(b) Atlas Copco petrol-driven power hammer, with driving dolly to fit the steel electrodes, and supporting rig consisting of base plate, pole, cradle and struts.

(c) concrete collars.

10.3 Depth

In unstable ground, such as the black soil country in Australia, deep bench marks usually go to three, sometimes six metres, and very occasionally to twelve. The depths attained before meeting firm rock in the western half of this survey were therefore surprising. The depths were:

MCM 1	near NM/J/31 at Tofmora	7.3 metres	along Highlands Highway
2		7.3	
3		7.9	
4		7.3	
5		5.5	
6		5.5	
7		2.7	
8		2.7	
9		3.3	
10		4.6	
11		7.0	
12		6.1	
13		15.6	
14		22.0	
15	near NM/J/35 and 36	14.6	
16	near NM/J/35 and 36	10.9	

17	near NM/J/34 at Wankum	25.3
18	near NM/J/33 at Raginam	76.0
19		31.1
20	near NM/J/32 at Zaklak	12.8

10.4 Location

The coordinates of all deep bench marks were determined for two reasons:

(a) to enable them to be more easily found in high grass in later years, perhaps after road re-alignment.

(b) the possible significance of any vertical movement in relation to any other marks, being driven as they are into bedrock.

Four were coordinated by radiation from pillars, one by traverse and the remaining fifteen by resection.

Two resection formulae were selected after reference to J.S. Allman's paper "Notes on Resection Computations" in The Australian Surveyor of March 1963 and were programmed on the HP9100B calculator by Mr. R. Bryant. Only the formula recommended for points outside the triangle formed by the known points was used, and the program listing is at Annex F.

10.5 Records

Bench mark sketches and data were recorded on PNG Public Works Department standard bench mark record sheets - see Figure 10 on the following page. The originals are with the Public Works Department Survey Branch in Port Moresby and copies are lodged with the Division of National Mapping in Canberra.

11. LEVELLING

11.1 Specifications

First order levelling was observed over all the bench marks in accordance with the Division of National Mapping specifications at Annex G. As described at Chapter 12 on height connections, the levelling terminated at a bench mark at the foot of each hill where a pillar was situated.

DEPARTMENT OF PUBLIC WORKS

FIGURE 10

SURVEY SECTION
BENCH MARK DATA

PROJECT: MARKHAM CRUSTAL MOVEMENT

BM NO.: MCM 18

RL: 390·2086 m.

DATUM: MEAN SEA LEVEL
(AA 0A8 RAGITSARI - 492·20 METRES)

ORDER: FIRST

GROUND MARK: 76·2m.CU-CLAD ROD DRIVEN TO BEDROCK. CAPPED & STAMPED

ACCESS NOTE: ON NORTHERN SIDE OF TRACK IN RAGINAM VILLAGE AT FOOT OF NM/J/33 FEATURE.

ESTABLISHED BY: DIVISION OF NATIONAL MAPPING

DATE: 6 SEPTEMBER 1973

FIELD BOOK: NM 14427

FILE NO.:

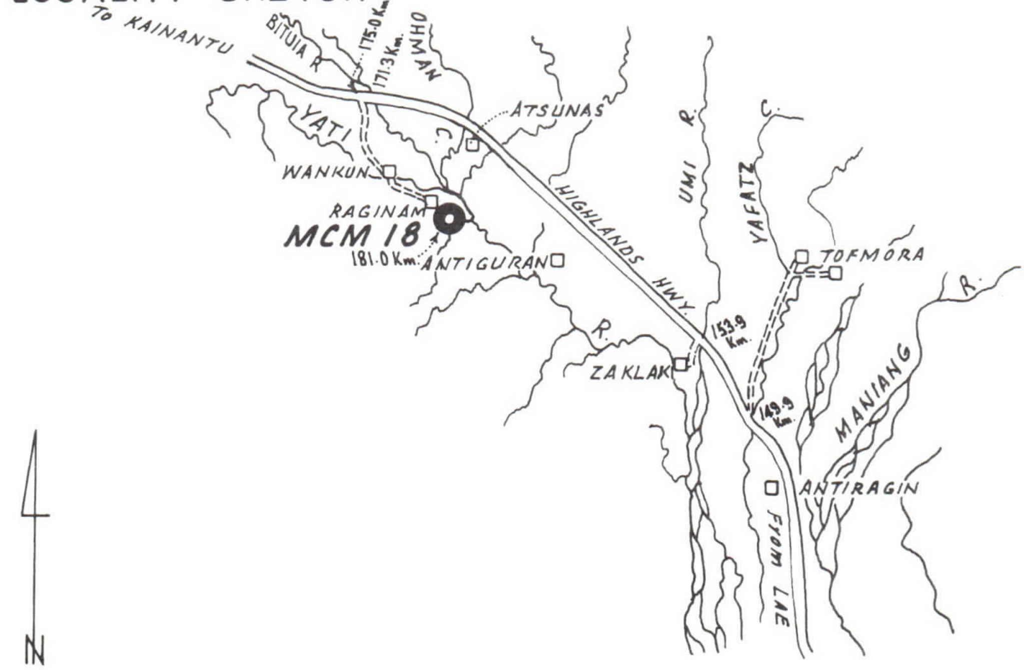
PHOTO REF.:

FILM NO.: RUN NO.: PHOTO NO.:

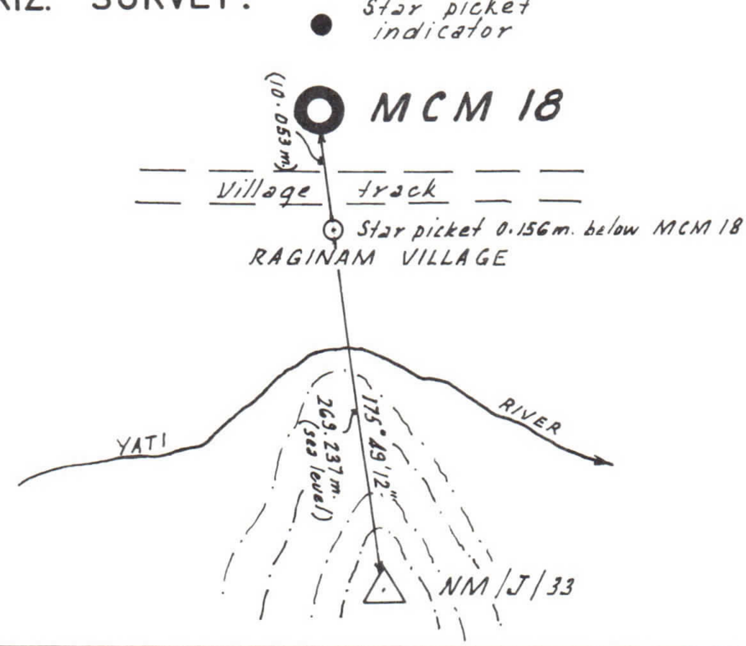
FOURMIL:

MILINCH:

LOCALITY SKETCH:



CONNECTIONS TO HORIZ. SURVEY:



BM has a concrete collar stamped MCM 18

AMG coordinates:

E. 399 910.576

N. 9 318 688.552

Not to scale

REMARKS:

FOLIO NO.

11.2 Equipment

The equipment used was:

- Zeiss Koni 007 level with metric micrometer
- Zeiss invar staves numbers 305 and 306, each with a pair of home-made struts for stability in wind
- Change Points - one three prong 6 kg "spider" base plate for use on firm surfaces and a 0.3 m long carrot shaped steel pin for use in soil.

11.3 Procedure

Two men alternated on observing and booking, while most of the staff work was done by two locally recruited men, Wanus and Jiram from Zaklak, who were 100% reliable. The detailed procedure is set out in the specifications. The agreement between the left face and right face observations was checked at each setup before the instrument was moved.

11.4 Problems

Of the twenty-three sections levelled, eight sections misclosed beyond the first order limits and were relevelled a third time by the other observer. The rerun always agreed with the result obtained by the first observer going in the same direction.

The two runs which agreed were meaned and adopted, regardless of direction, but in retrospect it appears that the change points may have been unsatisfactory and it is intended in future to use a hammered-in-change point at all times.

11.5 Corrections and Adjustments

The survey lies between latitudes 6°08' and 6°13', making orthometric corrections negligible.

After meaning two runs for each section there were no redundancies and consequently no adjustments were made.

11.6 Results

The adopted heights are set out below and the levelling analysis is on the following page. The figures for the rejected runs may be relevant for further analysis after the 1975 resurvey, and a record of all levelling observed is at Annex H.

Adopted Heights

Markham Valley Crustal Movement Survey

1973

Pillars

AA048	Ragitsari	492.2	Adopted new value (National Mapping reference 74/175)
NM/J/31		467.708	
NM/J/32		445.2826	
NM/J/33		475.2176	
NM/J/34		438.0728	
NM/J/35		466.681	
NM/J/36		491.0290	
A047	KAIAPIT	584.4	

Bench Marks

MCM 1	401.6130	MCM 11	403.8916
MCM 2	397.0776	MCM 12	403.2056
MCM 3	387.3226	MCM 13	409.9697
MCM 4	373.9364	TBM x Roads	415.9793
MCM 5	362.0462	MCM 14	417.3326
MCM 6	366.5212	MCM 15	412.3303
MCM 7	377.7831	MCM 16	407.508
TBM UMI River	380.5356	MCM 17	397.7378
MCM 8	383.6065	MCM 18	390.2086
MCM 9	392.0564	MCM 19	396.1267
MCM 10	401.2072	MCM 21	365.7416

FIELD BOOK N^os FWD RUN: *14423 — 14432* N^os BWD RUN: *14423 — 14432* INSTRUMENT: *KONI 007* N^os *157260 & 200895*

LEVELLED BY: *W.A.JEFFERY - R.J.BRYANT* DATE: *22-8-73 — 13-9-73* STAVES: *PRANI LATTE* N^os *305 & 306* FIGURE 11

FIELD BOOK PAGE FD/BD	BENCHMARKS FROM / TO	DISTANCE Diff BS-FS FD/BD	① Kms	FORWARD RUN ② LEFT FACE	③ RIGHT FACE	④ ½ (2+3)	⑤ 1/20 ④	⑥ ⑤x TEMP Corr.	⑦ (5 ±6)	BACKWARD RUN ⑧ LEFT FACE	⑨ RIGHT FACE	⑪ ½ (8+9)	⑫ 1/20 ⑪	⑬ ⑫x TEMP Corr.	⑭ (12 ±13)	±	MEAN ½(7 + 14)	D ⑮ (7-14)	D/√K ⑮/√①
	MCM 1 / MCM 2	+0.6 / -1.2	1.64	-90.702	-90.724	-90.7130	-4.5356	-	-4.5356	+90.698	+90.711	+90.7045	+4.5352	-	+4.5352	-	4.5354	0.0004	0.0003
	MCM 2 / MCM 3	-0.1 / +0.8	1.47	-195.115	-195.097	-195.1060	-9.7553	-	-9.7553	+195.100	+195.083	+195.0915	+9.7546	-	+9.7546	-	9.7550	0.0007	0.0006
	MCM 3 / MCM 4	+1.4 / -0.6	1.56	-267.719	-267.709	-267.7140	-13.3857	-	-13.3857	+267.734	+267.732	+267.7330	+13.3866	-	+13.3866	-	13.3862	0.0009	0.0007
	MCM 4 / MCM 5	-0.2 / -0.6	1.63	-237.851	-237.848	-237.8495	-11.8925	-	-11.8925	+237.765	+237.753	+237.7590	+11.8880	-	+11.8880	-	11.8902	0.0045	0.0035
	MCM 5 / MCM 6	+0.6 / -0.6	0.63	+89.526	+89.527	+89.5265	+4.4763	-	+4.4763	-89.475	-89.468	-89.4715	-4.4736	-	-4.4736	+	4.4750	0.0027	0.0034
	MCM 6 / MCM 7	-0.7 / 0.0	1.33	+225.258	+225.237	+225.2450	+11.2623	—	+11.2623	-225.234	-225.227	-225.2305	-11.2615	—	-11.2615	+	11.2619	0.0008	0.0007
	MCM 7 / TBM UMI R.	-0.3 / +0.9	1.32	+55.065	+55.069	+55.0670	+2.7534	-	+2.7534	-55.023	-55.036	-55.0295	-2.7515	—	-2.7515	+	2.7525	0.0019	0.0016
	TBM UMI R. / MCM 21	+0.4 / +0.1	1.53	-295.896	-295.872	-295.8840	-14.7942	-	-14.7942	+295.864	+295.893	+295.8785	+14.7939	-	+14.7939	+	14.7940	0.0003	0.0002
	TBM UMI R. / MCM 8	+1.4 / 0.0	0.66	+61.406	+61.426	+61.4160	+3.0708	-	+3.0708	-61.420	-61.425	-61.4225	-3.0711	-	-3.0711	+	3.0709	0.0003	0.0004
	MCM 8 / MCM 9	-0.8 / +0.3	1.65	+168.986	+168.989	+168.9875	+8.4494	-	+8.4494	-169.023	-168.998	-169.0105	-8.4506	-	-8.4505	+	8.4499	0.0011	0.0008
	MCM 9 / MCM 10	+0.4 / +0.4	1.62	+183.018	+183.004	+183.0110	+9.1505	-	+9.1505	-183.016	-183.029	-183.0225	-9.1511	-	-9.1511	+	9.1508	0.0006	0.0005
	MCM 10 / MCM 11	+0.1 / -0.8	1.57	+53.717	+53.703	+53.7100	+2.6855	-	+2.6855	-53.656	-53.676	-53.6660	-2.6833	-	-2.6833	+	2.6844	0.0022	0.0017
	MCM 11 / MCM 12	-0.6 / +0.5	1.62	-13.738	-13.725	-13.7315	-0.6866	—	-0.6866	+13.698	+13.722	+13.7100	+0.6855	-	+0.6855	-	0.6860	0.0011	0.0009
	MCM 12 / MCM 13	+0.4 / +0.8	1.65	+135.311	+135.319	+135.3150	+6.7657	-	+6.7657	-135.250	-135.251	-135.2505	-6.7625	-	-6.7625	+	6.7641	0.0032	0.0025
	MCM 13 / TBM X RD.	-0.4 / -0.8	0.47	+120.202	+120.183	+120.1925	+6.0096	—	+6.0096	-120.194	-120.191	-120.1925	-6.0096	-	-6.0096	+	6.0096	0.0	0.0
	TBM X RD. / MCM 19	+0.6 / -0.6	2.22	-397.025	-397.028	-397.0265	-19.8513	—	-19.8513	+397.061	+397.094	+397.0775	+19.8539	-	+19.8539	-	19.8526	0.0026	0.0017
	MCM 19 / MCM 18	+0.2 / -1.8	2.65	-118.316	-118.296	-118.3060	-5.9153	—	-5.9153	+118.409	+118.425	+118.4170	+5.9208	—	+5.9208	-	5.9181	0.0055	0.0034
	MCM 18 / MCM 17	+0.4 / +0.2	2.43	+150.596	+150.636	+150.6160	+7.5308	—	+7.5308	-150.552	-150.557	-150.5545	-7.5277	-	-7.5277	+	7.5292	0.0031	0.0020
	TBM X RD. / MCM 14	+0.4 / +0.6	1.02	+27.071	+27.067	+27.0690	+1.3535	-	+1.3535	-27.063	-27.061	-27.0620	-1.3531	-	-1.3531	+	1.3533	0.0004	0.0004
	MCM 14 / MCM 15	+0.4 / -1.8	1.59	-100.015	-100.026	-100.0205	-5.0010	—	-5.0010	+100.074	+100.073	+100.0735	+5.0037	—	+5.0037	-	5.0023	0.0027	0.0021
	MCM 15 / MCM 16	+0.4 / +1.0	1.55	-96.441	-96.449	-96.4450	-4.8223	-	-4.8223	+96.436	+96.462	+96.4490	+4.8224	-	+4.8224	—	4.8223	0.0001	0.0001
	MCM 16 / NM/J/35A	+0.6 /	1.01	+1158.705	+1158.692	+1158.6985	+57.9349	-	+57.9349										
					NM J 35A	— NM J 35	+1.2509		MCM 16	— NM J 35	+59.1858					+	59.1858		

PREPARED: *W.A.J.* *1/2/74* CHECKED: *R.J.B. 1/2/74* ACCEPTED: *D.R.C.*

12. HEIGHT CONNECTIONS FROM BENCH MARKS TO PILLARS

12.1 General

Due to the steepness of the hills on which the pillars stand it was considered impracticable to carry first order levels up to them from the valley floor. Accordingly a first order bench mark was established on the valley floor adjacent to each of the six pillars within the range of a Wild DI 10 Distomat.

Height differences between each pillar station and its adjacent bench mark were determined by observing simultaneous reciprocal vertical angles with Wild T3 theodolites and measuring slope distances with the Distomat.

A one-way levelling connection was made between MCM 16 and NM/J/35, as a rough check on the trigonometrical calculations. The differences of height determined by the two methods differed by 0.0128 metres. The trigonometrical value was adopted.

12.2 List of Equipment

.1 At Bench Mark

Wild T3 theodolite and lighting set	Koni 007 Automatic level
Kern 173 rigid tripod	Staff and staff bubble
Wild DI 10 Distomat	Observing screen with supporting frame
Adaptor (Wild T3 and T2 theodolite to Kern tripod)	UHF/FM transceiver
Wild T2 theodolite fitted with DI 10 adapter	12-volt accumulator
Mechanism Barometer	Steel pegs for supporting Kern tripod
Psychrometer	Sledgehammer
30-metre tape	Fieldbooks and pens

.2 At Pillar

Kern trivet	30-metre tape
Wild T3 theodolite and lighting set	Koni 007 Automatic level
Adaptor (T3 theodolite to trivet)	UHF/FM transceiver
Reflector prisms for Wild DI 10 Distomat	Observing screen and supporting frame
Barometer	Fieldbooks and pens
Psychrometer	

12.3 Field Method

In most cases it was more convenient to measure the slope distance from the bench mark on the valley floor rather than backpack the Distomat equipment and a 12-volt battery up the steep climb to the pillar station.

An observing screen was erected over both the bench mark and pillar stations to shield the theodolites from the effects of sun and wind. Three long steel pegs were driven into the ground around the bench mark to support the feet of the tripod.

The Distomat was set up over the bench mark and five measurements were made to the reflectors set on the pillar. Temperature and pressure were then recorded simultaneously at both stations to enable the atmospheric correction to the measured slope distance to be calculated.

The heights of the centre of the Distomat and of the optical centre of its reflectors above their respective station marks were then measured with an automatic level set up alongside each station reading to a vertically held tape.

The theodolites were then set up at each end of the line and the height of the centre of each trunnion axis above its respective station mark was determined in the same way.

Simultaneous (by UHF transceiver) reciprocal vertical angles were then observed to circular coloured cards ("red and whites") attached to the objective ends of the T3 telescopes - see Figure 12. Two double pointings were observed on each face, with the bubble centered.

To guard against gross errors the operation was repeated from a second station which was located on line some 3 to 5 metres from the bench mark. The mean of the two results was adopted.

12.4 Computations and Results

The observed height differences were as follows:

Stations		Approximate Slope & Distance		Height Difference		
				from BM	from Ecce	Adopted
MCM 1 to NM/J/31		11°	344 m	+66.095	66.095	66.095
MCM 21 to	32	13°	356	79.541	79.541	79.541
MCM 18 to	33	17°	282	85.007	85.012	85.009
MCM 17 to	34	14°	164	40.334	40.335	40.335
MCM 16 to	35	4°	877	59.169	59.177	59.173
				(59.186 by one way levels)		
MCM 16 to	36	6°	836	83.520	83.521	83.521

Derivation of the formula used, a sample calculation and a blank calculation form are at Annexes I, J and K.

The atmospheric correction to observed distance was calculated from the formula

$$c = D.10^{-6} \left(282 - \frac{76.024 \times P}{273.16 + t} + \frac{11.27 \times E}{273.16 + t}\right)$$

where

c = correction in metres

P = atmospheric pressure in millibars

E = vapour pressure in millibars

t = dry bulb Celsius temperature

The vapour pressure was adopted as 25 mb for all measurements with insignificant effect on the results.

A listing of the HP9100 program for this calculation is at Annex L.

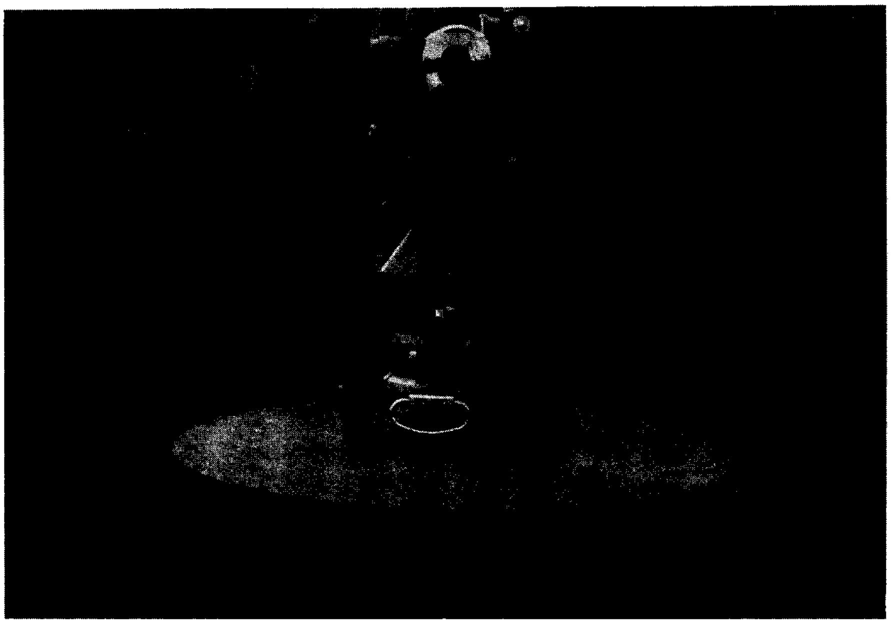
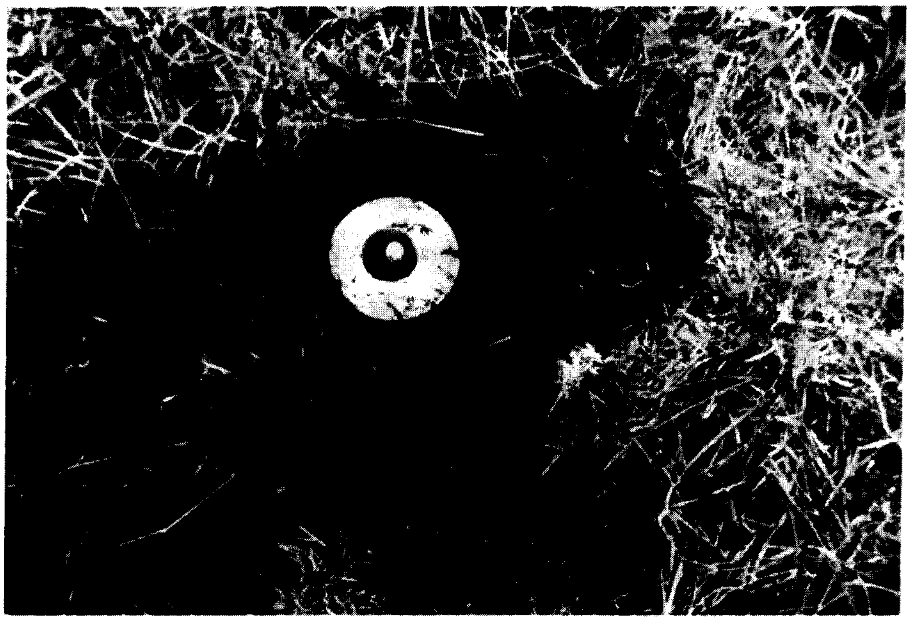


Figure 12. Wild T3 with Paper Target for Reciprocal Vertical Angles.



Deep bench mark with concrete collar.

13. MONITORING OF EARTHQUAKE ACTIVITY

The most probable values for the distances and directions between stations were derived from an adjustment of the whole figure. This assumed, of course, that no station had moved during the course of the survey.

By arrangement with the Geological Survey of Papua New Guinea, the Geophysical Observatory at Port Moresby, 360 km south east, advised the field party leader of any earthquakes occurring during the survey which were likely to be significant.

A Richter scale magnitude 5 earthquake, lasting about 80 seconds and centered about 250 km west, occurred on 13 August at 1830 hours. Three lines were remeasured but the changes were insignificant:

0.001 m in 16.5 km
0.003 m in 15.1 km
0.004 m in 7.3 km

A further short sharp tremor was felt on 27 August at 1753 hours, while measuring at NM/J/32. It was considered of no consequence compared with the first one and no special measures were taken.

14. CONNECTION TO THE AUSTRALIAN GEODETIC DATUM

As shown on the diagram at paragraph 3.1 the survey area lies between AA 047 KAIAPIT and AA 048 RAGITSARI, two stations on the first order geodetic network. Connections were surveyed from NM/J/32 ZAKLAK to AA 047 and from NM/J/35 ATSUNAS to AA 048.

The VARYCORD adjustment at Annex M gives coordinates of all stations on the Australian Geodetic Datum and shows the two surveyed connections.

As mentioned in the paragraph on adjustment, however, the coordinates used to determine future movements of the stations are from a free adjustment of the net holding only one point, NM/J/35, fixed, with coordinates given in Annex M.

Height connections to the two original trig stations were observed by vertical angles at the same time as the Geodimeter measurements.

15. ADJUSTMENT

15.1 Fixed Point

Program VARYCORD, as described in Technical Report 6, was used to adjust the whole network by least squares between stations AA 047 and AA 048 to obtain the best value for co-ordinates of NM/J/35 on the Australian Geodetic Datum. This adjustment is at Annex M. Holding the azimuth from NM/J/35 to NM/J/31, along the northern edge of the network, and the coordinates of NM/J/35 only, fixed, the network was again adjusted by VARYCORD.

The purpose of this was to locate and orient the network but at the same time to avoid the effect of scale difference between the original adjusted Tellurometer measurement AA 047 to AA 048 and the Geodimeter measurements.

15.2 Weights

The R option in VARYCORD weights observations in accordance with a priori standard errors of:

Directions 0.5" Distances 30 mm + 3 ppm

It is, in addition, possible to apply a weight factor to all distances.

At 9 km, the average line length in the Markham survey, the a priori errors give errors in position of:

23 mm and 57 mm respectively.

The internal standard error of the observed directions came down to 0.3" or better for one night's observations and the maker's figure for accuracy of the Geodimeter is 6 mm + 1 ppm. At the end of an average line these give errors of:

13 mm and 15 mm respectively.

Directions were observed over two or more nights, which would reduce the standard error in direction, but the maker's figures for the Geodimeter were almost certainly bettered and the proportion of direction error to distance error was assumed to remain at about 13:15.

This was an improvement from 23:57≙ 1/3 as in the R option, to 13:15 ≙ 1. Therefore a weight factor of 9 was introduced for all distances.

This was the same weight as normally used in geodetic adjustments involving Geodimeter measurements.

15.3 1973 Coordinates

The VARYCORD output at Annex N gives the station coordinates at August 1973.

15.4 Future Adjustments

The 1973 adjustment now rests on station NM/J/35, in the north west corner, and is oriented by an azimuth to NM/J/31 in the north east corner. No outside observations affect its dimensions or shape.

Adjustment of the first resurvey, at present scheduled for 1975, must assume that all stations have moved in relation to each other. Stations 31 and 35 were used for orientation in 1973, mainly because they are both on the same side of the Markham fault zone, but this azimuth may well change.

16. OTHER WORK

Astronomic latitude and longitude were observed at NM/J/32 ZAKLAK, as part of a general programme to accumulate data on deflections of the vertical wherever a geodetic survey is carried out.

17. ACKNOWLEDGEMENTS

The Division of National Mapping is grateful to the Public Works Department Regional Office at Lae, under Regional Engineer Mr Noel Whiley, and to the Survey Branch at Port Moresby, under Mr Gil Hole, who contributed so much in the way of stores and transport facilities, vehicles, fuel supplies, batteries and battery chargers, and in many other ways. Without their assistance the survey would have been more difficult and much more expensive.

The Agricultural Station at Mutsing, under Mr Bill Fullerton, gave every assistance on the job. The provision of facilities for battery charging, workshop and radio traffic and the accommodation at the station were greatly appreciated.

The opportunity to cooperate with the School of Surveying in the Papua New Guinea University of Technology at Lae was, we trust, beneficial to both sides. The students, under Mr Alan McCarthy, helped on various tasks and also carried out some of the work, such as the coordination of bench marks.

The Department of District Administration Sub-District Office at Kaiapit, under Mr P. Lancaster in 1972 and Mr Kaifu Memafu in 1973, undertook the negotiations with landowners and, in collaboration with the Department of Lands at Lae, under Mr O. Dent, arranged the reconnaissance of the scheme in 1972.

Mr Cliff Bloxidge of the Commonwealth Department of Works, and later of the Public Works Department, supervised the building of the excellent pillars and recovery marks in 1972.

The Road Operations Division of the Department of Transport in Lae, under Mr Max Hallett also supplied vehicles.

The survey party received the cooperation of all the village people in the area with whom they came in contact, in particular Nananas and Sabanga of Atsunas, Yaga of Wankum, Ragun of Raginam, David of Zaklak and Luke Sinap of Tofmora, and look forward to renewing their friendship with them in 1975.

GEODIMET

ANNEX A

Reduction of model 8 geodimeter observations, based on the original NatMap Fortran program. HP9100B Program – Instructions

STEP	KEY	Degrees, Fixed point, Decimals 4	DISPLAY			PRINT		
			x	y	z	x	y	z
0 0		Enter sides A & B of magnetic card.						
	cont.		1	8	0			
0 6		Enter sum of 4 phases C_1	C_1					
	cont.		- 1					
0 b		Enter sum of 4 phases R_1 if "so" or "os" SET FLAG	R_1					
	cont.		2	L_1	L_1			
0 6		Enter sum of 4 phases C_2	C_2					
	cont.		- 2					
0 b		Enter sum of 4 phases R_2 if "so" or "os" SET FLAG	R_2					
	cont.		3	L_2	L_2			
0 6		Enter sum of 4 phases C_3	C_3					
	cont.		- 3					
0 b		Enter sum of 4 phases R_3 if "so" or "os" SET FLAG	R_3					
-2 5	cont.		L_{3k}	L_{2k}	L_1			
	cont.		L_{mean}					
-3 0		Enter distance to nearest 2km below actual distance	P					
	cont.		ΣD					
-3 7		Enter dry temp's at geodimeter in z & y registers and vapour pressure (with sign) in x register.						
	cont.							
-5 3		Enter pressures at geodimeter in x & y registers						
	cont.							
-3 7		Enter dry temp's at reflector in z & y registers and vapour pressure (with sign) in x register						
	cont.							
-5 3		Enter pressures at reflector in x & y registers						
	cont.							

STEP	KEY	Degrees, Fixed point, Decimals 4	DISPLAY x	DISPLAY y	DISPLAY z	PRINT x	PRINT y	PRINT z
-8 7		Enter (geodimeter + reflector) constant.	K					
	cont.		D'					
-8 b		Enter beam curvature correction (without sign)	beam curv.					
	cont.		D"					
		DO NOT CONTINUE PAST THIS POINT WHEN REDUCING A GEODIMETER FIELDBOOK						
-9 1		Enter eccentric correction with sign	ecce. corr'n.					
	cont.							
-9 5		Read off slope distance (D) Press continue to return to the begining for next distance	D					

GEODIMET

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
0	0	Clear									
	1	8									
	2	↑									
	3	1									
	4	x → ( )									
	5	d									
	6	Stop	C_1			Enter the sum of 4 phases for Calibrate 1 to 3.					
	7	x → ( )									
	8	b									
	9	d									
	a	Chg Sgn									
	b	Stop	R_1			Enter the sum of 4 phases for Reflect 1 to 3. If "so" or "os" SET FLAG.					
	c	y ⇄ ( )									
	d	b									
1	0	if x > y									
	1	1									
	2	d									
	3	↑									
	4	2									
	5	·									
	6	5									
	7	+									
	8	↓									
	9	if flag									
	a	1									
	b	d									
	c	Set Flag									
	d	x ⇄ y									
2	0	−									
	1	if flag									
	2	2									
	3	7									
	4	Go to ( )( )									
	5	2									
	6	b									
	7	2									
	8	·									
	9	5									
	a	+									
	b	d									
	c	↑									
	d	1									

GEODIMET

ANNEX A

STEP		KEY	DISPLAY			STORAGE					
			X	Y	Z	f	e	d	c	b	a
3	0	+									
	1	y → ( )									
	2	d									
	3	3									
	4	if $x<y$									
	5	5									
	6	a									
	7	if $x=y$									
	8	4									
	9	2									
	a	↓									
	b	y → ( )									
	c	f									
	d	Go to ( )( )									
4	0	0									
	1	5									
	2	↓									
	3	4									
	4	0									
	5	0									
	6	÷									
	7	↓									
	8	—									
	9	f									
	a	if $x<y$									
	b	5									
	c	5									
	d	4									
5	0	·									
	1	9									
	2	8									
	3	8									
	4	+									
	5	y → ( )									
	6	e									
	7	Go to ( )( )									
	8	0									
	9	5									
	a	↓									
	b	2									
	c	0									
	d	÷									

GEODIMET

ANNEX A

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
6	0	Roll ↓									
	1	−									
	2	Roll ↑									
	3	÷									
	4	Roll ↓									
	5	+									
	6	f									
	7	if $x < y$									
	8	7									
	9	2									
	a	4									
	b	·									
	c	7									
	d	6									
7	0	2									
	1	+									
	2	y → ( )									
	3	d									
	4	f									
	5	−									
	6	4									
	7	·									
	8	2									
	9	x									
	a	·									
	b	5									
	c	+									
	d	↓									
8	0	int x									
	1	↑									
	2	5									
	3	×									
	4	e									
	5	↑									
	6	f									
	7	−									
	8	4									
	9	0									
	a	0									
	b	×									
	c	x ⇄ y									
	d	Roll ↑									

GEODIMET

ANNEX A

STEP		KEY	DISPLAY			STORAGE					
			X	Y	Z	f	e	d	c	b	a
9	0	−									
	1	Roll ↓									
	2	x⇄y									
	3	ent exp									
	4	2									
	5	÷									
	6	·									
	7	5									
	8	+									
	9	↓									
	a	int x									
	b	↑									
	c	ent exp									
	d	2									
a	0	×									
	1	↓									
	2	x⇄y									
	3	+									
	4	y⇄()									
	5	d									
	6	↑									
	7	Go to ()()									
	8	−									
	9	0									
	a	0									
	b										
	c										
	d										
-0	0	·									
	1	0									
	2	4									
	3	7									
	4	6									
	5	1									
	6	9									
	7	x									
	8	Roll ↓									
	9	−									
	a	y→()									
	b	b									
	c	d									
	d	↑									

ANNEX A

GEODIMET

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
-1	0	·									
	1	0									
	2	0									
	3	2									
	4	4									
	5	9									
	6	3									
	7	7									
	8	7									
	9	X									
	a	e									
	b	$x \rightleftarrows y$									
	c	—									
	d	$y \rightleftarrows ()$									
-2	0	e									
	1	RCL									
	2	$x \rightleftarrows y$									
	3	↑									
	4	b									
	5	Stop	L_{3k}	L_{2k}	L_1	Read off L_1, L_{2k}, L_{3k}.					
	6	+									
	7	↓									
	8	+									
	9	3									
	a	÷									
	b	d									
	c	+									
	d	5									
-3	0	Stop	L_{mean} / P			Read off the L_{mean}.					
	1	+				Enter the distance to the nearest 2km below the actual distance.					
	2	$y \rightarrow ()$									
	3	d									
	4	6									
	5	$x \rightarrow ()$									
	6	f									
	7	Stop	e	t°c	t°c	Enter the dry temperatures and the vapour pressure correction with sign at the Geodimeter/Reflector.					
	8	$x \rightarrow ()$									
	9	c									
	a	↓									
	b	+									
	c	2									
	d	÷									

GEODIMET

ANNEX A

STEP	KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
-4 0	2									
1	7									
2	3									
3	·									
4	2									
5	+									
6	8									
7	0									
8	·									
9	9									
a	6									
b	$x \rightleftarrows y$									
c	÷									
d	1									
-5 0	Acc +									
1	f									
2	Stop	Pmb	Pmb		Enter the pressure in mb at the Geodimeter/Reflector.					
3	+									
4	2									
5	÷									
6	↓									
7	×									
8	c									
9	+									
a	f									
b	↑									
c	7									
d	if $x = y$									
-6 0	6									
1	5									
2	Go to ()()									
3	6									
4	d									
5	↓									
6	Pause									
7	$y \rightarrow$ ()									
8	b									
9	8									
a	Go to ()()									
b	3									
c	5									
d	b									

ANNEX A

GEODIMET

STEP	KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
-7 0	Roll ↑									
1	+									
2	2									
3	÷									
4	3									
5	0									
6	8									
7	·									
8	6									
9	x⇄y									
a	−									
b	ent exp									
c	6									
d	÷									
-8 0	d									
1	↑									
2	↓									
3	×									
4	+									
5	1									
6	0									
7	Stop	K			Enter the Geodimeter plus Reflector constant with sign.					
8	+									
9	1									
a	1									
b	Stop	Beam Curv			Enter the Beam Curvature correction without sign					
c	−									
d	1									
-9 0	2									
1	Stop	Ecce Corrn			Read off the Slope Distance (without eccentric correction). Enter the eccentric correction with sign.					
2	+									
3	1									
4	3									
5	Stop	Slope Dist			Read off the Slope Distance.					
6	END									
7										
8										
9										
a										
b										
c										
d										

COMPARISON OF MEASURED DISTANCES

DRY BULB TEMPERATURES

ANNEX B

DATE	TIME	MEASURE	MEAN DRY TEMP GEOD	MEAN DRY TEMP REFL	MEAN OF MEASURES	MEAN OF SETS	MEAN OF DAYS	RANGE L1 L2k L3k mm	RANGE L1 L2k L3k PPM	RANGE PPM MEAS	RANGE PPM SETS	RANGE PPM DAYS
NM/J/32 to NM/J/31												
8.8.73	1555–1605	7345.471	23.80	23.45	7345.471			11	1.5	0.1		
8.8.73	1610–1617	.470	23.50	23.70		7345.467		14	1.9		1.2	
8.8.73	1759–1815	7345.465	22.00	22.35	7345.462			3	0.4	0.8		
8.8.73	1815–1834	.459	21.85	22.05				7	1.0			
11.8.73	1703–1716	7345.467	26.55	26.65	7345.470			4	0.5	0.7		
11.8.73	1717–1727	.472	26.10	26.15		7345.469	7345.467	4	0.5		0.3	0.5
11.8.73	1901–1910	7345.466	23.55	24.50	7345.468			11	1.5	0.7		
11.8.73	1911–1919	.471	23.45	24.15				8	1.1			
28.8.73	1832–1841	7345.468	24.60	24.65	7345.465			5	0.7	0.7		
28.8.73	1843–1849	.462	23.80	23.85		7345.465		11	1.5		0.0	
28.8.73	2027–2035	7345.466	23.80	23.85	7345.465			7	1.0	0.1		
28.8.73	2038–2047	.465	23.80	23.65				11	1.5			
NM/J/31 to NM/J/33												
10.8.73	1650–1701	14526.438	26.35	27.30	14526.441			10	0.7	0.3		
10.8.73	1706–1713	.443	26.25	27.30		14526.439		16	1.1		0.2	
10.8.73	1851–1902	14526.442	24.95	25.40	14526.438			5	0.3	0.5		
10.8.73	1905–1913	.435	24.85	25.25			14526.440	25	1.7			0.1
11.8.73	1728–1738	14526.444	25.60	26.35	14526.442			7	0.5	0.3		
11.8.73	1745–1752	.439	25.15	25.75		14526.441		4	0.3		0.2	
11.8.73	1928–1936	14526.439	23.30	23.45	14526.439			19	1.3	0.0		
11.8.73	1936–1945	.439	23.25	23.20				9	0.6			
NM/J/31 to NM/J/34												
10.8.73	1751–1801	16498.102	25.40	26.25	16498.104			22	1.3	0.2		
10.8.73	1806–1813	.106	25.25	25.90		16498.109		19	1.2		0.5	
10.8.73	1947–1957	16498.111	23.15	24.30	16498.113			5	0.3	0.3		
10.8.73	1959–2006	.116	22.90	24.00				16	1.0			
11.8.73	1753–1805	16498.112	24.80	26.10	16498.120			7	0.4	1.0		
11.8.73	1807–1817	.128	24.35	25.75		16498.115	16498.112	25	1.5		0.5	0.4
11.8.73	1950–1958	16498.111	23.15	23.65	16498.111			13	0.8	0.0		
11.8.73	1958–2005	.111	22.95	23.45				5	0.3			
13.9.73	1742–1753	16498.111	23.15	24.90	16498.112	16498.112		7	0.4	0.1	—	
13.9.73	1755–1804	.113	22.90	24.80				5	0.3			
NM/J/31 to NM/J/35												
12.8.73	1804–1812	16172.685	24.50	25.10	16172.688			5	0.3	0.3		
12.8.73	1816–1825	.690	24.50	24.95		16172.689		15	0.9		0.1	
12.8.73	1951–1959	16172.692	23.50	24.15	16172.690			20	1.2	0.2		
12.8.73	2000–2010	.688	23.40	23.95			16172.681	13	0.8			0.9
14.8.73	1720–1733	16172.665	26.25	25.85	16172.664			18	1.1	0.1		
14.8.73	1735–1747	.663	25.95	25.50		16172.674		36	2.2		1.2	
14.8.73	1915–1925	16172.686	24.05	23.25	16172.684			2	0.1	0.3		
14.8.73	1926–1935	.681	23.75	23.10				22	1.4			
NM/J/31 to NM/J/36												
9.8.73	1730–1743	15113.383	26.50	26.60	15113.379			4	0.3	0.5		
9.8.73	1749–1800	.375	26.10	26.25		15113.376		5	0.3		0.3	
9.8.73	1930–1943	15113.374	23.25	23.70	15113.374			55	0.3	0.0		
9.8.73	1947–1955	.374	23.10	23.55				29	1.9			
12.8.73	1732–1745	15113.387	25.05	25.55	15113.386		15113.383	12	0.8	0.2		1.0
12.8.73	1745–1755	.384	24.85	25.30		15113.391		2	0.1		0.7	
12.8.73	1930–1939	15113.392	23.70	24.45	15113.396			7	0.5	0.5		
12.8.73	1940–1950	.400	23.60	24.20				15	1.0			
13.9.73	1807–1816	15113.382	22.80	23.70	15113.382	15113.382		10	0.7	0.0	—	
13.9.73	1819–1829	.382	22.75	23.75				16	1.1			

COMPARISON OF MEASURED DISTANCES

DRY BULB TEMPERATURES

ANNEX B

DATE	TIME	MEASURE	MEAN DRY TEMP		MEAN OF			RANGE				
								L1	L2k L3k	PPM		
			GEOD	REFL	MEASURES	SETS	DAYS	mm	PPM	MEAS	SETS	DAYS
NM/J/32 to NM/J/33												
27.8.73	1801–1808	9626.475	27.05	27.20	9626.472			11	1.1	0.7		
27.8.73	1811–1818	.468	26.65	25.75				15	1.6			
						9626.472					0.0	
27.8.73	1952–2001	9626.474	24.15	24.25	9626.472			19	2.0	0.3		
27.8.73	2002–2008	.471	24.05	24.05				12	1.2			
							9626.470					0.3
28.8.73	1748–1756	9626.468	25.80	26.10	9626.472			10	1.0	0.9		
28.8.73	1759–1806	.477	25.65	26.00				5	0.5			
						9626.469					0.6	
28.8.73	2003–2012	9626.469	24.05	23.15	9626.466			9	0.9	0.7		
28.8.73	2014–2022	.462	23.90	22.80				8	0.8			
NM/J/32 to NM/J/34												
22.8.73	1727–1743	12048.072	25.70	25.40	12048.068			18	1.5	0.6		
22.8.73	1744–1755	.065	25.50	25.25				8	0.7			
						12048.071					0.5	
22.8.73	1940–1947	12048.072	24.05	23.55	12048.074			9	0.7	0.3		
22.8.73	1948–1957	.076	23.80	23.50				18	1.5			
							12048.071					0.1
23.8.73	1725–1735	12048.072	24.20	23.70	12048.071			9	0.7	0.2		
23.8.73	1737–1748	.070	24.05	23.45				14	1.2			
						12048.072					0.1	
23.8.73	1925–1935	12048.072	22.60	22.65	12048.072			6	0.5	0.1		
23.8.73	1936–1946	.073	22.55	22.60				14	1.2			
NM/J/32 to NM/J/35												
14.8.73	1750–1805	12907.527	25.75	26.00	12907.530			12	1.0	0.6		
14.8.73	1807–1816	.534	25.45	25.10				43	3.6			
						12907.537					1.2	
14.8.73	1937–1949	12907.545	23.45	25.10	12907.544			6	0.5	0.2		
14.8.73	1950–1958	.543	23.35	22.90				11	0.9			
							12907.537					0.1
15.8.73	1709–1716	12907.539	25.75	25.75	12907.540			14	1.2	0.2		
15.8.73	1717–1727	.541	25.70	25.60				7	0.6			
						12907.538					0.4	
15.8.73	1910–1923	12907.536	24.65	24.70	12907.535			10	0.8	0.2		
15.8.73	1924–1935	.534	24.35	24.50				28	2.3			
NM/J/32 to NM/J/36												
27.8.73	1735–1746	12138.632	28.20	27.90	12138.628			16	1.3	0.7		
27.8.73	1748–1757	.624	27.40	27.35				11	0.9			
						12138.634					0.9	
27.8.73	1933–1939	12138.639	25.50	25.65	12138.639			10	0.8	0.0		
27.8.73	1943–1950	.639	24.50	25.55				7	0.6			
28.8.73	1730–1738	12138.641	26.10	26.30	12138.640	12138.640	12138.637	10	0.8	0.2	—	0.5
28.8.73	1739–1746	.638	25.95	26.10				4	0.3			
12.9.73	1810–1822	12138.647	22.95	23.00	12138.640			4	0.3	1.1		
12.9.73	1825–1832	.634	22.70	22.90				27	2.2			
						12138.639					0.2	
12.9.73	2010–2017	12138.626	23.05	22.85	12138.638			53	4.4	2.0		
12.9.73	2020–2027	.650	23.05	22.85				20	1.6			
NM/J/34 to NM/J/33												
22.8.73	1756–1805	2474.237	25.35	24.50	2474.238			10	4.0	1.2		
22.8.73	1806–1818	.240	25.15	24.20				19	7.7			
						2474.239					0.8	
22.8.73	1959–2007	2474.239	23.80	23.20	2474.240			13	5.3	0.4		
22.8.73	2008–2015	.240	23.75	23.20				8	3.2			
							2474.240					1.2
23.8.73	1749–1800	2474.248	23.60	23.65	2474.247			4	1.6	0.8		
23.8.73	1802–1808	.246	23.05	23.60				3	1.2			
						2474.242					4.4	
23.8.73	1946–1955	2474.237	22.50	21.95	2474.236			5	2.0	0.4		
23.8.73	1956–2003	.236	22.40	21.90				3	1.2			

COMPARISON OF MEASURED DISTANCES

DRY BULB TEMPERATURES

ANNEX B

DATE	TIME	MEASURE	MEAN DRY TEMP GEOD	MEAN DRY TEMP REFL	MEAN OF MEASURES	MEAN OF SETS	MEAN OF DAYS	RANGE L1 mm	RANGE L2k L3k PPM	RANGE PPM MEAS	RANGE PPM SETS	RANGE PPM DAYS
NM/J/35 to NM/J/34												
16.8.73	1730-1743	2724.341	25.55	25.85	2724.342			9	3.3	0.7		
16.8.73	1745-1755	.343	25.35	25.80		2724.344		5	1.8		1.5	
16.8.73	1945-1955	2724.345	23.80	23.05	2724.346			14	5.1	0.7		
16.8.73	1957-2005	.347	23.90	22.70				18	6.6			
17.8.73	1729-1739	2724.336	26.35	27.15	2724.339			15	5.5	2.2		
17.8.73	1740-1750	.342	26.20	26.50		2724.344	2724.342	16	5.9		3.3	1.8
17.8.73	1935-1944	2724.346	23.65	22.95	2724.348			9	3.3	1.1		
17.8.73	1946-1956	.349	23.50	23.00				12	4.4			
18.8.73	1740-1749	2724.345	25.95	26.15	2724.340			10	3.7	3.3		
18.8.73	1750-1756	.336	25.65	25.80		2724.339		10	3.7		0.7	
18.8.73	1938-1948	2724.346	23.95	23.85	2724.338			10	3.7	5.9		
18.8.73	1950-1958	.330	23.90	23.80				17	6.2			
NM/J/34 to NM/J/36												
20.8.73	1739-1749	3292.078	25.40	25.35	3292.083			16	4.9	3.0		
20.8.73	1750-1758	.088	25.00	24.90		3292.086		7	2.1		1.5	
20.8.73	1937-1947	3292.087	23.00	22.70	3292.088			12	3.6	0.6		
20.8.73	1949-1955	.089	22.85	22.60			3292.086	8	2.4			0.3
21.8.73	1750-1800	3292.087	25.70	26.00	3292.086			3	0.9	0.9		
21.8.73	1801-1807	.084	25.20	25.15		3292.087		10	3.0		0.9	
21.8.73	1953-2001	3292.086	23.35	23.35	3292.089			7	2.1	1.8		
21.8.73	2002-2011	.092	23.10	23.35				15	4.6			
NM/J/33 to NM/J/35												
16.8.73	1710-1718	4334.762	25.95	25.90	4334.764			22	5.1	1.2		
16.8.73	1720-1729	.767	25.75	25.70		4334.765		8	1.8		0.5	
16.8.73	1910-1924	4334.767	23.95	24.30	4334.766			13	3.0	1.6		
16.8.73	1926-1942	.774	23.80	23.00				13	3.0			
17.8.73	1833-1843	4334.762	24.95	24.95	4334.762			16	3.7	0.2		
17.8.73	1846-1856	.761	24.60	24.60		4334.763	4334.764	6	1.4		0.5	0.5
17.8.73	2000-2009	4334.760	23.40	23.10	4334.764			18	4.2	1.8		
17.8.73	2010-2018	.768	23.45	23.00				6	1.4			
18.8.73	1720-1729	4334.760	26.55	26.45	4334.760			16	3.7	0.0		
18.8.73	1730-1738	.760	26.20	26.05		4334.763		10	2.3		1.2	
18.8.73	1920-1928	4334.762	24.15	23.85	4334.765			11	2.5	1.4		
18.8.73	1930-1936	.768	24.00	23.55				17	3.9			
NM/J/35 to NM/J/36												
14.8.73	1817-1827	1121.967	25.20	25.00	1121.964			12	10.7	6.2		
14.8.73	1828-1835	.960	25.00	24.75		1121.964		12	10.7		0.0	
14.8.73	2000-2007	1121.962	23.35	23.25	1121.964			3	2.7	4.5		
14.8.73	2008-2016	.967	23.30	23.35			1121.965	4	3.6			0.9
15.8.73	1728-1737	1121.961	25.70	25.70	1121.961			13	11.6	0.0		
15.8.73	1737-1745	.961	25.55	25.40		1121.965		7	6.2		7.1	
15.8.73	1940-1946	1121.966	24.05	23.80	1121.969			10	8.9	5.3		
15.8.73	1948-1956	.972	23.95	23.75				4	3.6			
NM/J/33 to NM/J/36												
20.8.73	1717-1727	4264.144	26.05	26.35	4264.144			9	2.1	0.0		
20.8.73	1728-1737	.144	25.65	25.80		4264.144		3	0.7		0.2	
20.8.73	1916-1926	4264.146	23.15	23.00	4264.143			14	3.3	1.4		
29.8.73	1927-1935	.140	23.10	22.85			4262.145	16	3.8			0.5
21.8.73	1733-1741	4264.142	26.00	25.55	4264.143			14	3.3	0.5		
21.8.73	1742-1749	.144	25.95	25.60		4264.146		1	0.2		1.6	
21.8.73	1937-1941	4264.149	23.70	24.10	4264.150			7	1.6	0.2		
21.8.73	1942-1952	.150	23.55	23.85				13	3.0			

SUMMARY OF OBSERVED SEA LEVEL DISTANCES

STATION DATE	TOFMORA TIME	NM J 31 TO DISTANCES	STATION RAGINAM FREQ CORRECTIONS	NM J 33 CORRECTED DISTANCES
10-08-73	1650-1701	14526,441	-.002	14526.438
10-08-73	1706-1713	14526,446	-.003	14526.443
10-08-73	1851-1902	14526,445	-.003	14526.442
10-08-73	1905-1913	14526,439	-.004	14526.435
11-08-73	1728-1738	14526,445	-.001	14526.444
11-08-73	1745-1752	14526,439	-.000	14526.439
11-08-73	1928-1936	14526,440	-.002	14526.439
11-08-73	1936-1945	14526,440	-.001	14526.439

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	PPM	S.E. OF MEAN METRES	PPM
0	8	.003	.202	.001	.071

MEAN OF ACCEPTABLE MEASUREMENTS 14526.440

STATION DATE	TOFMORA TIME	NM J 31 TO DISTANCES	STATION WANKUN FREQ CORRECTIONS	NM J 34 CORRECTED DISTANCES
10-08-73	1751-1801	16498,105	-.003	16498.102
10-08-73	1806-1813	16498,110	-.004	16498.106
10-08-73	1947-1957	16498,116	-.005	16498.111
10-08-73	1959-2006	16498,120	-.005	16498.116
11-08-73	1753-1805	16498,113	-.001	16498.112
11-08-73	1807-1817	16498,130	-.002	16498.128
11-08-73	1950-1958	16498,113	-.002	16498.111
11-08-73	1958-2005	16498,114	-.003	16498.111
13-09-73	1742-1753	16498,112	-.001	16498.111
13-09-73	1755-1804	16498,116	-.002	16498.113

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	PPM	S.E. OF MEAN METRES	PPM
0	10	.007	.400	.002	.127

MEAN OF ACCEPTABLE MEASUREMENTS 16498.112

STATION DATE	TOFMORA TIME	NM J 31 TO DISTANCES	STATION OHMAN FREQ CORRECTIONS	NM J 36 CORRECTED DISTANCES
09-08-73	1730-1743	15113,384	-.001	15113.383
09-08-73	1749-1800	15113,378	-.002	15113.375
09-08-73	1930-1943	15113,378	-.004	15113.374
09-08-73	1947-1955	15113,377	-.003	15113.374
12-08-73	1732-1745	15113,388	-.001	15113.387
12-08-73	1745-1755	15113,384	-.001	15113.384
12-08-73	1930-1939	15113,395	-.003	15113.392
12-08-73	1940-1950	15113,403	-.003	15113.400
13-09-73	1807-1816	15113,383	-.001	15113.382
13-09-73	1819-1829	15113,383	-.001	15113.382

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	PPM	S.E. OF MEAN METRES	PPM
0	10	.008	.538	.003	.170

MEAN OF ACCEPTABLE MEASUREMENTS 15113.383

STATION DATE	ZAKLAK TIME	NM J 32 TO DISTANCES	STATION RAGINAM FREQ CORRECTIONS	NM J 33 CORRECTED DISTANCES
27-08-73	1801-1808	9626,473	.001	9626.475
27-08-73	1811-1818	9626,467	.001	9626.468
27-08-73	1952-2001	9626,473	.000	9626.474
27-08-73	2002-2008	9626,471	.000	9626.471
28-08-73	1748-1756	9626,468	.000	9626.468
28-08-73	1759-1806	9626,476	.001	9626.477
28-08-73	2003-2012	9626,469	.000	9626.469
28-08-73	2014-2022	9626,462	.000	9626.462

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	PPM	S.E. OF MEAN METRES	PPM
0	8	.005	.479	.002	.169

MEAN OF ACCEPTABLE MEASUREMENTS 9626.470

STATION DATE	WANKUN TIME	NM J 34 TO DISTANCES	STATION ZAKLAK FREQ CORRECTIONS	NM J 32 CORRECTED DISTANCES
22-08-73	1727-1743	12048,071	.001	12048.072
22-08-73	1744-1755	12048,064	.000	12048.065
22-08-73	1940-1947	12048,071	.001	12048.072
22-08-73	1948-1957	12048,076	-.000	12048.076
23-08-73	1725-1735	12048,072	-.000	12048.072
23-08-73	1737-1748	12048,070	.001	12048.070
23-08-73	1925-1935	12048,073	-.001	12048.072
23-08-73	1936-1946	12048,074	-.001	12048.073

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	PPM	S.E. OF MEAN METRES	PPM
0	8	.003	.268	.001	.095

MEAN OF ACCEPTABLE MEASUREMENTS 12048.071

SUMMARY OF OBSERVED SEA LEVEL DISTANCES ANNEX C

STATION ZAKLAK NM J 32 TO STATION TOFMORA NM J 31

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
08-08-73	1555-1605	7345,471	-.000	7345.471
08-08-73	1610-1617	7345,470	-.000	7345.470
08-08-73	1759-1815	7345,466	-.001	7345.465
08-08-73	1815-1834	7345,459	.000	7345.459
11-08-73	1703-1716	7345,468	-.001	7345.467
11-08-73	1717-1727	7345,473	-.000	7345.472
11-08-73	1901-1910	7345,467	-.001	7345.466
11-08-73	1911-1919	7345,471	-.000	7345.471
28-08-73	1832-1841	7345,468	.001	7345.468
28-08-73	1843-1849	7345,462	.000	7345.462
28-08-73	2027-2035	7345,466	-.000	7345.466
28-08-73	2038-2047	7345,463	.002	7345.465

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	12	.004	.516	.001	.149

MEAN OF ACCEPTABLE MEASUREMENTS 7345.467

STATION ZAKLAK NM J 32 TO STATION OHMAN NM J 36

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
27-08-73	1735-1746	12138,630	.002	12138.632
27-08-73	1748-1757	12138,622	.001	12138.624
27-08-73	1933-1939	12138,639	.000	12138.639
27-08-73	1943-1950	12138,639	.000	12138.639
28-08-73	1730-1738	12138,640	.001	12138.641
28-08-73	1739-1746	12138,637	.001	12138.638
12-09-73	1810-1822	12138,648	-.001	12138.647
12-09-73	1825-1832	12138,635	-.001	12138.634
12-09-73	2010-2017	12138,627	-.000	12138.626
12-09-73	2020-2027	12138,652	-.001	12138.650

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	10	.008	.688	.003	.218

MEAN OF ACCEPTABLE MEASUREMENTS 12138.637

STATION WANKUN NM J 34 TO STATION RAGINAM NM J 33

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
22-08-73	1756-1805	2474,237	-.000	2474.237
22-08-73	1806-1818	2474,240	.000	2474.240
22-08-73	1959-2007	2474,239	.000	2474.239
22-08-73	2008-2015	2474,241	-.000	2474.240
23-08-73	1749-1800	2474,248	.000	2474.248
23-08-73	1802-1808	2474,246	.000	2474.246
23-08-73	1946-1955	2474,237	.000	2474.237
23-08-73	1956-2003	2474,236	.000	2474.236

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.004	1.767	.002	.625

MEAN OF ACCEPTABLE MEASUREMENTS 2474.240

STATION ATSUNAS NM J 35 TO STATION TOFMORA NM J 31

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
12-08-73	1804-1812	16172,687	-.002	16172.685
12-08-73	1816-1825	16172,691	-.001	16172.690
12-08-73	1951-1959	16172,695	-.003	16172.692
12-08-73	2000-2010	16172,690	-.002	16172.688
14-08-73	1720-1733	16172,669	-.004	16172.665
14-08-73	1735-1747	16172,666	-.004	16172.663
14-08-73	1915-1925	16172,691	-.005	16172.686
14-08-73	1926-1935	16172,686	-.006	16172.681

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.011	.699	.004	.247

MEAN OF ACCEPTABLE MEASUREMENTS 16172.681

STATION ATSUNAS NM J 35 TO STATION ZAKLAK NM J 32

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
14-08-73	1750-1805	12907,531	-.004	12907.527
14-08-73	1807-1816	12907,538	-.003	12907.534
14-08-73	1937-1949	12907,550	-.005	12907.545
14-08-73	1950-1958	12907,547	-.004	12907.543
15-08-73	1709-1716	12907,541	-.002	12907.539
15-08-73	1717-1727	12907,544	-.003	12907.541
15-08-73	1910-1923	12907,539	-.003	12907.536
15-08-73	1924-1935	12907,537	-.003	12907.534

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.006	.455	.002	.161

MEAN OF ACCEPTABLE MEASUREMENTS 12907.537

SUMMARY OF OBSERVED SEA LEVEL DISTANCES — ANNEX C

STATION ATSUNAS NM J 35 TO STATION RAGINAM NM J 33

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
16-08-73	1710-1718	4334,763	-.001	4334.762
16-08-73	1720-1729	4334,768	-.001	4334.767
16-08-73	1910-1924	4334,769	-.001	4334.767
16-08-73	1926-1942	4334,775	-.001	4334.774
17-08-73	1833-1843	4334,763	-.001	4334.762
17-08-73	1846-1856	4334,762	-.001	4334.761
17-08-73	2000-2009	4334,761	-.001	4334.760
17-08-73	2010-2018	4334,769	-.001	4334.768
18-08-73	1720-1729	4334,760	0.000	4334.760
18-08-73	1730-1738	4334,760	.000	4334.760
18-08-73	1920-1928	4334,762	-.000	4334.762
18-08-73	1930-1936	4334,769	-.000	4334.768

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	12	.004	1.024	.001	.296

MEAN OF ACCEPTABLE MEASUREMENTS 4334.764

STATION ATSUNAS NM J 35 TO STATION WANKUN NM J 34

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
16-08-73	1730-1743	2724,342	-.001	2724.341
16-08-73	1745-1755	2724,343	-.001	2724.343
16-08-73	1945-1955	2724,346	-.001	2724.345
16-08-73	1957-2005	2724,347	-.001	2724.347
17-08-73	1729-1739	2724,337	-.001	2724.336
17-08-73	1740-1750	2724,343	-.000	2724.342
17-08-73	1935-1944	2724,347	-.001	2724.346
17-08-73	1946-1956	2724,350	-.001	2724.349
18-08-73	1740-1749	2724,345	-.000	2724.345
18-08-73	1750-1756	2724,336	-.000	2724.336
18-08-73	1938-1948	2724,346	-.000	2724.346
18-08-73	1950-1958	2724,330	-.000	2724.330

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	12	.005	2.003	.002	.578

MEAN OF ACCEPTABLE MEASUREMENTS 2724.342

STATION ATSUNAS NM J 35 TO STATION OHMAN NM J 36

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
14-08-73	1817-1827	1121,968	-.000	1121.967
14-08-73	1828-1835	1121,961	-.000	1121.960
14-08-73	2000-2007	1121,963	-.000	1121.962
14-08-73	2008-2016	1121,967	-.000	1121.967
15-08-73	1728-1736	1121,961	-.000	1121.961
15-08-73	1737-1745	1121,961	-.000	1121.961
15-08-73	1940-1946	1121,966	-.000	1121.966
15-08-73	1948-1956	1121,972	-.000	1121.972

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.004	3,692	.001	1,305

MEAN OF ACCEPTABLE MEASUREMENTS 1121.965

STATION OHMAN NM J 36 TO STATION RAGINAM NM J 33

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
20-08-73	1717-1727	4264,145	-.000	4264.144
20-08-73	1728-1737	4264,145	-.000	4264.144
20-08-73	1916-1926	4264,146	-.000	4264.146
20-08-73	1927-1935	4264,140	-.000	4264.140
21-08-73	1733-1741	4264,142	.000	4264.142
21-08-73	1742-1749	4264,144	-.000	4264.144
21-08-73	1937-1941	4264,149	-.000	4264.149
21-08-73	1942-1952	4264,151	-.000	4264.150

REJECTS	GOOD MEAS.	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.003	.803	.001	.284

MEAN OF ACCEPTABLE MEASUREMENTS 4264.145

STATION OHMAN NM J 36 TO STATION WANKUN NM J 34

DATE	TIME	DISTANCES	FREQ CORRECTIONS	CORRECTED DISTANCES
20-08-73	1739-1749	3292,078	-.000	3292.078
20-08-73	1750-1758	3292,088	-.000	3292.088
20-08-73	1937-1947	3292.087	-.000	3292.087
20-08-73	1949-1955	3292,089	-.000	3292.089
21-08-73	1750-1800	3292,087	0.000	3292.087
21-08-73	1801-1807	3292,084	-.000	3292.084
21-08-73	1953-2001	3292,086	.000	3292.086
21-08-73	2002-2011	3292,092	.000	3292.092

REJECTS	GOOD MEAS,	STANDARD DEVIATION METRES	STANDARD DEVIATION PPM	S.E. OF MEAN METRES	S.E. OF MEAN PPM
0	8	.004	1,262	.001	.446

MEAN OF ACCEPTABLE MEASUREMENTS 3292.086

HP 9100B PROGRAM LISTING

Running Mean, Standard Deviation and Standard Error

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
0	0	Clear									
	1	1									
	2	Stop	x_1	0	0	Enter the first observation					
	3	↑									
	4	↑									
	5	1									
	6	Print									
	7	$x \rightarrow ()$									
	8	d									
	9	↓									
	a	X									
	b	Acct									
	c	↑									
	d	Stop	x_i			Enter succesive observations					
1	0	IF FLAG				SET FLAG after last observation and set PRINTER to X, Y & Z					
	1	2									
	2	c									
	3	$x \rightarrow ()$									
	4	c									
	5	+									
	6	$y \rightarrow ()$	Calculates the mean for each successive observation								
	7	b									
	8	d									
	9	↑									
	a	1									
	b	+									
	c	↓									
	d	÷									
2	0	Print		Mean		Prints running mean					
	1	$x \rightarrow ()$									
	2	d									
	3	c									
	4	↑									
	5	x									
	6	Acc +									
	7	b									
	8	↑									
	9	Go to ()()									
	a	0									
	b	d									
	c	d									
	d	↑									

Running Mean, Standard Deviation and Standard Error

STEP	KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
3 0	↑									
1	RCL									
2	Roll ↑									
3	÷									
4	y → ()									
5	f									
6	x									
7	f									
8	x									
9	↓									
a	−									
b	d	Calculates Standard Deviation								
c	↑		$S.D. = \sqrt{\frac{\Sigma v^2}{n-1}}$							
d	1									
4 0	−									
1	f									
2	Roll ↓									
3	÷									
4	d									
5	Roll ↓									
6	$\sqrt{x}$									
7	x ⇄ y									
8	Roll ↑									
9	Print	Std Deviation	Mean	n	PRINTS STANDARD DEVIATION, MEAN and Number of observations					
a	$\sqrt{x}$									
b	Roll ↑									
c	x ⇄ y									
d	÷	Calculates Standard Error		$S.E. = \sqrt{\frac{\Sigma v^2}{n(n-1)}}$						
5 0	0									
1	↑									
2	Roll ↓									
3	Print	0	Std Error	0	Prints Standard Error of the mean					
4	END									
5										
6										
7										
8										
9										
a										
b										
c										
d										

ANNEX E

At: NM/J/34 WANKUN

RO: NM/J/32 0° 0' 0" T3 No 83450

To Station	NM/J/33							
Date	3.9.73				4.9.73			
Set Number	1	2	3	4	5	6	7	8
Range within Set	3.2	4.4	2.9	3.3	3.4	2.6	3.1	4.7
Max Res fr Set Mean	1.7	2.3	1.8	1.8	1.7	1.3	1.6	2.9
Range between Sets	1.9							
Mean	10° 33' 52.03" SE of Mean 0.21 SD of one dble ptg 1.43							

To Station	NM/J/35							
Date	3.9.73				4.9.73			
Set Number	1	2	3	4	5	6	7	8
Range within Set	2.6	3.8	4.4	3.5	2.5	2.6	4.2	1.6
Max Res fr Set Mean	1.5	2.5	2.5	2.0	1.6	1.6	2.2	1.0
Range between Sets	2.1							
Mean	257° 39' 45.88" SE 0.19 SD 1.29							

To Station	NM/J/36							
Date	3.9.73				4.9.73			
Set Number	1	2	3	4	5	6	7	8
Range within Set	3.7	3.7	4.3	3.6	1.9	3.5	3.2	3.6
Max Res fr Set Mean	2.6	2.3	2.6	1.9	1.1	2.1	1.9	2.2
Range between Sets	1.65							
Mean	276° 15' 29.99" SE of Mean 0.20 SD of one dble ptg 1.39							

To Station	NM/J/31							
Date	3.9.73				4.9.73			
Set Number	1	2	3	4	5	6	7	8
Range within Set	3.2	4.7	1.8	3.4	6.5	3.9	3.3	5.1
Max Res fr Set Mean	1.6	3.5	1.0	1.7	3.7	2.6	1.7	2.6
Range between Sets	1.6							
Mean	336° 04' 36.30" SE 0.22 SD 1.53							

At: NM/J/35 ATSUNAS

RO: NM/J/32 0° 0' 0" T3 No 83450

To Station	NM/J/33									
Date	1.9.73						2.9.73			
Set Number	1	2	3	4	5	6	7	8	9	10
Range within Set	2.8	4.8	3.7	4.3	2.2	5.4	1.5	3.7	3.0	2.3
Max Res fr Set Mean	2.2	2.4	2.2	2.4	1.2	2.8	0.8	1.9	1.7	1.7
Range between Sets	1.6									
Mean	34° 02' 29.46" SE of Mean 0.17 SD of one dble ptg 1.34									

To Station	NM/J/34									
Date	1.9.73						2.9.73			
Set Number	1	2	3	4	5	6	7	8	9	10
Range within Set	5.2	2.9	5.1	3.3	1.6	4.6	3.2	3.6	2.4	1.7
Max Res fr Set Mean	3.6	1.6	2.7	1.9	0.8	2.7	1.9	2.0	1.6	1.2
Range between Sets	1.8									
Mean	65° 45' 48.31" SE 0.17 SD 1.35									

To Station	NM/J/36									
Date	1.9.73						2.9.73			
Set Number	1	2	3	4	5	6	7	8	9	10
Range within Set	3.0	4.5	3.3	3.0	1.9	3.0	2.3	2.9	2.8	2.3
Max Res fr Set Mean	1.9	2.5	2.0	1.7	1.0	1.9	1.3	1.8	1.6	1.2
Range between Sets	1.8									
Mean	315° 06' 8.08" SE of Mean 0.16 SD of one dble ptg 1.22									

To Station	NM/J/31									
Date	1.9.73						2.9.73			
Set Number	1	2	3	4	5	6	7	8	9	10
Range within Set	1.6	2.3	2.3	1.0	4.0	3.5	5.2	3.0		
Max Res fr Set Mean	0.9	1.1	1.4	0.7	2.1	2.2	3.2	1.6		
Range between Sets	1.4									
Mean	333° 40' 33.49" SE 0.18 SD 1.24									

At: NM/J/36 OHMAN

RO: NM/J/32 0° 0' 0" T3 No 83450

To Station	NM/J/33														
Date	29.8.73			30.8.73						31.8.73					
Set Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Range within Set	3.2	1.5	1.7	4.0	5.0	4.0	3.0	4.2	3.9	3.0	2.6	2.6	3.2	2.5	3.0
Max Res fr Set Mean	1.8	0.9	1.0	2.0	3.0	2.5	1.7	2.8	2.4	1.6	1.4	1.3	2.0	1.3	1.5
Range between Sets	2.8														
Mean	45° 15' 57.53" SE of Mean 0.14 SD of one dble ptg 1.32														

To Station	NM/J/34														
Date	29.8.73			30.8.73						31.8.73					
Set Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Range within Set	2.6	2.8	1.6	2.9	5.3	5.5	2.7	4.3	1.8	4.5	3.0	3.4	2.9	1.4	4.6
Max Res fr Set Mean	1.6	1.8	1.1	1.9	2.9	2.9	2.0	2.4	1.0	2.4	1.9	2.0	1.6	0.8	2.4
Range between Sets	3.2														
Mean	80° 37' 05.71" SE 0.15 SD 1.41														

To Station	NM/J/35														
Date	29.8.73			30.8.73						31.8.73					
Set Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Range within Set	1.8	2.1	3.1	5.1	3.5	3.4	3.3	4.3	2.8	3.6	3.1	2.4	3.0	3.8	2.9
Max Res fr Set Mean	1.1	1.1	1.9	2.9	2.2	2.0	1.8	2.2	1.5	2.4	1.6	1.5	2.0	2.2	1.5
Range between Sets	2.5														
Mean	131° 21' 40.76" SE of Mean 0.14 SD of one dble ptg 1.37														

To Station	NM/J/31														
Date	29.8.73			30.8.73						31.8.73					
Set Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Range within Set	5.3	3.6	3.7	3.9	4.3	2.9	2.6	3.6	4.3	3.6	4.8	2.0	2.8	3.1	3.5
Max Res fr Set Mean	3.2	2.2	2.0	2.1	2.3	1.7	3.0	1.9	2.0	1.8	3.0	1.2	1.6	1.6	1.8
Range between Sets	3.5														
Mean	331° 17' 23.86" SE 0.17 SD 1.65														

ANALYSIS OF ANGLES

ANNEX E

At: NM/J/31 TOFMORA RO: NM/J/32 0° 0' 0" T3 No 29970

To Station	NM/J/33
Date	7.9.73 / 8.9.73 (from set 8)
Set Number	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Range Within Set	2.3 3.9 2.8 5.2 3.5 2.5 4.7 2.7 2.7 3.7
Max Res fr Set Mean	1.2 2.2 1.4 3.9 1.9 1.9 2.9 1.6 1.5 2.0
Range between Sets	1.8
Mean	36° 09' 26.86 SE of Mean 0.18 SD of one dble ptg 1.36

To Station	NM/J/34
Date	7.9.73 / 8.9.73 (from set 8)
Set Number	1 2 3 4 5 6 7 8 9
Range Within Set	7.7 3.4 5.8 4.3 2.8 4.5 2.5 2.7 3.7
Max Res fr Set Mean	4.4 1.9 3.9 2.4 1.9 2.3 1.4 1.5 2.0
Range between Sets	2.8
Mean	41° 41 30.97 SE 0.26 SD 1,91

To Station	NM/J/35
Date	7.9.73 / 8.9.73 (from set 8)
Set Number	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Range Within Set	3.1 4.0 4.4 2.4 1.2 3.3 3.5 3.2 2.2 3.6
Max Res fr Set Mean	1.9 2.9 2.4 1.3 0.7 1.9 2.3 1.8 1.3 2.2
Range between Sets	1.7
Mean	51° 11' 26.05" SE of Mean 0.16 SD of one dble ptg 1.26

To Station	NM/J/36
Date	7.9.73 / 8.9.73 (from set 8)
Set Number	1 2 3 4 5 6 7 8 9
Range Within Set	2.5 4.0 3.8 5.4 4.0 3.5 3.6 3.6 2.9 3.0
Max Res fr Set Mean	1.3 2.1 2.3 3.2 2.2 1.9 2.1 2.2 1.6 1.6
Range between Sets	2.1
Mean	52° 32' 44.62" SE 0.23 SD 1.81

At: NM/J/32 ZAKLAK RO: NM/J/33 0° 0' 0" T3 No 83450

To Station	NM/J/34
Date	8.9.73 / 9.9.73 (from set 5)
Set Number	1 2 3 4 5 6 7 8
Range within Set	2.8 1.9 2.8 3.1 3.5 2.1 2.1 2.6
Max Res fr Set Mean	1.6 1.1 1.7 1.8 2.3 1.4 1.3 1.6
Range between Sets	0.8
Mean	2° 42' 04.12" SE of Mean 0.13 SD of one dble ptg 0.92

To Station	NM/J/35
Date	8.9.73 / 9.9.73 (from set 5)
Set Number	1 2 3 4 5 6 7 8 9
Range within Set	2.0 1.8 1.5 2.3 1.5 1.7 1.5 3.6
Max Res fr Set Mean	1.1 1.1 0.8 1.2 0.9 0.9 0.8 2.2
Range between Sets	1.2
Mean	14° 36' 1.51" SE 0.12 SD 0.80

To Station	NM/J/36
Date	8.9.73
Set Number	1 2 3 4 5 6 7 8
Range within Set	3.7 2.0 3.3 2.9 2.2 2.1 1.6 4.0
Max Res fr Set Mean	2.7 1.3 1.8 1.8 1.2 1.5 0.9 2.4
Range between Sets	1.5
Mean	18° 20' 27.77" SE of Mean 0.17 SD of one dble ptg 1.16

To Station	NM/J/31
Date	
Set Number	1 2 3 4 5 6 7 8 9
Range within Set	2.1 2.4 4.0 1.4 3.3 2.9 3.1 2.9
Max Res fr Set Mean	1.2 1.3 2.9 0.8 1.7 1.7 1.6 1.7
Range between Sets	0.7
Mean	117° 05' 08.13" SE 0.15 SD 1.03

At: NM/J/33 RAGINAM RO: NM/J/32 0° 0' 0" T3 No 29970

To Station	NM/J/34
Date	5.9.73 / 6.9.73 (from set 5) / 11.9.73 (from set 9)
Set Number	1 2 3 4 5 6 7 8 9 10 11 12
Range within Set	2.0 7.3 4.9 5.6 1.7 2.3 4.2 2.0 4.8 5.0 2.1 5.3
Max Res fr Set Mean	1.0 4.3 2.7 2.9 1.0 1.2 2.2 1.1 2.5 2.8 1.2 2.7
Range between Sets	3.3
Mean	193° 15' 55.73" SE of Mean 0.18 SD of one dble ptg 1.56

To Station	NM/J/35
Date	5.9.73 / 6.9.73 (from set 3) / 11.9.73 (from set 7)
Set Number	1 2 3 4 5 6 7 8 9 10
Range within Set	2.3 6.0 2.5 5.2 2.7 5.9 5.7 4.7 5.0 5.3
Max Res fr Set Mean	1.3 3.1 1.3 2.8 1.8 4.4 3.2 3.4 3.4 2.7
Range between Sets	2.6
Mean	228° 38' 29.83" SE 0.27 SD 2.11

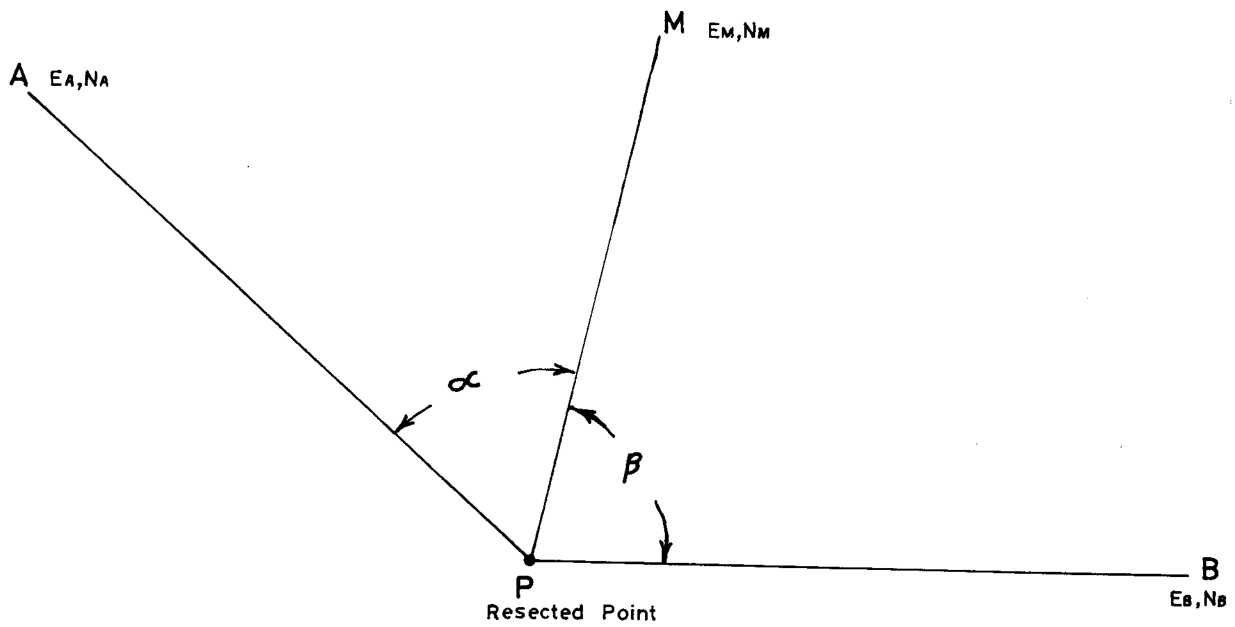
To Station	NM/J/36
Date	5.9.73 / 6.9.73 (from set 5) / 11.9.73 (from set 9)
Set Number	1 2 3 4 5 6 7 8 9 10 11 12
Range within Set	4.3 6.2 7.9 3.3 2.7 3.1 3.4 5.9 5.5 4.4 2.7 4.0
Max Res fr Set Mean	2.3 3.6 5.4 2.1 1.4 1.6 1.8 3.4 2.8 2.3 1.7 2.3
Range between Sets	4.0
Mean	243° 36' 23.73" SE of Mean 0.22 SD of one dble ptg 1.85

To Station	NM/J/31
Date	5.9.73 / 6.9.73 (from set 5) / 11.9.73 (from set 9)
Set Number	1 2 3 4 5 6 7 8 9 10 11 12
Range within Set	4.0 5.2 6.2 4.3 3.7 3.2 2.7 1.8 3.4 3.6 6.4 3.6
Max Res fr Set Mean	2.2 2.8 4.1 2.2 2.0 2.3 1.5 1.0 1.8 2.1 4.3 2.4
Range between Sets	3.0
Mean	333° 14' 35.69" SE 0.20 SD 1.69

HP 9100 B PROGRAM

RESECTION USING CASSINI METHOD

Preferred for use when resected point lies outside the triangle formed by the three observed points.
When using this program the following notation must be used.



RESECTION USING THE CASSINI METHOD **ANNEX F**

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
0	0	Clear									
	1	1									
	2	Stop	N_A	E_A	0	Enter the coordinates of point A					
	3	x → ( )									
	4	f									
	5	y → ( )									
	6	e									
	7	↓									
	8	2									
	9	Stop	N_B	E_B	0	Enter the coordinates of point B					
	a	x → ( )									
	b	d									
	c	y → ( )									
	d	c									
1	0	↓									
	1	3									
	2	Stop	N_M	E_M		Enter the coordinates of point M					
	3	x → ( )									
	4	b									
	5	y → ( )									
	6	a									
	7	e									
	8	x ⇄ y									
	9	−									
	a	y → ( )									
	b	9									
	c	↑									
	d	c									
2	0	−									
	1	y → ( )									
	2	8									
	3	b									
	4	↑									
	5	f									
	6	−									
	7	y → ( )									
	8	7									
	9	d									
	a	↑									
	b	b									
	c	−									
	d	y → ( )									

RESECTION USING THE CASSINI METHOD ANNEX F

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	STORAGE e	STORAGE d	STORAGE c	STORAGE b	STORAGE a
3	0	6									
	1	Stop	α''	α'	α°	Enter	the	angle	α		
	2	Go to()()									
	3	Sub/Ret									
	4	−									
	5	7									
	6	4									
	7	↑									
	8	↑									
	9	Pause									
	a	Go to (X)									
	b	−									
	c	0									
	d	0									
-0	0	x ← ( )									
	1	7									
	2	×									
	3	e									
	4	+									
	5	y ⇄ ( )									
	6	9									
	7	↓									
	8	×									
	9	f									
	a	+									
	b	y → ( )									
	c	7									
	d	Stop	β''	β'	β°	Enter	the	angle	β		
-1	0	Go to ()()									
	1	Sub/Ret									
	2	−									
	3	7									
	4	4									
	5	↑									
	6	↑									
	7	x ← ( )									
	8	6									
	9	×									
	a	c									
	b	+									
	c	y ⇄ ( )									
	d	8									

RESECTION USING THE CASSINI METHOD ANNEX F

STEP		KEY	DISPLAY			STORAGE					
			X	Y	Z	f	e	d	c	b	a
-2	0	↓									
	1	×									
	2	d									
	3	+									
	4	x ← ( )									
	5	7									
	6	x ⇄ y									
	7	−									
	8	x ← ( )									
	9	9									
	a	↑									
	b	x ← ( )									
	c	8									
	d	−									
-3	0	↓									
	1	x ⇄ y									
	2	÷									
	3	y → ( )									
	4	6									
	5	1									
	6	x ⇄ y									
	7	÷									
	8	y → ( )									
	9	5									
	a	+									
	b	y → ( )									
	c	4									
	d	↑									
-4	0	a									
	1	×									
	2	x ← ( )									
	3	9									
	4	↑									
	5	x ← ( )									
	6	5									
	7	×									
	8	Roll ↓									
	9	+									
	a	b									
	b	+									
	c	x ← ( )									
	d	7									

RESECTION USING THE CASSINI METHOD **ANNEX F**

STEP	KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	STORAGE e	STORAGE d	STORAGE c	STORAGE b	STORAGE a
-5 0	−									
1	x ← ( )									
2	4									
3	÷									
4	y → ( )									
5	c									
6	x ← ( )									
7	6									
8	x ⇄ y									
9	x ← ( )									
a	7									
b	x									
c	b									
d	Roll ↑									
-6 0	x									
1	a									
2	+									
3	↓									
4	+									
5	x ← ( )									
6	9									
7	x ⇄ y									
8	−									
9	x ← ( )									
a	4									
b	÷									
c	Roll ↑									
d	Clear x									
-7 0	Roll ↓									
1	c									
2	x ⇄ y									
3	Stop	Np	Ep	0	Read off the coordinates of the unknown point P					
4	x → ( )									
5	−									
6	a									
7	6									
8	0									
9	÷									
a	Roll ↓									
b	+									
c	x ← ( )									
d	−									

RESECTION USING THE CASSINI METHOD ANNEX F

STEP		KEY	DISPLAY			STORAGE					
			X	Y	Z	f	e	d	c	b	a
-8	0	∂									
	1	Roll ↑									
	2	÷									
	3	÷									
	4	Roll ↓									
	5	+									
	6	↓									
	7	tan x									
	8	↑									
	9	/									
	a	$x \rightleftarrows y$									
	b	÷									
	c	Clear x									
	d	Roll ↑									
-9	0	Clear x									
	1	Roll ↑									
	2	Sub/Ret									
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

Division of National Mapping

First Order Levelling

Instructions and Specifications

1. Accuracy

The two levellings of each section between permanent bench marks shall not differ by more than $4(K)^{0.5}$mm where K is the distance in kilometres between bench marks measured along the levelling route.

1.2 Allowable discrepancies between backward and forward runs of first order levelling are shown in the attached table for distances of from 0.1 to 20.0 kilometres (not included in this report).

2. Collimation

2.1 A collimation test shall be carried out each day before levelling commences.

2.2 The collimation error of the level should not exceed 1.0 mm over a distance of 50 metres.

2.3 This interval of 1.0 mm is equal to 0.02 staff units (i.e. 2.0 units on the micrometer drum).

3. Length of Sights

3.1 The length of any levelling sight should be such as to permit the certain reading of the staff and shall never exceed 40 metres. At 40 metres the stadia interval on the staff is 8.0 staff units.

3.2 The lengths of foresights and backsights shall be measured by stadia and, as far as practicable, shall be of equal length. The total length of backsights should in no case differ from the total length of foresights between bench marks by more than 15.0 metres. 15 metres is represented by a staff interval of 3.0 staff units.

3.3 Each stadia wire need only be read to the nearest 0.1 of a staff unit (i.e. to the nearest small graduation on the staff).

4. Readings

4.1 Observations and recordings of the centre wire should be made to the nearest small graduated division of the micrometer (i.e. 0.00005 metres).

4.2 Observations and recordings of the stadia readings should be made to the nearest small graduated division of the staff.

4.3 The sequence of readings shall be:

Backsight stadia
Backsight left face
Foresight left face
Foresight stadia
Foresight right face
Backsight right face

4.4 The difference between the readings of the left and right faces of the staff should fall within the range of 60.645 to 60.655 staff units.

5. Temperature and Refraction

5.1 The temperature of the air shall be recorded together with the time of reading at the commencement of each new page of observations.

5.2 All sight lines shall clear the intervening ground between the level and the staff by at least 0.30 metres (i.e. 6.0 staff units).

5.3 Staff readings of less than 6.0 staff units will not be accepted.

6. Conversion of Staff Readings to Metres

6.1 $\frac{\text{Staff reading}}{20}$ = Staff interval in metres

6.2 $\frac{\text{Stadia interval}}{0.20}$ = Distance in metres

7. Units of Measurement

7.1 Staff Unit = 5 centimetres = 0.05 metres

7.2 Smallest staff graduation = 5 mm = 0.005 metres

7.3 1.0 micrometer unit = 0.5 mm = 0.0005 metres

7.4 0.1 micrometer units (smallest micrometer graduation) = 0.05 mm = 0.00005 metres

8. Use of Micrometer

8.1 The last movement of the micrometer drum to bring the cross hairs of the level onto the staff graduation should be in a clockwise direction.

9. Change Points

9.1 Two types of change point mark will be provided. The three pronged round plate should only be used on firm ground where there is no grass (e.g. consolidated road shoulders, concrete, gravel roads). This plate should not be used on soft ground or in grass. The tapered pin is for use in soft ground and on grassed surfaces. It should be driven into the ground, using the "dolly" provided, until the flat surface at the top of the pin is resting firmly on the ground. Bitumen surfaces are to be avoided.

9.2 Care should be taken to ensure that the spherical surface on which the staff is placed is not damaged when placing or driving the change points.

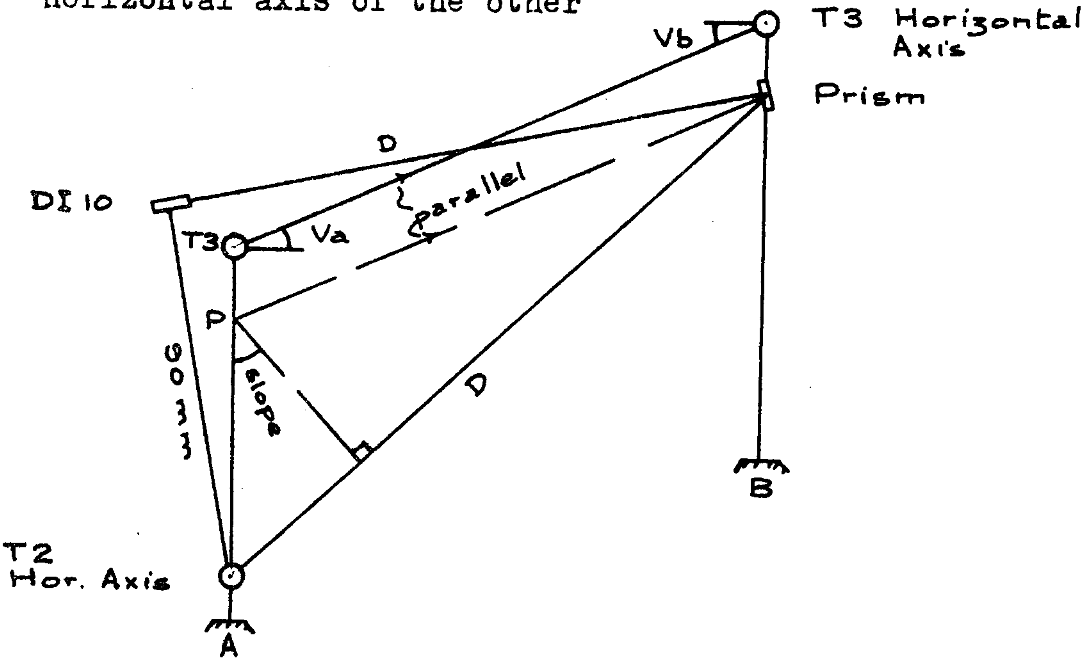
9.3 The staff base guide plate should be used when holding the staff on either the change point plate or pin but this guide plate must be removed when holding on a bench mark.

MARKHAM VALLEY FIRST ORDER LEVELLING 1973

FROM	TO	DIFF HEIGHT FORWARD	DIFF HEIGHT BACKWARD	$.004(k)^{\frac{1}{2}}m$ DIST.	RUN DIFF.	FIELD BOOKS
MCM 1	MCM 2	-4.5288	+4.5356 +4.5352	.0051 1.62	.0068 .0064	14425 14423 14425
MCM 2	MCM 3	-9.7553 -9.7546	+9.7667	.0048 1.47	.0114 .0121	14425 14423
MCM 3	MCM 4	-13.3857	+13.3866	.0050 1.57	.0009	14426 14427
MCM 4	MCM 5	-11.8795	+11.8880 +11.8925	.0051 1.62	.0085 .0130	14426 14427
MCM 5	MCM 6	+4.4763	-4.4736 -4.4691	.0032 0.62	.0027 .0072	14426 14427
MCM 6	MCM 7	+11.2704	-11.2623 -11.2615	.0046 1.33	.0081 .0089	14426 14427
MCM 7	TBM UMI R.	+2.7534	-2.7515	.0046 1.32	.0019	14425
TBM UMI R.	MCM 8	+3.0708 +3.0711	-3.0677	.0033 0.67	.0031 .0034	14424
MCM 8	MCM 9	+8.4494	-8.4505	.0052 1.66	.0011	14423 14423
MCM 9	MCM 10	+9.1511	-9.1506	.0051 1.62	.0005	14428
MCM 10	MCM 11	+2.6855 +2.6833	-2.6778	.0050 1.57	.0077 .0055	14429 14430
MCM 11	MCM 12	-0.6866	+0.6855	.0051 1.62	.0011	14429
MCM 12	MCM 13	+6.7658	-6.7625	.0052 1.65	.0033	14430
MCM 13	MCM 14	+7.3631	-7.3627	.0049 1.50	.0004	14430
MCM 14	MCM 15	-5.0010	+5.0037	.0050 1.59	.0027	14431 14432
MCM 15	MCM 16	-4.8223	+4.8224	.0049 1.52	.0001	14431 14432
MCM 17	MCM 18	-7.5277	+7.5308	.0062 2.43	.0031	14428
MCM 18	MCM 19	+5.9208	-5.9153	.0065 2.65	.0055	14428 14429
MCM 19	TBM X RD	+19.8539	-19.8439 -19.8513	.0060 2.25	.0100 .0026	14431
TBM UMI R.	MCM 21	-14.7942 -14.7832	+14.7936 +14.7939	.0049 1.53	.0006 .0107	14424 14426
MCM 13	TBM X road	+6.0096	-6.0096	.0027 0.47	.0000	14430
MCM 16	NM/J/35		+59.1858			14432

REDUCTION FORMULA FOR HEIGHT CONNECTION BY DISTANCE AND VERTICAL ANGLES

Using: DI 10 mounted on a Wild T2 for distance measurement to standard prisms
Two T3's for vertical angles, each observing to the horizontal axis of the other



$$\text{Slope (T2 to Prism)} = \frac{V_a - V_b}{2} + \frac{\cos\left(\frac{V_a - V_b}{2}\right) \times \left(H_a^{T3} - H_a^{T2} - H_b^{T3} + H_b^{Prism}\right)}{D \times 206264.8}$$

where D = slope distance DI 10 to Prism

then Diff Ht A to B= $+H_a^{T2}$ + D.sin Slope(T2 to Prism)$-H_b^{Prism}$

The T3 vertical angles are corrected to the slope T2-Prism

The distance DI 10 to Prism equals the distance T2-Prism to within 1 mm at 4.05 metres, and the difference reduces to an insignificant figure after that, regardless of slope.

The distance T2 to P= $H_a^{T3}-H_a^{T2}-H_b^{T3}+H_b^{Prism}$ is generally less than 10 mm when vertical angles are observed directly between T3's and distances between DI 10 and prism. It varies slightly with the footscrew adjustments.

But if say a T3 is used at one end and a T2 at the other the difference in axis heights will cause the above distance to attain about 50 mm. Being a vertical distance rather than at right angles to the line of sight it should be multiplied by cosine slope before use in angular corrections to the observed slope. 50 mm will produce a 1 mm correction to the difference in height at 12° slope.

The same effect will occur if targets are used instead of the axis of the other instrument. Therefore the cosine slope has been put on the reduction form, although it can usually be ignored.

HEIGHT CONNECTION BY T2 & DISTOMAT & T3 VERTICAL ANGLES

FROM	TO
A MCM 17	B NM/J/34 WANKUN

Fd. Bk. No 14827	A to B		A to B	
STATIONS	MCM 17	NMJ34	MCM 17 ECCE	NMJ34
SLOPE DIST.	163·604		161·522	
ATMOS	+ ·006		+ ·006	
CORRD DIST DI 10 TO PRISM	163·610		161·528	
VERTICAL ANGLES				
FIELD BOOK	14726	14719	14726	14719
DATE	3 SEP 73	3 SEP 73	4 SEP 73	4 SEP 73
TIME	1520	1520	1320	1320
ANGLE ±	+13 50 43·9	-13 50 48·1	+13 59 10·80	-13 59 19·1
MEAN	+13° 50' 46·0"		+13 59 14·95	
DATE				
TIME				
ANGLE				
MEAN				
MEAN SLOPE T3 To T3	+ 13° 50' 46·0"		+ 13° 59' 14·95"	
CORRECTIONS TO SLOPE				
Ht. T3 at A +	+ 1·594		+ 1·707	
Ht. T2 at A −	− 1·549		− 1·662	
Ht. T3 at B −	− 0·415		− 0·415	
Ht. PRISMS B +	+ 0·360		+ 0·361	
	− 0·010		− 0·009	
COS SLOPE ×	0·971		0·970	
206264·8 ×				
SLOPE DIST ÷	163·610		161·528	
SECONDS ±	− 12·607		− 11·433	
SLOPE T2 to PRISM	+ 13° 50' 33·39"		13° 59' 03·46"	
HEIGHT DIFFERENCE				
Ht. T2 at A +	+ 1·549		+ 1·662	
DIST × SIN SLOPE ±	+ 39·145		+ 39·034	
Ht PRISM B −	− 0·360		− 0·361	
DIFF HT. A-B	+ 40·334		+ 40·335	

HEIGHT CONNECTION BY T2 & DISTOMAT & T3 VERTICAL ANGLES

FROM TO

A ____________ B ____________

Fd. Bk. Nº	A to B		A to B	
STATIONS				
SLOPE DIST.				
ATMOS				
CORRº DIST DI 10 TO PRISM				
VERTICAL ANGLES				
FIELD BOOK				
DATE				
TIME				
ANGLE ±				
MEAN				
DATE				
TIME				
ANGLE				
MEAN				
MEAN SLOPE T3 To T3				
CORRECTIONS TO SLOPE				
Ht. T3 at A +				
Ht. T2 at A −				
Ht. T3 at B −				
Ht. PRISMS B +				
COS SLOPE ×				
206264·8 ×				
SLOPE DIST ÷				
SECONDS ±				
SLOPE T2 to PRISM				
HEIGHT DIFFERENCE				
Ht. T2 at A +				
DIST × SIN SLOPE ±				
Ht PRISM B −				
DIFF HT. A-B				

ATMOSPHERIC CORRECTION FOR THE WILD DI 10 DISTOMAT **ANNEX L**

STEP		KEY	DISPLAY X	DISPLAY Y	DISPLAY Z	STORAGE f	e	d	c	b	a
0	0	Clear									
	1	1									
	2	Stop	t °c	0	0	Enter the dry temperature in degrees centigrade					
	3	↑									
	4	2									
	5	7									
	6	3									
	7	.									
	8	1									
	9	6									
	a	+									
	b	y → ( )									
	c	a									
	d	Stop	E mb			Enter the vapour pressure in millibars					
	0	↑									
	1	1									
	2	1									
	3	.									
	4	2									
	5	7									
	6	x									
	7	a									
	8	÷									
	9	y → ( )									
	a	b									
	b	Stop	P mb			Enter the pressure in millibars					
	c	↑									
	d	7									
2	0	6									
	1	.									
	2	0									
	3	2									
	4	4									
	5	x									
	6	a									
	7	÷									
	8	↓									
	9	chg Sgn									
	a	↑									
	b	b									
	c	+									
	d	2									

ATMOSPHERIC CORRECTION FOR THE WILD DI 10 DISTOMAT ANNEX L

STEP		KEY	DISPLAY			STORAGE					
			X	Y	Z	f	e	d	c	b	a
3	0	8									
	1	2									
	2	+									
	3	1									
	4	0									
	5	0									
	6	0									
	7	0									
	8	0									
	9	0									
	a	÷									
	b	Stop	D			Enter the distance					
	c	x									
	d	↑									
4	0	Roll ↓									
	1	x⇄y									
	2	+									
	3	Stop	Correction (mm)	Corrected Distance	Distance	Read off the correction, the corrected and uncorrected distance					
	4	End									
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										
	0										
	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	a										
	b										
	c										
	d										

The formula is:

$$C = D.10^{-6}\left(282 - \frac{76{\cdot}024 \times P}{273{\cdot}16 \times t} + \frac{11{\cdot}27 \times E}{273{\cdot}16 \times t}\right)$$

where

C = correction in metres.

P = atmospheric pressure in millibars.

t = dry bulb temperature - Celsius.

E = vapour pressure in millibars.

SURVEY ADJUSTMENT - LEAST SQUARES VARIATION OF COORDINATES ON THE SPHEROID

NG - MARKHAM VALLEY CRUSTAL MOVEMENT SURVEY SECTION MARKHAM

AUSTRALIAN GEODETIC DATUM
A= 6378160,00 MS 1/R= 298,250

STATION		SERIAL	SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING MS	NORTHING	CONVERGENCE	HEIGHT MS
FIXED POINTS									
RAGITSARIA	AA 048	1	6, 6, 45,0274	146, 3, 43,3137	55,	396212,110	9324265,778	-0, 5, 59,59	492,2
KAIAPIT	AA 047	8	6, 16, 6,1581	146, 16, 53,9210	55,	420557,441	9307071,503	-0, 4, 42,38	584,4
ADJUSTED POINTS									
	NM J 35	2	6, 7, 35,9148	146, 5, 23,8470	55,	399305,069	9322708,322	-0, 5, 49,68	466,681
	NM J 36	3	6, 7, 37,7356	146, 6, ,2921	55,	400425,421	9322654,296	-0, 5, 45,82	491,029
	NM J 34	4	6, 8, 57,2336	146, 4, 48,4867	55,	398222,441	9320209,144	-0, 5, 54,75	438,073
	NM J 31	5	6, 10, 48,2223	146, 13, 33,5215	55,	414365,102	9316826,323	-0, 4, 59,99	467,708
	NM J 33	6	6, 9, 55,5827	146, 5, 43,9630	55,	399930,649	9318420,139	-0, 5, 49,73	475,218
	NM J 32	7	6, 12, 46,9511	146, 10, 6,1217	55,	407996,515	9313170,585	-0, 5, 24,04	445,283

HEIGHT DATUM IS BASED ON THE HEIGHT OF RAGITSARIA AA 048 492.2 METRES

RAGITSARIA AA 048 SECTION MARKHAM SERIAL 1

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 6, 45,0274	146, 3, 43,3137	55,	396212,110	9324265,778	-0, 5, 59,59	492,2

TO		SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
KAIAPIT	AA 047	8	125, 21, 19,80	-,03		29797,474	
	NM J 35	2	116, 49, 38,97	,03		3463,893	

NM J 35 SECTION MARKHAM SERIAL 2

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 7, 35,9148	146, 5, 23,8470	55,	399305,069	9322708,322	-0, 5, 49,68	466,681

TO		SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
	NM J 32	7	137, 45, 21,05	-,13		12907,542	-,005
	NM J 33	6	171, 47, 50,69	-,31		4334,767	-,003
	NM J 34	4	203, 31, 9,34	-,10		2724,341	,001
RAGITSARIA	AA 048	1	296, 49, 28,25	-,18		3463,893	-,029
	NM J 36	3	92, 51, 28,68	,32		1121,963	,002
	NM J 31	5	111, 25, 54,00	,41		16172,675	,006

NM J 36 SECTION MARKHAM SERIAL 3

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 7, 37,7356	146, 6, ,2921	55,	400425,421	9322654,296	-0, 5, 45,82	491,029

TO	SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
NM J 32	7	141, 29, 43,55	,16		12138,642	-,005
NM J 33	6	186, 45, 40,64	,60		4264,146	-,001
NM J 34	4	222, 6, 49,55	-,11		3292,088	-,002
NM J 35	2	272, 51, 24,79	-,32		1121,963	,002
NM J 31	5	112, 47, 7,91	-,34		15113,376	,007

NM J 34 SECTION MARKHAM SERIAL 4

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 8, 57,2336	146, 4, 48,4867	55,	398222,441	9320209,144	-0, 5, 54,75	438,073

TO	SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
NM J 32	7	125, 51, 27,55	-,18		12048,078	-,007
NM J 33	6	136, 25, 19,70	-,31		2474,240	0,000
NM J 35	2	23, 31, 13,12	,13		2724,341	,001
NM J 36	3	42, 6, 57,23	,13		3292,088	-,002
NM J 31	5	101, 56, 3,43	,23		16498,103	,009

NM J 31 SECTION MARKHAM SERIAL 5

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 10, 48,2223	146, 13, 33,5215	55,	414365,102	9316826,323	-0, 4, 59,99	467,708

TO	SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
NM J 32	7	240, 13, 35,74	-,11		7345,471	-,004
NM J 33	6	276, 23, 2,99	-,50		14526,437	,003
NM J 34	4	281, 55, 7,05	-,46		16498,103	,009
NM J 35	2	291, 25, 1,51	,16		16172,675	,006
NM J 36	3	292, 46, 19,33	,91		15113,376	,007

NM J 33 — SECTION MARKHAM SERIAL 6

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 9, 55,5827	146, 5, 43,9630	55,	399930,649	9318420,139	-0, 5, 49,73	475,218

TO		SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
	NM J 32	7	123, 9, 18,10	,16		9626,473	-,003
	NM J 34	4	316, 25, 13,75	,23		2474,240	0,000
	NM J 35	2	351, 47, 48,54	-,45		4334,767	-,003
	NM J 36	3	6, 45, 42,39	-,40		4264,146	-,001
	NM J 31	5	96, 23, 53,48	,47		14526,437	,003

NM J 32 — SECTION MARKHAM SERIAL 7

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 12, 46,9511	146, 10, 6,1217	55,	407996,515	9313170,585	-0, 5, 24,04	445,283

TO		SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
KAIAPIT	AA 047	8	116, 1, 32,28	,52		13949,689	0,000
	NM J 33	6	303, 8, 49,84	-,39		9626,473	-,003
	NM J 34	4	305, 50, 53,34	,22		12048,078	-,007
	NM J 35	2	317, 44, 50,71	,24		12907,542	-,005
	NM J 36	3	321, 29, 17,13	,09		12138,642	-,005
	NM J 31	5	60, 13, 58,12	-,68		7345,471	-,004

KAIAPIT AA 047 — SECTION MARKHAM SERIAL 8

SOUTH LATITUDE	EAST LONGITUDE	ZONE	EASTING	NORTHING	CONVERGENCE	HEIGHT
6, 16, 6,1581	146, 16, 53,9210	55,	420537,441	9307071,503	-0, 4, 42,38	584,4

TO		SERIAL	ADJ AZIMUTH	OBS	LAPLACE	ADJ LENGTH	OBS
	NM J 32	7	296, 0, 47,95	-,98		13949,689	
RAGITSARIA	AA 048	1	305, 19, 54,54	,98		29997,474	

WHOLE ADJUSTMENT	AVERAGE	,33	AVERAGE	,004
	MAXIMUM	,98	MAXIMUM	,029 AT 2
ABSOLUTE	AVERAGE	0,00	AVERAGE	-,001

PROGRAM AMENDED MAY 1971 GEODETIC SURVEY OF AUSTRALIA COMPUTED 10/05/74

SURVEY ADJUSTMENT - LEAST SQUARES VARIATION OF COORDINATES ON THE SPHEROID

NG - MARKHAM VALLEY CRUSTAL MOVEMENT SURVEY SECTION MARKHAM

AUSTRALIAN GEODETIC DATUM
A= 6378160.00 MS 1/F= 298.250

UNIT WEIGHTS ACCORD WITH THE FOLLOWING STANDARD ERRORS -
DIRECTIONS (SECONDS) AZIMUTHS DISTANCES MS
0.5 1.0 0.03 +3.0 PPM
NORMAL SECTION AZIMUTHS

OBSERVED VALUES OF ANGLES AND AZIMUTHS REJECTED IF MORE THAN 999. SECONDS FROM VALUES COMPUTED FROM COORDINATES
OBSERVED VALUES OF DISTANCES REJECTED IF MORE THAN 999. MS FROM VALUES COMPUTED FROM COORDINATES
NO REJECTIONS

ORDER OF MATRIX = 10 BANDWIDTH = 9 BANDMAT = 55 INVERSION TIME IN SECONDS .002
NUMBER OF ACCEPTABLE OBSERVATIONS 46 OF WHICH ANGLES = 30 AZIMUTHS = 1 DISTANCES = 15

STATION	SERIAL	SOUTH LATITUDE	ADJ-INIT	EAST LONGITUDE	ADJ-INIT	RHO	NU	HEIGHT MS
FIXED POINTS								
NM J 35	2	6. 7. 35.9148	0.0000	146. 5. 23.8470	0.0000	6336185.87	6378403.20	466.681
ADJUSTED POINTS								
NM J 36	3	6. 7. 37.7355	-.0045	146. 6. .2922	.0022	6336185.99	6378403.24	491.029
NM J 34	4	6. 8. 57.2336	-.0064	146. 4. 48.4868	.0068	6336191.20	6378404.99	438.073
NM J 31	5	6. 10. 48.2221	.0021	146. 13. 33.5218	.0018	6336198.52	6378407.44	467.708
NM J 32	7	6. 12. 46.9509	-.0091	146. 10. 6.1219	.0019	6336206.38	6378410.08	445.283
		AVERAGE	.0059	AVERAGE	.0032			
		MAXIMUM	.0091 AT 7	MAXIMUM	.0068 AT 4			

NOTE: AUSTRALIAN GEODETIC DATUM VALUES ARE ADOPTED FOR: COORDINATES OF NM/J/35
AZIMUTH NM/J/35 TO NM/J/31

OBSERVATIONS AT NM J 35 — SERIAL 2 — SOUTH LATITUDE 6. 7. 35.9148 — EAST LONGITUDE 146. 5. 23.8470 — HEIGHT 466.681 MS — SECTION MARKHAM

OBSERVATIONS TO	SERIAL	ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 32	7	137. 45. 20.88	20.68	-.20			12907.541	12907.537	-.004
NM J 33	6	171. 47. 50.44	50.14	-.30			4334.767	4334.764	-.003
NM J 34	4	203. 31. 9.04	8.99	-.05			2724.340	2724.342	.002
NM J 36	3	92. 51. 28.50	28.76	.26			1121.964	1121.965	.001
NM J 31	5	111. 25. 53.89	54.17	.28	53.89	0.00	16172.679	16172.681	.002
ORIENTATION CONSTANT		137. 45. 20.68	AVERAGE	.22	AVERAGE			AVERAGE	.002
			MAXIMUM	.30	MAXIMUM			MAXIMUM	.004

OBSERVATIONS AT	SERIAL	SOUTH LATITUDE	EAST LONGITUDE	HEIGHT		SECTION
NM J 36	3	6. 7. 37.7355	146. 6. .2922	491.029	MS	MARKHAM

OBSERVATIONS TO		ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 32	7	141. 29. 43.40	43.55	.15			12138.640	12138.637	-.003
NM J 33	6	186. 45. 40.45	41.08	.63			4264.145	4264.145	0.000
NM J 34	4	222. 6. 49.34	49.27	-.07			3292.087	3292.086	-.001
NM J 35	2	272. 51. 24.61	24.31	-.30			1121.964	1121.965	.001
NM J 31	5	112. 47. 7.81	7.41	-.40			15113.378	15113.383	.005
ORIENTATION CONSTANT		141. 29. 43.55	AVERAGE	.31	AVERAGE			AVERAGE	.002
			MAXIMUM	.63	MAXIMUM			MAXIMUM	.005

OBSERVATIONS AT	SERIAL	SOUTH LATITUDE	EAST LONGITUDE	HEIGHT		SECTION
NM J 34	4	6. 8. 57.2336	146. 4. 48.4868	438.073	MS	MARKHAM

OBSERVATIONS TO		ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 32	7	125. 51. 27.39	27.17	-.23			12048.076	12048.071	-.005
NM J 33	6	136. 25. 19.47	19.20	-.27			2474.239	2474.240	.001
NM J 35	2	23. 31. 12.82	13.05	.23			2724.340	2724.342	.002
NM J 36	3	42. 6. 57.02	57.16	.13			3292.087	3292.086	-.001
NM J 31	5	101. 56. 3.33	3.47	.14			16498.104	16498.112	.008
ORIENTATION CONSTANT		125. 51. 27.17	AVERAGE	.20	AVERAGE			AVERAGE	.003
			MAXIMUM	.27	MAXIMUM			MAXIMUM	.008

OBSERVATIONS AT	SERIAL	SOUTH LATITUDE	EAST LONGITUDE	HEIGHT		SECTION
NM J 31	5	6. 10. 48.2221	146. 13. 33.5218	467.708	MS	MARKHAM

OBSERVATIONS TO		ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 32	7	240. 13. 35.74	35.55	-.20			7345.469	7345.467	-.002
NM J 33	6	276. 23. 2.91	2.41	-.51			14526.437	14526.440	.003
NM J 34	4	281. 55. 6.95	6.52	-.43			16498.104	16498.112	.008
NM J 35	2	291. 25. 1.40	1.60	.20			16172.679	16172.681	.002
NM J 36	3	292. 46. 19.23	20.17	.94			15113.378	15113.383	.005
ORIENTATION CONSTANT		240. 13. 35.55	AVERAGE	.45	AVERAGE			AVERAGE	.004
			MAXIMUM	.94	MAXIMUM			MAXIMUM	.008

OBSERVATIONS AT		SERIAL	SOUTH LATITUDE	EAST LONGITUDE	HEIGHT		SECTION
	NM J 33	6	6. 9. 55.5826	146. 5. 43.9632	475.218	MS	MARKHAM

OBSERVATIONS TO		ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 32	7	123. 9. 17.97	18.08	.11			9626.471	9626.470	-.001
NM J 34	4	316. 25. 13.52	13.80	.28			2474.239	2474.240	.001
NM J 35	2	351. 47. 48.29	47.91	-.37			4334.767	4334.764	-.003
NM J 36	3	6. 45. 42.20	41.81	-.39			4264.145	4264.145	0.000
NM J 31	5	96. 23. 53.40	53.77	.37			14526.437	14526.440	.003
ORIENTATION CONSTANT		123. 9. 18.08	AVERAGE	.31	AVERAGE			AVERAGE	.002
			MAXIMUM	.39	MAXIMUM			MAXIMUM	.003

OBSERVATIONS AT		SERIAL	SOUTH LATITUDE	EAST LONGITUDE	HEIGHT		SECTION
	NM J 32	7	6. 12. 46.9509	146. 10. 6.1219	445.283	MS	MARKHAM

OBSERVATIONS TO		ADJ AZIMUTH	OBS DIRN	OBS-ADJ	LPL AZ	LPL-ADJ	ADJ LENGTH	OBS LENGTH	OBS-ADJ
NM J 33	6	303. 8. 49.70	49.40	-.30			9626.471	9626.470	-.001
NM J 34	4	305. 50. 53.19	53.52	.33			12048.076	12048.071	-.005
NM J 35	2	317. 44. 50.55	50.91	.37			12907.541	12907.537	-.004
NM J 36	3	321. 29. 16.98	17.18	.20			12138.640	12138.637	-.003
NM J 31	5	60. 13. 58.13	57.53	-.60			7345.469	7345.467	-.002
ORIENTATION CONSTANT		303. 8. 49.40	AVERAGE	.36	AVERAGE			AVERAGE	.003
			MAXIMUM	.60	MAXIMUM			MAXIMUM	.005

WHOLE ADJUSTMENT	AVERAGE	.31	AVERAGE	0.00		AVERAGE	.003
	MAXIMUM	.94	MAXIMUM	0.00 AT 5 AND 0.		MAXIMUM	.008 AT 4
ABSOLUTE	AVERAGE	0.00	AVERAGE	0.00		AVERAGE	0.000