AGSO

MUNDARING GEOPHYSICAL OBSERVATORY: ANNUAL REPORT 1991

BY P J GREGSON

RECORD 1994/27

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

AGSO Record 1994/27

MUNDARING GEOPHYSICAL OBSERVATORY

ANNUAL REPORT

1991

by

P J Gregson

DEPARTMENT OF PRIMARY INDUSTRIES AND ENERGY

Minister for Resources: Hon. David Beddall, MP
Secretary: Greg Taylor

AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Executive Director: Harvey Jacka

ISSN: 1039-0073
ISBN: 0 642 21215 5

CONTENTS

TABLES

FIGURES

SUMMARY

Annual reports detailing observatory activities have been prepared up till 1990. This report covers activity for the year 1991.

Basic program in geomagnetism, ionospherics and seismology continued at the Mundaring Geophysical Observatory during the period. The main instruments were an Eschenhagen normal-run magnetograph, an IPS type 4B ionosonde, a Worldwide Standard Seismograph, and a Seismic Research Observatory.

Seismographs were operated at Ballidu, Coolgardie, Forrest, Kellerberrin, Kununurra, Marble Bar, Manton Dam (NT), Meekatharra, Morawa, Mundaring, Rocky Gully, Narrogin and Warburton.

The observatory operated nine accelerographs in the South-west seismic zone. Another13 accelerographs in WA are operated by the Water Authority and Telecom.

The earthquake list (ML>2) shows details of 217 Western Australian earthquakes during the year.

Isoseismal maps waere prepared for earthquakes that occurred near Kalgoorlie, Karratha, Albany, Shay Gap and Cranbrook.

A major project to determine varying responses of different sub-soil conditions to earthquake vibrations concluded in June.

1. INTRODUCTION

The Mundaring Geophysical Observatory opened on 18 March 1959. Descriptions of the observatory and an outline of activity there to the end of 1990 have been given in previous records (e.g. Gregson 1992). This report outlines the activity during the year. Principal events in the observatory's history are given in Appendix 1.

The observatory controls seismic recording at Ballidu, Coolgardie, Forrest, Kellerberrin, Kununurra, Manton Dam (NT), Marble Bar, Meekatharra, Morawa, Mundaring, Nanutarra, Narrogin, Rocky Gully and Warburton. The seismograph at Narrogin is a Seismic Research Observatory (SRO) and is operated in co-operation with the United States Geological Survey. The seismograph was modified in December by personnel from Albuquerque Seismological Laboratory (ASL) as part of the Incorporated Research Institutions for Seismology (IRIS) upgrade of the global seismographic network.

Nine accelerographs are now operating in the Southwest Seismic Zone with a further 13 being operated in co-operation with the Water Authority of Western Australia and Telecom. The responsibility of maintaining accelerographs owned by the Water Authority (WAWA) and located at dam sites was transferred from the observatory to the water authority during the year.

An exchange of data as required is still maintained. Magnetic recording is carried out at Gnangara and Learmonth, and ionospheric recording at Mundaring.

A joint project between the BMR, the Academy of Science and the Promotion of Science in Japan to determine the likely response of sediments near Perth to earthquake vibrations was concluded.

All observatory staff listed in Table 1 contributed to this report.

2. STAFF AND VISITORS

Observatory staff are listed in Table 1 and staff absences other than recreation leave are listed in Table 2. Students who attended the observatory for work experience and other personnel associated with the observatory's operations are shown in Tables 3 and 4 respectively. Table 5 lists the conferences and training courses attended and Table 6 the addresses given by staff. P.J. Gregson was a member of the Geophysics Advisory Committee, Curtin University of Technology, and was elected to the honorary position of Associate Member of the Department of Exploration Geophysics. He also served on a WA Department of Mines Technical Working Group on seismicity in mines in Western Australia. A visit to China was made in October by P.J. Gregson related to co-operative projects in seismology between the BMR and the Chinese State Seismological Bureau. A report on the visit is given in Appendix 2.

Visitors to the observatory are listed in Table 7.

Significant staffing changes were made during the year. B.J. Page, G. Woad and B.A. Gaull accepted early retirement packages on 8 February, 20 June and 30 August respectively. Owen McConnel (Technical Officer Grade 4) commenced duty on 4 November as the only replacement for the above positions. The hours of Y.M. Moller and L.A. Van Reeken were increased from 20 to 25 hours/week on 23 May. This resulted in changes in work practices and has lead to a decrease in the efficiency of operating a first class observatory.

3. SEISMOLOGY

Seismograph stations

Permanent seismograph stations were operated throughout the year at Ballidu (BAL), Coolgardie (COOL), Forrest (FORR), Kellerberrin (KLB), Kununurra (KNA), Manton Dam (MTN), Marble Bar (MBL), Meekatharra (MEKA), Morawa (MRWA), Mundaring (MUN), Nanutarra (NANU), Narrogin (NWAO), Rocky Gully (RKG) and Warburton (WARB). An insensitive seismograph was operated in the Mundaring office.

No further progress was made with the installation of a three component broad band seismograph at Yerdanie Rock.

A borehole was drilled at Fitzroy Crossing in preparation for installing a similar system as proposed for Yerdanie Rock.

Details of station locations are given in Table 8 and seismograph calibration data are shown in Table 9. Brief descriptions of individual station operations are given below.

The most significant problem in operation the seismograph stations was the spasmodic jump of the Omega clock displays which provided time control to the seismograms.

Ballidu (BAL). This station continued to operate exceptionally well with only 0.4% record loss. The seismometer was changed on 12 March to allow the existing seismometer to be serviced. The system was re-calibrated. At the same time cable terminations in the vault were standardised.

Coolgardie (COOL). Only 0.4% of record was lost during the year. The seismometer was changed on 27 March as the existing seismometer had a sticky movement. The replaced seismometer was serviced.

Forrest (FORR). Total record loss was 1.2% which was an improvement over the previous year. Problems with the recorder drum translation caused 0.9% of the loss and the balance by broken pens. Minor problems were experienced with pen heat control. This was rectified by replacing the pen heat control board.

Although the seismometer is 5 kilometres from the east-west standard gauge railway line, an average of about 12 trains a day caused disturbance over several minutes each. The proposal to relocate the seismometer further from the line in 1991 was deferred till 1992.

Kellerberrin (KLB). This station operated well with only 0.7% of record loss due to power failure and line outage. There was some sporadic cross interference on the Telecom line with Ballidu

Kununurra (KNA). Operational problems were similar to previous years, i.e. pen pressure (0.1%) and power failures (1.9%). Late changes contributed to a further 1.1% of record loss.

A visit was made to the station in December. The charging system needs simplification as currently there are two chargers in parallel. The automatic calibrator was unserviceable and was returned to Mundaring for repair.

Manton Dam (MTN). The station operated well during the year with an experienced operator. Broken recording pens and a failed recorder drive motor resulted in a total of 1% record loss.

Marble Bar (MBL). Total record losses were high (14%). In June lightning damaged the Telecom line and the discriminator. At the same time the electronics vault at the remote end was flooded and the 42.50 pre-amplifier damaged. Both the discriminator and amplifier were returned to Mundaring for repair. Loss in recording time was 11.3%. Other causes of record loss were power (0.6%), recorder failure (0.6%), late record change (0.5%), broken pens (0.4%) and pen pressure (0.2%). The automatic calibrator failed during the year and was replaced.

Meekatharra (MEKA). There was negligible record loss during the year, however the local background noise (crushing plants) became too great and the station was closed temporarily on 16 June. It is proposed to resite the seismometer at a location away from interference and use radio telemetry back to the recording site.

Morawa (MRWA). The major problem was sporadic jumps in the Omega clock system. An EMI clock was installed temporarily but this was not reliable. A record loss of 4.6% resulted from these problems. Power failures caused a further 0.5% loss.

The recorder was transferred to Mundaring on 5 September and a Telecom line used to telemeter data to Mundaring using FM telemetry. The seismograph has operated well since then.

Mundaring (MUN). The high gain system operated well with a line outage causing the only significant record loss of 0.7%.

Line outages on the World Standard line resulted in 1.2% record loss and recording paper falling off drums, a further 0.7%.

From November 18, recording of the two short period horizontal components ceased. An old Data General Dasher 286 was linked across the digital data line and a program organised by Vic Dent was used to capture short period events. The data is examined daily and any data for local earthquakes are transferred to floppy discs and can be analysed on a NEC PC computer.

The Wood Anderson seismometers were returned from headquarters after modification. They had not been re-installed by the end of the year.

Nanutarra (NANU). Persistent jumping in the display on the Omega clock face made time control almost impossible in the latter part of the year. Routine analysis of seismograms was discontinued from October 12. The problem had not been solved by the end of the year. A visit is planned for early in 1992.

Narrogin (NWAO). The SRO ceased recording on 11 November. The existing system was upgraded by staff from the Albuquerque Seismological Laboratory (ASL) to a high performance continuous-recording broad band digital IRIS 2 system.

Details of the upgrade are given in a USGS open-file report 89-471 by Peterson and Hutt (1989).

A simplified schematic of internal digital data flow is shown in Figure 1. The VBB sensor signals are digitised at a high sampling rate, then filtered and decimated to 20 samples per second. Data samples are four bytes in length, representing 32-bit integer words. Data taken from the VBB stream are filtered, then decimated to 1 sample per second to form the LP data stream. Similarly, the VLP data stream, decimated to 0.1 sample per second, is derived from the LP data stream. The linear-phase digital FIR filters provide very sharp low-pass corners with maximum bandwidth. Sampling rates are adjustable up to a maximum of 200 samples per second for each of the optional VSP and LG sensors. Normally, each of the VSP and LG components will be sampled at a rate of 100 samples per second. VSP and LG data samples are two bytes in length at the encoder but expanded to four bytes for processing. At this stage VSP and LG components are not available at Narrogin but it is envisaged that VSP will be in the future. Amplitude response curves are shown in Figure 2.

An automatic signal detector may be operated on any or all of the continuous data streams to detect events. The detector, based on the algorithm described by Murdock and Hutt (1983) and Murdock and Halbert (1987), is used to extract segments of event data for storage and recording and to generate a listing of each detection that includes detection time, direction of first motion, maximum amplitude of first four cycles, average period of first four cycles, and values indicating background level and quality of onset for each event. Normally, short-period event detection will be performed on the vertical-component VBB channel so that event lists are generated even at stations where VSP data are not recorded. Listings of detections are stored and recorded with the data and automatically printed out on the station printer.

Prior to storage in buffers and recording, or transmission in the case of the separated version, all of the digital data streams are compressed using a Steim compression algorithm which forms first differences between successive four-byte samples. At most stations, the amplitude difference between successive samples for the VSP and VBB signals can be represented by one byte 99% of the time, providing an average compression ratio of about 3.72 to 1. LP and VLP samples often require two bytes for representation, but the low sampling rates make compression less important. A decompression algorithm provides perfect reconstructions of the original signals for display and analysis.

The data processing module has a 40 -megabyte hard disk drive used primarily for on-line data storage. The disk has two circular buffers, one for continuous data and one for event data. Each component of data is stored in a separate file, and the relative sizes of the data files are adjustable via commands placed in the system configuration file. At least 24 hours of VBB data, one week of LP data, and one month of VLP data will be stored in the continuous data buffer. Similarly, there will be at least a full day of event data stored in the event buffer. The primary purpose of the data buffers is to provide near real time access to the digital data.

Digital data are recorded on high-density (150-megabyte) tape cartridges. Each cartridge has sufficient capacity to store over two weeks of VBB, LP, and VLP continuous data and VSP and LG event data. Automatic switchover occurs if the on-line cartridge fills with data or fails. Data are recorded in the new Standard for Exchange of Earthquake Data (SEED) format. The SEED format, developed and described by Halbert and others (1987), has been adopted for use by the Federation of Digital Broadband Seismograph Networks (FDSN). All of the information needed for data analysis - station co-ordinates, sampling rates, calibration, and many other parameters - is recorded at the station together with the data. The data format remains unchanged from the time the data are initially recorded at the station through processing and distribution to the end user. This preserves data fidelity and reduces the processing load at data collection and management centres. State-of-health information, message text, event logs, and all operator commands and logs will be recorded on the tape together with the data. It will not be necessary for any paper logs to accompany the tapes to the data collection centre. Recorded data does not flow through the disk buffer memories. Data will continue to record on tape should the hard disk drive fail. The tapes are sent to ASC (Canberra) for copying before being sent to ASL.

One of the most important and innovative features of the IRIS-2 system is the availability of the digital data to the host organisation and to other organisations that require near real--time data for analysis. There are three ports, in addition to the port used for the operator terminal, through which digital data can be accessed; one is designated for real-time telemetry, one is designated for a dial-up modem, and one is designated for a local work station. More ports can be added if necessary.

Although it remains an important network design goal, the real-time telemetry of data from stations to the data collection centre is not likely to be implemented from many stations in the very near future because of the high cost of equipment and circuits. However, system design included the capability for attaching a satellite earth station in the future should real-time satellite telemetry become feasible.

Each system is equipped with a modem for use with a commercial telephone circuit. The dial-up circuit can be used to access buffered data and perform all of the functions available to the operator through the operator terminal. Access will be limited by a password. Stations may elect to provide 'open' or 'limited' access to their system. Anyone may dial into an 'open' station to retrieve segments of data. The cost of the call is borne by the caller, and calls are limited to 30 minutes. Dialling into 'limited' access stations will be restricted to the data collection and network maintenance centres and to others at the discretion of the station.

Analog recording has been reduced to a SP-Z and LP-Z channel both with world standard response.

One shortcoming is the lack of suitable filters to analyse local earthquake data from the on-line VBB data. It is anticipated that ASL will be able to improve this situation in the near future.

Rocky Gully (RKG). Total record loss for the year was 9.0% which was unsatisfactory. The 42.50 pre-amplifier failed, resulting in 6.2% of the loss. The excessive time resulted from failure to identify the problem and delays in replacing the amplifier. Late record changes contributed 1.8% of the record loss. Fluctuating pen heat caused 0.8% record loss. The recording room temperature varies over a wide range in winter causing loss of pen heat. Inconsistent pen pressure and the pen slipping on the motor shaft contributed to poor records for a week.

Warburton (WARB). Operator reliability throughout the year was a big improvement over 1990. Total record loss for the year was 0.4%.

Temporary stations.

Kelunji seismographs installed at Northam (NOR), Clackline (CLK) and Wooroloo (WOO) in November 1990 were closed on 4 February so they could be shifted to Ongerup where five sites were occupied during February and April (see Table 8 for details).

Accelerographs

Twenty-two accelerographs were in operation in Western Australia in 1991. Nine were owned by the Bureau of Mineral Resources; ten by the Water Authority of Western Australia (WAWA) and three by Telecom. All instruments were maintained by observatory staff until midyear when the WAWA took over responsibility for maintaining their accelerographs.

The Water Authority A700 accelerographs were located on the following dams - Canning (2); Serpentine (2); Lake Argyle (2); North Dandalup (1) and Victoria (1). SMA1 and MO2 accelerographs were operated at Mundaring Weir. The three Telecom accelerographs were SMA1 instruments and were operated for the four years in the main telephone exchange building in Perth.

All BMR accelerographs were located in the south-west seismic zone.

The deployment of the two BMR A700 recorders was varied during the year. The recorder at Emmott's farm, Cadoux (CA-E) was closed in June and relocated to Meckering (ME-3) in July. The recorder at Kalajzic's farm at Cadoux (CA-A) was returned to Mundaring for servicing in September, and then was used to replace the recorder at ME-3 in October, which has been malfunctioning.

Because of continuing false triggering at DOW, the analog board in the Kelunji recorder was exchanged with a replacement (from PIT) in October. This seemed to decrease the frequency of false triggers. The accelerometer at Dowerin has continued to operate on horizontal channels only, while the vertical sensor is in the USA awaiting repair. The "Guria" programs operating the Kelunji accelerographs at Goomalling and Dowerin were upgraded from Version 4.04 to Version 4.07C during the year (GOO in July and DOW in August).

The MO2 recorders at Cadoux, Ballidu and Meckering continued to operate normally during 1991, although only the recorders at Cadoux were triggered by earthquakes.

In June, a Sprengnether 2Hz seismometer coupled to a Kelunji recorder was used to determine the free period of the Northam hospital. The building is a "T" shaped building, seven storeys high. The foot of the "T" was considered as being south for the purpose of orienting the seismometer. Readings of 30 second duration were made at the centre of each arm on the top floor and at the centre of the south arm on the second and sixth storey. Recordings were analysed by K.F. McCue as part of a risk study for the hospital.

Details of instrumentation type, calibration data, location and dates of operation are given in Tables 11 and 12.

Strong motion data recorded during the year is listed in Table 13.

Seismicity

Table 10 lists 217 earthquakes of magnitude ML 2.0 or greater that were located in Western Australia in 1991. In the South-West Seismic Zone those of magnitude ML 1.5 or greater have been located. Epicentres of those with magnitude ML 2.5 or greater are shown in Figure 3. Areas of significant activity are discussed below. Where zone numbers are used they refer to zones defined by Gaull and others (1990).

Four earthquakes of magnitude ML 4 or greater occurred in the region of Western Australia during the year. These occurred 5 km S of Kalgoorlie on 3 March (ML 4.2); 111 km NE of Marble Bar on 23 September (ML 4.0); 158 km N of Exmouth on 18 October (ML 4.3) and 20 km SW of Cranbrook on 13 December (ML 4.3). Of the 83 earthquakes of magnitude 2.5 or greater shown in Figure 1, just over half (53%) were located within defined zones and a further 24% adjacent to these zones. The remaining 19 (23%) were located away from defined zones.

Southwest Seismic Zone (zones 1 and 2). Earthquakes were located in the zone (Figure 4) which was slightly more than 1990. Cadoux continued to be an active area (27 events). The largest being ML 3.3 occurring on 8 January. Other areas of activity were Meckering (18); Quairading (9); Nyabing (12); Brookton (6) and Wyalkatchem (6). Minor activity occurred near Burakin (5); Merredin (2); Ongerup (3); Beacon (3); Pingrup (2); Wooroloo (2); Cranbrook (2) and Gnowangerup (2). Single earthquakes located near Wubin; Beacon; York; Wongan Hills; Kellerberrin; Darkan; Katanning; Tambellup; Ballidu; Dumbleyung; Calingiri; Pingelly; Kirup and Mingenew. The latter two are of particular interest as they are located very close to the Darling Fault where no previous activity has been recorded. They were magnitude ML 2.7 and 2.9 and occurred on 2 May and 17 August respectively.

Kalgoorlie (zone 7). Small tremors and frequent blasting are felt in the Kalgoorlie area. A magnitude ML 4.2 earthquake occurred near Kalgoorlie on 9 March. This is described below. The severity of the earthquake caused considerable concern to the mining company and the State Mines Department that the latter initiated a working group to examine all matters related to seismicity in mines in Western Australia. A report was prepared on Kalgoorlie seismic events 1964-1971 (Gregson, 1992).

Earthquake intensities and isoseismal maps

Isoseismal maps were prepared for 4 earthquakes as described below. Old newspaper reports were used to prepare an isoseismal map for a 1906 magnitude 7 $^3/_4$ earthquake that was located off the north-west coast (Gregson & Everingham, 1991).

Kalgoorlie, 9 March (Figure 5). Kalgoorlie-Boulder is the centre of gold mining on the Golden Mile, Eastern Goldfields and the residents are familiar with frequent mine explosions. On 9 March 1991 at 9.36 a.m. (WST), the residents were shaken much more severely by a magnitude ML 4.2 earthquake. The epicentre was determined as 5 km SSE of Kalgoorlie which is consistent with reports of maximum intensity.

The maximum intensity at the surface was MM VI which was experienced in Boulder up to 3 km from the epicentre. The radius of the MM V was 7 km. Population in the region outside Kalgoorlie-Boulder is sparse and only scattered reports were received. The maximum intensity reported outside the town was MM IV at a distance of 30 km east.

The Kalgoorlie Prison in South Boulder suffered damage valued at $30,000 (personal communication). Severe damage (MM VIII) occurred in the underground mine workings near the Perserverence and Lake View shafts between the 500 m and 600 m levels. Stope pillars creaked, timbers fell and rails lifted from the floor of the drives. In some areas at about 500 m, the floor heaved, water flow increased and drives disappeared as a result of collapse. The Perserverence shaft was stripped of timbers below 500 m by falling rock. One "crib" room was damaged by dislodgment of rocks.

A phone conversation between two people 7 km apart in Boulder (S) and Kalgoorlie (N) lends support to the epicentre determination.

S "Did you feel that" N "No...........yes I did".

Aftershocks occurred at follows:

Date 1991	Time UT	Lat° S	Long° E	ML
Mar 09	0318	30.72	121.42	0.5
Mar 09	0405	30.72	121.42	0.8
Mar 09	0821	30.72	121.42	0.7
Mar 09	1629	30.72	121.42	1.4
Mar 10	0552	30.72	121.42	1.5
Apr 10	0606	30.72	121.42	3.1
Apr 10	0635	30.72	121.42	2.5
Apr 11	0205	30.72	121.42	1.5
Apr 12	0137	30.72	121.42	1.5

Karratha, 9 April (Figure 6). A magnitude ML 3.5 earthquake located just offshore between Karratha and Wickham occurred at 10.00 p.m. (120 EMT) on 9 April, 1991. Apart from the few towns, the region is sparsely populated.

The maximum intensity experienced was MM IV in the Karratha - Roebourne region. The radius of the MM IV isoseismal was 30 km and the earthquake was felt over an area of 5000^2 km.

The region is significant because of the north-west gas facilities at Burrup Peninsula, gas pipeline, the iron ore port facilities at Dampier and the town of Karratha (population 11,000).

Other earthquakes located within 50 km are:

Date		Time UT	Lat° S	Long° E	Magnitude
1968	Jul 04	0648	20.80	117.10	4.8 MB
1987	Jun 19	1332	20.56	116.69	3.7 ML
1989	Apr 30	1616	20.52	117.26	2.5 ML
1990	Oct 29	0452	20.71	116.82	2.8 ML

Albany, 22 September (Figure 7). A Richter magnitude 2.5 seismic event occurred at 1.01 a.m. (local time) on 23 September. The epicentre was located about 10 km south-west of the Albany townsite. The maximum MM intensity experienced was IV with ground vibrations and windows rattling. Where it was possible to determine the direction from which the ground vibrations came at Grassmere and Albany, they were consistent with the epicentre.

There were several reports of explosion like sounds and flashes of light, co-incident with the time of the seismic event. It is possible that a meteorite sighting occurred simultaneously.

A series of 14 earthquakes ranging from magnitude 1.2 to 4.5 occurred 15 km to the east in May 1977. The details of the largest are shown below.

Date	Time	Lat° S	Long° E	Depth	Magnitude
1977 May 05	19 19 07.6	35.00	117.95	10N	ML 4.5

Shay Gap, 23 September (Figure 8). At 5.20 a.m. (24 September local time) a Richter magnitude 4 earthquake occurred 60 km south-east of Shay Gap. The region is sparsely populated with the closest report being about 15 km from the epicentre. MM intensities of IV were reported up to 75 km from the epicentre.

Six earthquakes of magnitude 4.0 or greater have been recorded within 50 km of the epicentre of this earthquake.

Date	Time	Lat° S	Long° E	Depth	Mag	Place
1975 Jul 25	22 23 41.7	21.09	120.47	10N	MB 5.0	90 km E Shay Gap
1982 Nov 03	02 40 32.0	20.53	120.48	37	ML 5.2	Shay Gap, WA
1985 Apr 09	07 18 04.8	20.49	120.52	10N	ML 3.0	100 km E Marble Bar
1988 Jan 28	01 46 30.0	21.05	120.60	5N	ML 4.8	90 km E Marble Bar
1988 Jan 28	01 49 34.0	21.05	120.60	5N	ML 4.6	90 km E Marble Bar
1988 Jan 28	01 56 17.5	21.05	120.60	5N	ML 5.0	90 km E Marble Bar
1988 May 16	18 16 00.5	21.42	120.19	5N	ML 3.0	55 km SE Marble Bar

Cranbrook, 13 December (Figure 9). The earthquake occurred at 1.48 p.m. WSST. The maximum MM intensity reported was V at a location 20 km northwest of Cranbrook where a skid mounted bed unit moved off it's foundation.

The radius of the MM IV isoseismal was 45 km and the earthquake was felt up to distances of 90 km.

Only one other earthquake has been reported within 20 km of this location. Details are shown below.

Date	Time	Lat° E	Long° S	Depth	Mag	Place
1977 04 09	09 47 57.0	34.44	117.44	10N	ML 3.5	WA

Water level monitoring

Three ground water instruments measuring water level changes were operated throughout the year. There were no significant recordings.

Microzonation

Field work and basic analysis were completed by June. Operational procedures and preliminary results are presented in a report by Gaull and Others (1992).

Data distribution, publication and requests

Monthly lists of Western Australian earthquakes were distributed to interested recipients.

Numerous requests for seismic data were attended to during the year. Narrogin magnetic tapes were sent to the Australian Seismological Centre (Canberra) where they were copied prior to being forwarded to Albuquerque Seismological Laboratory (ASL). Mundaring WWSS and Narrogin SRO seismograms were sent to the WDC-A and ASL for copying. With the upgrade of Narrogin to an IRIS system, seismograms were no longer required to be sent to ASL.

4. GEOMAGNETISM

The Eschenhagen 20mm/hr magnetograph continued operating at Gnangara recording the three components D, H and Z until February when it was decommissioned. Routine recording with the Elsec Automatic Observatory (AMO) continued throughout the year. Three components D, F and I were recorded digitally at minute intervals.

An EDA fluxgate magnetometer was operated at Learmonth throughout the year. Three components X, Y and Z are recorded digitally at minute intervals on an EDAS tape recorder.

GNANGARA

Eschenhagen magnetograph. The magnetograph operated satisfactorily without loss of record until it was decommissioned on 10 February. There were no abrupt changes in base or scale values.

Adopted scale and baseline values for 1991 are shown below. The corrections applied to derive the adopted values are given in Table 14. The standard deviations from adopted values were not computed for the short period of operation.

SD = 1.09'/mm	So = 2.46 nT/mm	SZ = 5.10 nt/mm
BD = 3°02.3'W	BHt = 23112 nT	BZt = 53800 nT

Temperature coefficients (Table 17). Values of qH = 0.0 nT/°C remained valid for the period of operation and qZ = 1.0 nT/°C has applied since August 1988.

Scale values. A magnetograph calibration MCO2 was used in conjunction with Helmholtz coils to determine H and Z scale values once weekly.

Automatic Magnetic Observatory (AMO)

Routine recording continued throughout the year using the Elsec Automatic Magnetic Observatory at Gnangara. Variations in the three components D, F and I are recorded at minute intervals. Data are telemetered back to the Mundaring office using a Telecom line and recorded on a dedicated NEC APC IV computer using $5^1/_4$" discs formatted for 1.2 mbyte capacity. A Cleveland PC is located at Gnangara as a backup in the event of the communication link or NEC PC failing. An SPS-1000 backup power supply is installed at Gnangara to ensure that operation continues in the event of a mains power failure. The NEC PC at Mundaring is operated from continuous SRO power.

The main problems during the year were associated with transmission of data from Gnangara to Mundaring. There were several Telecom line outages and faults with the line modems (Data phone 300). In the winter months there were frequent occurrences of loss of data transmission on cold and wet mornings. The problem was temporarily solved by placing the modem at Gnangara in a warm location. It was discovered in November that the 9V power supply in the modems was only delivering 7V. The power supply in all three modems were upgraded and there have been no more problems of this nature. Even with the transmission problems there was no loss of data as the backup at Gnangara was available.

The orientation of the AMO coils were adjusted on 5 January so that recordings of 5000 for ΔD and ΔI were closer to the mean values of these components. Coil adjustments were:-

D $4^\circ 55'$ to $4^\circ 40'$ and I $6^\circ 01'$ to $5^\circ 50'$

Scale values for D and I were determined geometrically using the formulae:

DSV = tan 1'/mean H and ISV = tan 1'/mean F.

Values for 1991 were:

DSV = 0.01483'/count and ISV 0.00587'/count

Adopted baseline (at 5000 counts) values are given in Table 20 and Figure 10 with standard deviation between observed and adopted values in Table 19. There were no abrupt changes in adopted scale and baseline values other than when the AMO coils were re-oriented on 5 January.

All control values are filed on the BMR Data General computer in a file GNA1991BLV.

Magnetometers

Absolute observations of D, F and I were made at weekly intervals. A DIM (S/N 313837) and Elsec PPM (S/N 215) were used throughout the year on piers NE and NW respectively. There were no corrections applied to the values measured.

Routine observations of D, H and Z using the Elsec PVM were discontinued.

Comparisons

Comparisons were made through baseline values between the Gnangara DIM (S/N 313837) and DIM's (S/N 353758 and 311847) on transit to and from Learmonth respectively. Comparison results are shown in Table 15.

Reference marks

Auxillary reference marks were not checked during the year. Results from previous measurements are shown in Table 16.

Date reduction and publication

Routine distribution and publication of data from Gnangara is shown in Table 29.

The last batch of Eschenhagen magnetograms up to 7 February were sent to headquarters for the reduction of mean hourly values. Weekly files of AMO digital data were transferred to the BMR Data General computer where they are stored for later processing. All control data is prepared at Mundaring.

Monthly and annual mean values of H, D, Z and F for 1991 are listed in Table 21. The values were determined by averaging all minute values for each month. Annual values and secular variations for all components since 1981 are shown in Table 22. Changes in D continue the easterly trend by 4.4'. H continued to decrease by 22 nT and Z increased by 8 nT. The mean value of F decreased by 18 nT.

K- Indices for each week are dispatched to the Ionospheric Prediction Service (Sydney) from where they are distributed to their recipients. Components of K-Index are stores on computer at headquarters.

Checked data for solar flare effects for 1989 were prepared for the IAGA bulletin.

LEARMONTH

EDA fluxgate magnetograph. Components of X, Y and Z were recorded throughout the year without significant loss. Recording of an F channel were spasmodic, but as the field could be defined by X, Y and Z it was not a problem.

Figures 11, 12, 13 and 14 show the observed and adopted values for zero, scale, baseline at temperature and baseline at 25°C respectively. Temperature coefficients used were those shown below. Adopted control values are listed in Table 25 and standard deviations between observed and adopted values in Table 26. Corrections applied to observed values for each instrument are shown in Table 23.

There were unexplained jumps in values as follows:

Z	zero value	April 01	0000 UT	+ .46 counts
Y	scale value	March 01	0000 UT	- 0.07 nT/count
X	base value (25°C)	September 10	0000 UT	+ 5 nT
Y	base value	Mar 01	0000 UT	+ 10 nT

All control values are filed on the BMR Data General computer in file LRM1991BLV.

Temperature coefficients

The scale value for the Doric thermograph was re-determined (Figure 15) using values for the whole year. There was only a slight difference from that used in 1990 but it was considered a better result as the full year's data was used for 1991.

$$T^{\circ}C = 0.0204 \times \text{count} + 4.43$$

Temperature coefficient for each recording component X, Y and Z were determined from observed baseline values at temperature and temperature determined from the Doric thermograph. Plots of each component are shown in Figure 16.

X $+1.19$ nT/^{o}C Y -0.31 nT/^{o}C Z 1.74 nT/^{o}C

Temperature coefficients used previously are shown in Table 24.

Magnetometers

Absolute observations for D, F and I were made at weekly intervals using a DIM and Elsec E801 proton precession magnetometer. The DIM was changed on 24 August as the one in use was poorly adjusted giving large differences between complementary readings. Both DIM's used at Learmonth were compared with the Gnangara DIM (see Table 15).

Reference marks

Auxillary marks were not used or checked during the year.

Data reduction and publication

Routine distribution and publication of data from Learmonth is shown in Table 29.

All control data is prepared at Mundaring. Digital tapes of minute values of X, Y and Z are sent direct to headquarters where they are stored for further processing.

Monthly mean and annual values of field components were determined at headquarters and are shown in Table 27 and 28 respectively. The trends indicated since installation of the magnetograph in 1986 are D becoming more easterly (2.8' /annum); H increasing (15 nT/annum); Z remaining fairly constant and F increasing (6 nT/annum).

Magnetic surveys

A compass swing bay survey was carried out for the Federal Airports Corporation (FAC) at Jandakot in September. A Wild compass theodolite and Elsec magnetometer was used for this purpose. The results are shown in Figure 17.

Northern Territory observatory site

Several sites in the vicinity of Kakadu National Park were inspected with the view of establishing a new magnetic observatory within the next few years (see report Appendix 3).

5. IONOSPHERICS

A quarter-hourly sounding schedule was continued throughout the year using a model 4B ionosonde. Observatory staff maintained the ionosonde, with spare parts and film being supplied by the Ionospheric Prediction Service.

Three special sounding programs were run during the year when soundings were made at 5 minute intervals. These were March 14-27 (sundial campaign), October 1-10 (terminator campaign) and December 1-31.

A total of 6.9% of record was lost; 3.9% as a result of the film jamming; 1.9% due to equipment failure and 1.1% because the film ran out. Equipment failure occurred on two occasions. In April after a protective ELCB threw out, the standby battery did not hold up. The batteries were replaced. On August 14 the mains power switch was left off during a routine service visit. The batteries flattened and the main recording CRO was damaged. Recording was temporarily made on the monitor CRO until a replacement was provided by IPS.

Data distribution and publication

The F2 layer critical frequency at each six hours UT and local noon were scaled. The six-hourly values were sent to IPS for distribution internationally and the monthly median of the noon values wqas telex to the International Radio Consultative Committee (Geneva) for the determination of the index IF2. The Hourly values of all parameters are published in the IPS Series D and are distributed internationally. Ionograms are available on loan within Australia from IPS and internationally through the WDC-A.

6. GENERAL OPERATIONS

Computing

An Apple Macintosh IIci computer and laser printer (Personal Laser Writer) were added to the system. The need for this computer arose because all future upgrades of the Phillip Institute of Technology Seismic Interpretation (PITSIS) will be written for the Apple Macintosh.

A SUN workstation was purchased in preparation for analysing digital data from the proposed Yerdanie seismograph.

Works program

There were no major works projects during the year. Only urgent minor maintenance was carried out. IPS erected a security fence around the ionospheric building at the Weir site.

7. ACKNOWLEDGEMENTS

The assistance of the daily attendants listed in Table 4 and the co-operation of Telecom for housing the seismograph at Marble Bar is hereby acknowledged. Remote seismometers and telemetry equipment were located on the properties of K. Quartermaine (Narrogin), V. Wright (Kellerberrin) and T. Mailey (Ballidu).

8. REFERENCES

EVERINGHAM, I.B., McEWIN, A.J. & DENHAM, D., (1982) - Atlas of isoseismal maps of Australian earthquakes. *Bureau of Mineral resources, Geology and Geophysics,* Bulletin, 214.

GAULL, B.A., MICHAEL-LEIBA, M.O., & RYNN, J.M.W., (1990) - Probabilistic earthquake risk maps of Australia. *Australian Journal of Earth Sciences,* 37, 169-187.

GREGSON, P.J., (1992) - Mundaring Geophysical Observatory Report 1990. *Bureau of Mineral Resources, Geology and Geophysics,* Record, 1992/ (unpublished).

GREGSON, P.J., 1986 - Australian Seismological Report 1982. *Bureau of Mineral Resources, Geology and Geophysics,* Report 273.

GREGSON, P.J., & EVERINGHAM, I.B. (1991) - Indian Ocean earthquake felt in Australia 19 November 1906. *Bureau of Mineral Resources, Geology and Geophysics, Journal*

McCUE, K.F., 1980 - Magnitude of some early earthquakes in southeastern Australia. *Search,* 11 (3), 78-80.

PETERSON, J., & HUTT, C.R., (l989) - IRIS/USGS Plans for upgrading the global seismograph network. *U S Geological Survey, Open file Report* 89-471.

MURDOCK & HUTT, C.R. (1983) - A new event detector designed for the seismic research observatories. *U S Geological Survey, Open file Report* 83-785.

MURDOCK, & HALBERT (1987) - A C language implementation of the SRO (Murdock) detector/analyzer. *U S Geological Survey, Open file Report* 87-158.

APPENDIX 1

PRINCIPAL EVENTS

MUNDARING GEOPHYSICAL OBSERVATORY 1957-1991

1957 May	Geomagnetic recording commenced at Gnangara (La Cour)
1959 Mar 18	Transfer of observatory from Watheroo to Mundaring
1959 Apr 03	Ionospheric recording commenced (Type 2 ionosonde)
1959 Jul 30	MUN seismograph recording commenced (Benioff)
1960 Mar-Oct	Atmospheric noise recording (for CSIRO)
1960 Apr 30	Eschenhagen normal magnetograph replaced La Cour at Gnangara
1960 May 01	Cossor ionosonde replaced Type 2
1960 Jun 22	Absolute magnetic observations commenced in new absolute house
1962 Jun	WWSS system commenced recording at MUN
1963 Apr 19-Dec 17	GRV seismograph operation
1963 May 30-Dec 19	NGN seismograph operation
1964 Nov 06	KLG SP seismograph recording commenced
1965 Nov 29-1966 Aug 24	LVS seismograph operation
1965 Nov	KNA SP-Z seismograph recording commenced; operation intermittent till February 1972
1967 Feb	Fremantle Region Upper Mantle Project
1967 Oct 26	MEK SP-Z seismograph recording commenced
1968 Oct-Nov 26	Field seismograph operation at Meckering
1968 Nov16-1971 Dec 31	AFMAG recording at Mundaring
1970 Jan 01	Routine analysis of KNA seismograms commenced
1970 Feb 26	IPS IIIE ionosonde replaced Cossor
1971 Feb 10-1972 Jul 31	KAA SP-Z seismograph operation
1971 Nov 30	Two MO2 accelerographs installed at Meckering
1972 Feb 29	KNA seismograph upgraded to 3 components
1972 Mar 01	MO2 accelerograph (PWD) installed at Kununurra
1972 Jun 27	Proton scalar magnetometer introduced for Z baseline control
1972 Oct 12-1975 Feb	MBT SP-Z seismograph recording
1972 Nov 16	MO2 accelerograph (PWD) at Kununurra
1973 Jan 31	Mobile SP-Z recording at various sites in SW seismic started
1973 Mar 01	MEK reduced to 3 component SP
1973 Mar 30	KLG reduced to SP-Z
1973 May 23	MUN 2 Wood Andersons installed
1973 May 25	MUN Benimore SP-Z withdrawn; Benioff SP-Z started
1974 Apr 01	Proton vector coils introduced for Z baseline control
1974 May 01	Proton vector coils introduced for H baseline control

1974 Jun 17-31	Riometer recording at Mundaring during solar eclipse
1974 Sep-1978 Jun	GLS SP-Z recording
1975 Jul 18-Nov 19	Earthtide recording at Mundaring
1975 Mar	Magnetic pulsation recording commenced at Mundaring
1975 Mar 19-Aug 15	SWV SP-Z recording
1975 Sep 02-1976 Feb 05	NWAO SP-Z recording
1976 Mar 27	NWAO Seismic Research Observatory commenced
1976 Jun	MBL SP-Z recording commenced
1976 Sep-1977 Nov 27	XMI recording
1976 Oct	Special ionospheric sounding, solar eclipse (23 Oct)
1977 Nov 28	A third MO2 accelerograph installed at Meckering
1978 Feb	A fourth MO2 accelerograph installed at Meckering
1978 Jun 27	WBN SP-Z recording commenced
1980 Jun 19	NAU SP-Z recording commenced
1981 Aug 07-1982 Mar 27	BAL SP-Z recording commenced
1981 Sep 23	KLG SP-Z recording commenced
1981 NOv 19-1982 Jun 27	Walpole SP-Z field recording
1982 Nov 26	BAL SP-Z recording commenced
1983 Aug 03	RKG SP-Z recording commenced
1984 Jun 21	MRWA SP-Z recording commenced
1986 Mar 04	First digital accelerograph (A700) installed at Cadoux
1986 Apr 30	MEK SP-Z recording transferred to MEKA
1986 May 12	KLG SP-Z recording transferred to KLGA
1986 Oct 26	Geomagnetic recording commenced at Learmonth
1987 Jan 16	Program of strong motion recording commenced on WAWA dams
1987 Jun 27	WBN SP-Z recording transferred to WARB
1987 Oct 22	NAU SP-Z recording transferred to NANU
1988 Apr	Office accommodation extended
1988 Aug 10	KLGA SP-Z recording transferred to COOL
1988 Oct 07	FORR SP-Z recording commenced
1988 Dec	Webster computer installed
1989 Sep 13	First Kelunji recording equipment installed at Dowerin
1990 - 1991	Perth microzonation project
1990 Jul 03	GNA routine AMO recording commenced
1991 Feb 10	GNA Eschenhagen magnetic recording ceased
1991 Dec 15	NWAO SRO upgraded to an IRIS system

APPENDIX 2

REPORT OF VISIT TO CHINA

PURPOSE OF VISIT

The purpose of the visit was to:

1. Pursue the program of co-operation between the Chinese State Seismological Bureau (SSB) and the Australian Bureau of Mineral Resources (BMR). The two projects concerned with this visit were:
   (a) Digital earthquake strong motion project.
   (b) Comparative seismicity study.

2. To attend the China International Symposium on Geological hazards and prevention.

Officers

Mr Garry Gibson (Phillip Institute of Technology, Vic).
Mr Peter Gregson (BMR, Mundaring Geophysical Observatory, WA)

Dates

Oct 18-19 1991 Hong Kong.
Oct 20-25 Beijing - symposium.
Oct 26-31 Beijing - Beijing strong motion observation centre (BSMOC).
Nov 01-03 Guangzhou - seismological Bureau of Guangdong Province.

VISIT TO ROYAL OBSERVATORY HONG KONG

The observatory was visited on Sat 19 October.
Unfortunately the scientific officer Mr Wai Hung Leung (seismology) was not available, however the seismic operations were inspected guided by Mr Ming Sun Chau and Mr On Wong.

In recent years, considerable interest has been generated in local and regional seismicity. The occurrences of disastrous earthquakes in China, such as the Tangshan earthquake in 1976, heighten the awareness of the need to take seismic risk into account in engineering studies.

In order to monitor in more detail the location and magnitude of earthquakes in the vicinity of Hong Kong, a network of three short-period seismographs was installed in 1979. The stations, each equipped with a vertical-component high-gain short-period seismometer, are located at Tsim Bei Tsui, Yuen Ng Fan and Cheung Chau. These sites are located near the northwestern, southwestern and eastern extremity of Hong Kong so that sufficiently long baselines are available for the computations of epicentral positions by triangulation. The array of seismographs is designed such that epicentral parameters of earthquakes occurring within 60 km from the Royal Observatory can be readily estimated. These sites are also relatively 'quiet' in terms of background seismic noise.

The signals collected at the stations are amplified electronically and transmitted to a central recording station at Royal Observatory headquarters through telephone lines. The signals are registered on three pen-and-ink recorders. They are also digitised at a rate of 20 samples per second and passed to the memory of a microcomputer which holds the latest 10 seconds of data. Should the amplitudes of the signal exceed a specified threshold, the content of the buffer together with data in the next 5 minutes are recorded on a floppy disk. Thus only significant tremors are recorded. The digital records are retrieved for analysis on a microcomputer using a combination of visual and correlation methods. Since the establishment of the local seismograph network in 1979, three felt earthquakes, all of magnitude 1.5, with their epicentres lying within the Hong Kong territory were detected. Two occurred at Lantau Island in August and October 1982 and one occurred near Mai Po in December 1983.

Strong motion accelerographs were installed in 1977. Since ground accelerations depend on the type of soil or rock at each site, the accelerographs were placed at different locations, viz, Tate's Cairn on granite, and Royal Observatory on decomposed granite. The accelerograph records provide information on ground accelerations due to earthquakes which is extremely useful for researches in engineering seismology. However, since installation, these strong motion accelerographs have not been triggered.

The Royal Observatory participates in two international seismological networks: the Worldwide Standardised Seismograph Network since 1963 and the Regional Seismological Network for Southeast Asia since 1979. The former is based in Washington and monitors the larger earthquakes in a global scale and publishes monthly and annual seismological bulletins. The latter is based on Manila and monitors in greater detail the seismic activity of Southeast Asia, including the earthquakes of relatively smaller magnitude in the region.

Preliminary analysis of the seismograms is carried out routinely at the Royal Observatory. The results are sent by mail on a monthly basis to other centres such as the International Seismological Centre (ISC) in the United Kingdom; the United States Geological Survey (USGS); the State Seismological Bureau (SSB) in Beijing; the Guangdong Seismological Bureau (GSB) and the Macau Observatory. They are also sent to WAshington via GTS in the form of coded 'SEISMO' messages; and to a number of Southeast Asian countries by telex.

At the request of local and overseas scientific institutions, the Royal Observatory provides seismological information for their special studies and investigations. Technical reports on the seismology in Hong Kong are published from time to time. Topics covered include the seismicity of Hong Kong and the statistical analysis of earthquake occurrence in the vicinity of Hong Kong. The observatory also provides the time service for Hong Kong and is a member of the Pacific Tsunami Warning System.

The observatory is located at 134 Nathan Street, Kowloon, Ph 732 9430.

CHINA INTERNATIONAL SYMPOSIUM ON GEOLOGICAL HAZARDS AND PREVENTION

Date:	21-25 October
Location:	Beijing Friendship Hotel
Delegates:	Australian delegates: G. Gibson (PIT) and P.Gregson (BMR). Approximately 200 Chinese and 23 from foreign countries including France (3), USA (3), Sth Africa (3), Australia (2), Canada (2) and one each from Germany, Taiwan, Fiji, Israel, Philippines, Indonesia, Thailand and Vietnam.
Program:	Mon - general hazards sessions Tue - general hazards sessions Thu pm - presentation of Chinese hazard maps and poster session. Fri am -general hazards session Fri pm -special topic sessions (concurrent) (a) earthquake and land fissures (b) avalanche, landslides and debris flow (c) land subsidence etc

Remote sensing branch sessions were held on Thursday and Friday with a visit to the Remote Sensing Centre on Friday afternoon.

Topics:	Over 50 papers were presented during the general hazards sessions covering the following topics:	
	General hazards on specific areas	16
	Earthquake related	8
	Landslides	10
	Slumping, subsidence	7
	Flooding	4
	Erosion	4
	Mining	1
	Permafrost	1

Eight papers were presented during the special topic session (a).

Australian papers were:
P.J. Gregson - Seismic hazards in Australia
G. Gibson - Tennant Creek and Newcastle earthquakes.

Scientific value

As an international symposium it would have had little impact. The majority of the foreign delegates were primarily in Beijing for other reasons.

Although the papers and topics presented were of interest, the subject matter was very broad. The most value would have been for the Chinese delegates in obtaining a broad view of geological hazards in China.

Some useful contacts were made, particularly related to seismic zoning and mine induced seismicity.

BMR - SSB DIGITAL EARTHQUAKE STRONG MOTION PROJECT

Date: 26-31 October.
Location: Beijing Strong Motion Observation Centre, Beijing.
Objective and relevance: To obtain representative intra-plate strong motion data as quickly as possible. Both China and Australia experience large intra-plate earthquakes. To reduce the damaging effects from these earthquakes it is important that records of strong ground motion are obtained. These data are necessary to improve earthquake hazard assessment and develop better building codes.

Key personnel:	Peng Ke-zhon,	Director BSMOC	Beijing
	Zhou Yongnian,	Assoc Prof IEM	Harbin
	Wang Jinhang,	IEM	Harbin
	Zhang Wen-Bo,	BSMOC	Beijing
	Shuangjiu Yu,	Senior engineer BSMOC	Beijing
	Jiang Yicang,	SSB office	Zhao
	Ma Chungin,	Director seismic data exhibition	Tangshan
	Wu WeiLian,	Field officer BSMOC	Beijing
	Ge Zhizhou,	Director Planning Dept	Beijing

BSMOC	Beijing Strong Motion Observation Centre
IEM	Institute of Engineering Mechanics
SSB	State Seismological Bureau

Professor Peng - made only a brief appearance as he was committed to other duties outside Beijing.

Professor Zhou -	stand in for Prof Peng.
Wang Jinhang -	designed the WLJ-200 series accelerometer. He was quite capable of learning to operate the system and played a key part in the installation.
Zhou Wen Bo -	although he had only been with the SSB for one month he was a student of Prof Peng's. He was most capable and familiar with computer operation. He was able to pick up the operation of the Kelunji system very quickly. He will probably carry out the routine operation of the Kelunji.
Zhou Yongnian -	Further analysis of the data will be made by Zhou at Harbin.

Kelunji installation

One Kelunji recorder was installed at the SSB office at Zhao Ge Zhang mine site, about 30 km east of Tangshan.

The Kelunji was connected to a WLJ-200 accelerometer. The latter was bonded to the concrete floor using an araldite type glue. The orientation of the accelerometer was 1. east 2. north and 3. vertical (I suspect that the polarity is reversed, and this will be checked by Wang).

Installation went without any significant hitch although occasionally communication difficulties slowed progress down.

The only concern with the installation was whether the charger was capable of delivering enough current to keep the battery charged. Time will tell. The Chinese expressed some concern with the high sensitivity of the trigger in that the memory would fill before a month. They agreed to leave it as it was at this stage. Both GG and PJG considered it would be ok.

Installation was completed by 0400 UT and a small ML ~ 1.6 was recorded at 0429 UT (see Appendix 6). This created much excitement by all concerned.

It is proposed to service the Kelunji at monthly intervals or after a large earthquake.
Site code is ZHA on rock basement.
The delay in access to the second Kelunji (see later) proved useful in the end as it enabled a final run through the total system with Zhang and Wang. The Kelunji and accelerometer were left set up at BSMOC (Beijing) where experience can be obtained by the operators in the next few weeks. It is proposed to install the system at Zhao on the first maintenance visit.

The second Kelunji would be installed at Zhao on soil about 15 km east of the first site.

Maintenance

Any board maintenance will be arranged through G. Gibson (PIT). If there are program changes (although this is unlikely) EPROMS can be changed on site.

It is considered that the most probable source of failure is the battery charger which can be upgraded on site.

Accelerometer WJL-200

The new model is more compact that that tested in Australia. All three components were mounted in the one case measuring about 10 to 12 cm cube. It proved quite satisfactory and had an acceptable noise level, better than the unit tested at PIT. The possibility of including facility for calibration was discussed and this should be no problem. Currently full scale +/- 5V = 2g. This could be charged to +/- 1g. The power requirement is +/- 15V at 80 ma.

The accelerometer is glued (araldite or equivalent) to the basement. They have had no problems in separating the accelerometer at a later date.

Single horizontal and vertical components are available.

The current price of a three component unit is about US$2000.

Data Exchange

Existing data - A typical copy of Chinese data is already in Australia. Zhou will attempt to prepare a digital copy on disc before our departure from Beijing. Failing this, a copy will be brought to Australian when they next visit (May 1992?). Data will be mainly from the Tangshan area.

It was agreed that significant strong motion digital data that is available for Australian earthquakes should be gathered together for exchanging with the Chinese during their next visit. This needs to be co-ordinated in Australia before their visit.

New data - China will send copies of all digital recordings recorded on the Kelunjis at Zhao, together with earthquake parameters. This will be on a monthly basis organised by Zhou from Harbin, even through the earthquake parameters will come from another source.

Initially data will be sent to K.F. McCue, BMR, Canberra.

Likewise copies of strong motion digital data from BMR (Canberra - Mundaring) and PIT together with earthquake parameters will be sent to Prof. Zhou Yongnian, 9 Xuefu Rd, Harbin, China. This applies to events of > 0.01g for the duration of the project.

Analysis of data in China will be carried out by Zhou at Harbin Institute of Engineering Mechanics (SSB).

Visit to Australia

It is proposed that at least two Chinese delegates should visit Australia in April/May 1992. It is likely that these would be Prof. Zhou and Wang Jinhang. The decision rests with the SSB Department of Co-operation. It would be desirable if Zhang Wan Bo were included in the delegation as he appeared the most familiar with computers.

The duration of the visit would be two weeks and would include visits to Canberra (BMR) and Melbourne (PIT).

The main purpose of the visit would be to learn about further developments in digital equipment and to discuss progress on the project. It could be possible to combine the visit with the Australian earthquake symposium proposed to be held in Melbourne in April or May 1992. This would allow the Chinese to meet a larger number of Australian seismologists.

A visit to Mundaring, either coming into Australia or when leaving Australia could be considered. This would be worthwhile for the Chinese who could be shown a recent fault scarp (Meckering 1968) and the IRIS system currently being installed at NWAO. It would also give the them a better appreciation of the Australian operations. There would be little difference in the external flight costs to perth or Sydney.

The Chinese would fund costs to and from Australia. Internal costs in Australia would have to be funded from Australian sources as was ours in China from Chinese funds.

Tangshan earthquake 1976 (ML = 7.8)

Sites of interest were visited, e.g. ruins at the library at the mine college and the railway workshop. The fault scarp was also visited. It has been preserved in a few locations. The scarp with slip of 1.35m and vertical movement 0.70m is not as impressive as at Meckering. The scarp consisted of many enechelon scarps along a length of 11 km.

Most of Tangshan has been rebuilt and there is little evidence of the destruction of 1976. The city is now ordered and clean. However the SSB office at Zhao, built after the earthquake appears to be of poor construction and has many cracks.

Jiang Yiang was at Zhao Ge Zhang during the earthquake and was lucky to survive. He states that his goldfish jumped out of their bowl a few days before the earthquake. Fish in the river jumped out of the river and pigs ran away and did not come back. He considers the main method of prediction is change in seismicity pattern and underground water levels, however he was not specific.

The area has been quite active recently.

1990	12	14	0817	40° 06' N	119° 02' E	MS = 4.1
1991	03	21	0519	39 36	118 23	4.1
	05	07	0025	39 50	118 50	4.1
	05	29	1902	39 43	118 18	4.8
	05	30	0706	39 41	118 16	5.2
	07	11	1905	39 44	118 20	4.2
	07	27	1754	39 57	118 44	4.6
	09	30	0903			5.4
	10	17	0219			3.8 ML = 4.3

Since May approximately 1000 small earthquakes have been recorded in the area.

Duration of the project

It was agreed that the project should continue initially until October 1993 (i.e. two years). A meeting should be held prior to October 1993 to discuss the result of the project and to consider any continuation.

Equipment entry into China

Difficulty was experienced in taking equipment into China.

PJG and GG entered China on different flights. The Kelunji carried by PJG was held by customs and would not be released and were were advised that it had to be taken out of China. All efforts by the SSB could not alter the decision by customs until a day before we left for Guangzhou.

The Kelunji carried by GG fortunately entered unnoticed and could be left in China.

This was a most unsatisfactory situation. In future all necessary documentation must be completed by the appropriate authority prior to leaving Australia. This matter was apparently requested on this occasion but not attended to.

AUSTRALIA-CHINA COMPARATIVE SEISMICITY STUDY

Date: 1-3 November 1991

Location: Seismological Bureau Guangdong Province (SBGP), Guangzhou

Objectives and Relevance: To compare the effects on earthquake risk assessments, using different methods of analysis, of data sets covering short and long periods; to compare the seismicity in the southeast China Earthquake Zone with that in Australia, taking into account the geological environments of both regions. In some parts of China the history of large earthquakes spans 2,000 years or more; in Australia the comparative time sequence is approximately 200 years. Which of the two data sets best predicts the seismicity over the next 30 to 50 years needs to be established by statistical analysis of the data. The effect of truncating the time series on the earthquake risk assessments is very important in Australia where only a short data set is available, in the context of the time scales associated with the geological process. Some areas of both China and Australia have been more prone to earthquakes over the last 50 years than others, and some virtually aseismic. Whether or not this pattern can be related to the geology or intraplate tectonics needs to be established.

Key Personnel:

Lin Jizeng	Vice Director	SBGP	Guangzhou
Feng Xuamin	Comprehensive prediction	SBGP	Guangzhou
Zhou Chuqajan	Comprehensive prediction	SBGP	Guangzhou
Siin Wei	Comprehensive prediction	SBGP	Guangzhou
Xie Zhi	Telemetered network	SBGP	Guangzhou
Wang Jianguo	Radio Manager	SBGP	Guangzhou
Li Boshan	Project Officer	SBGP	Guangzhou

Preliminaries

Prof Lin	Descriptive outlines of the seismicity of the south-east coastal region.
P.J. Gregson	Seismicity in Australia.
G. Gibson	Specifics of Tennant Creek earthquake; reservoir induced earthquake and a recent swarm in Victoria.

Exchange of data file

(a) Australian data file in PDE format was presented to Prof Lin containing earthquake data for all M>3 events since 1844 to the present. The data was on 3 1/2", 5 1/4" disk and magnetic tape. The preferred media is 3 1/2" disk but 5 1/4" is also ok.

(b) The Chinese data base (D Base III) containing historical data from about 1400 to the present was given to PJG on 5 1/4" disk. A letter for customs clearance was also given.
The data format is as follows. Note time used is Beijing time - UT + 8 hours.
Year (4); Month (2); Day (2); Hour, Minute, Second (7); Latitude (4); Longitude (5); Magnitude (MS) (2); Depth (3).

(c) Periodic updates of the data base to be made by both co-operating countries for the duration of the project.

Supplementary information

The following to be exchanged by post as soon as possible between Prof Lin (China) and P.J. Gregson (Aust).

(a) Geological map.
(b) Tectonic map.

(c) Mechanisms.
(d) Zone and risk maps, intensity recurrence maps.
(e) Relevant publications and references.
(f) Phase data for larger earthquakes.
(g) SBGP relationship between ML and MS. (All Chinese magnitudes quoted as MS, even for small earthquakes).
(h) Attenuation data.

Papers left with SBGP

Gaull and others (1990)	Probabilistic earthquake risk maps of Australia.
Gaull and others (1987)	Probabilistic earthquake risk maps of southwest Western Australia.
Gaull and Gregson (991)	A new local magnitude scale for Western Australian earthquakes.
Gregson and Everingham (1991)	Indian Ocean earthquake felt in Australia 19 November 1906.

Suggested analysis procedure

Preliminary suggestions were:
(a) Time distribution.
(b) Define earthquake zones.
(c) Examine mechanism and stress fields.

Future meetings

It was difficult to define a time schedule until supplementary information had been exchanged and at least some preliminary work had been done by both countries with each others data. It was agreed that we should communicate on this matter when some progress had been made.

Consideration was given to possible dates:

(a) April/May 1992 - to co-incide with the proposed visit to Australia by SSB personnel working on the strong motion project. This could also be tied in with the Australian earthquake symposium in Melbourne.

(b) October 1992 - to co-incide with the International symposium on earthquake risk in Beijing.

April/May 1992 is considered as probably being too early.

Pearl River Delta Telemetry Network

SBGP is in the process of installing a digital telemetered network in the Pearl River Delta area.

Basically the network consists of about 11 seismometers, all but one being Teledyne - Geotech SP-Z (S13). One station is a broad band Guralp. Sample rate is 100 sps and is transmitted using Chinese built digital VHF (223.4 MHz), 9600 band radios (GS200). The data acquisition is Teledyne-Geotech. The cost of the system was approximately US$500,000 not including the computer. The system is both expensive and power hungry.

The digital radio is interesting and it could be worth obtaining specifications from Wang, Jianguo.

APPENDIX 3

NORTHERN TERRITORY - GEOPHYSICAL OBSERVATORY SITES

P. Gregson visited the Northern Territory in December 1991 to investigate possible sites for a geomagnetic observatory. At the same time consideration was given to the possibility of including a seismograph site to replace Manton Dam (MTN). The Manton Dam site has become unacceptable for a seismograph site.

Site testing was confined to the vicinity of Kakadu National Park for the following reasons:

(a) The general area satisfied the location of the geographic distribution of magnetic stations in Australia.

(b) A site within the national park boundaries was favourable for long term protection against future encroachment by development.

(c) The General Manager, Northern Operations had expressed interest in discussions with Charlie Barton of BMR.

The requirements of an earthquake seismograph site were considered secondary as the flexibility of locating a seismograph are much greater than for a magnetic site.

SITES INSPECTED

Sites within the park were restricted by the availability of power, phone lines and personnel to carry out weekly magnetic control observations. Three sites were inspected and tested within the Kakadu National Park (Figure 18).

1. Park headquarters (Jabiru)
2. South Alligator Ranger Station
3. Kapalga Research Station.

Detailed site locations are shown in Figure 19.

GEOLOGY

Figure 20 shows the geology of the area including all the sites. For further clarity, refer to BMR maps:

Geology of the Pine Creek Geosyndine	1:500,000	
Cahill	1:100,000 series	sheet 5472
Kapalga	1:100,000 series	sheet 6372

Site 1. Laterite outcrops over Archean granite or gneiss. Surrounding material is unconsolidated sand, ferruginous clayey sand. Ironstone pebbles are in abundance.

Site 2. Cainozoic silt, sand and clay. No sign of any lateritic material.

Site 3. Cainozoic sand, gravel and laterite. Numerous ironstone pebbles.

MAGNETIC TESTING

An Elsec PPM was used to read total force (F) at 10 metre intervals over a 200 metre traverse at each site. Sites 1 and 3 showed large variations over intervals of 10 metres.

Site 2 was the only acceptable site with variations of only a few nanoteslas over 10 metres and a total of 20 nT over the 200 metre traverse.

OTHER CRITERIA
Other criteria such as power, phone etc are summarised in the following Table.

RECOMMENDATION FOR MAGNETIC OBSERVATORY

Sites 1 and 3 are unsatisfactory sites because of the large magnetic variations over short distances.

Site 2 is the only satisfactory magnetic site and satisfies all the major criteria for a magnetic observatory.

(1) Geomagnetic field - regional: site 46690nT

(2) Magnetic anomalies - variations only a few nanoteslas over 10m intervals. Total 20 nT over 200m.

(3) Electronically homogenous - ?

(4) Magnetic gradient - as for 2 above.

(5) Artificial sources - no railway lines, 400m* to closest man made structures, 800m* to main road; no transmitters. * distances to closest boundary of proposed clear zone.

(6) Clear zone - ample room for clear zone effectively increasing the distances in (5) above.

(7) Future development - there are no plans to develop the ranger station. There is ample room to develop in other directions should the need arise, once a magnetic station is established or approved.

(8) Access - access to the site is by a track to the northern boundary of the clear zone.

(9) Vandalism - the range station is a buffer zone between the highway and the proposed site. There is limited public access to the ranger station. The magnetic buildings would not be seen from the highway. Access to them would have to be made through the ranger station where there are houses occupied.

(10) Flooding - the site is free from flooding.

(11) Utility requirements
  (a) Power - reliable 250V 50Hz power is provided to the ranger station using their own generating plant. Supply is continuous. The plant is serviced monthly with short breaks in supply but never more than 2 hours. An underground cable about 500 m long would have to be laid from the existing distribution point to the magnetic instrument building.

  (b) Telecom (Darwin) advise that there are circuits available to the South Alligator Ranger Station. Contact Judy Shellbrake. Ph: 008 089 155

SITE PREPARATION

Although the South Alligator River site is lightly timbered (Figure 4) only minor clearing would be necessary for the instrument building for both erection and fire protection. The same would apply to the absolute shelter. Insignificant clearing would be required for line of sight between the absolute shelter and reference marks.

About 500m of power cable would have to be laid from the existing system to the instrument building. All underground cabling would need to be protected from termites.

Fencing of the site would not be necessary as it is buffered from public access by the ranger station. All that would be required are restricted access signs on the track at the northern boundary of the clear zone.

SEISMIC TESTING

An MEQ800 portable seismograph was used for site testing.
Unfortunately geological conditions that make a good magnetic site do not necessarily make a good seismic site.

Test recordings were made at South Alligator River (site 2) and Kapalga (site 3).

Both sites could run on 96db peaking at 0.2 sec, i.e. magnification 250K. Site 2 was disturbed by larger vehicles along the Arnhem highway. Both sites are significantly better than the Manton Dam site. In the case of site 2 it would be desirable if the seismometer was located as far south as possible from the highway.

Figures 21 and 22 show comparative recordings at Manton Dam and South Alligator River of two events on 3 December 1991.

The most desirable site for a seismometer would be at Gu Ngalarr-Ngalarr located about 3.5 km west of the South Alligator Ranger Station (Figure 18). This outcrop is Proterozoic Sandstone with an elevation of 111m. Unfortunately there is a Telecom tower at the peak with a generator running continuously. It should however be possible to find a suitable site on the road running south of the tower that is still an outcrop and has line of site back to the ranger station. Solar panels and radio telemetry could be used. This road was closed during my visit.

PROCEDURE

To proceed further, a formal request needs to be made from the BMR to the ANP & WS through Dr A Press in Darwin. Approval for the site will require acceptance by the Northern Land Council (NLC), but this is done through Dr Press.

The formal request needs to include:

1. Why an observatory site is required, i.e. a broad summary of the purposes of magnetic and seismic recording. It helps the NLC make a positive decision if they understand the purpose of the recordings.

2. Why a site in the park is necessary.

3. What are the impacts on the park, e.g. clearing, buildings, etc.

4. What is the desired tenure. They prefer a license rather than a lease.

5. What are the power (load etc) and phone requirements.

6. What are the servicing requirements by both BMR and local personnel.

7. What is the renumeration for the latter.

8. What time frame is the BMR looking at.

Although most of this information has been conveyed to Dr Press either by letter or verbally it is necessary to present it formally in a request for site tenure.

TABLE
SITE SELECTION CRITERIA

	PARK HEADQUARTERS	SOUTH ALLIGATOR RIVER	KAPALGA
Authority	Australian National Parks & Wildlife Service (ANP & WS)	Australian National Parks & Wildlife Service (ANP & WS)	CSIRO with ultimate authority for use of land being with ANP & WS.
Darwin contact	Dr Tony Press General Manager, Northern Operations Australian Parks & Wildlife Service Box B1260 P O Darwin NT 0801 Ph: 089 81 5299	Dr Tony Press General Manager, Northern Operations Australian Parks & Wildlife Service Box B1260 P O Darwin NT 0801 Ph: 089 81 5299	Dr Laurie Corbett CSIRO Div Wildlife & Ecology Ph: 089 22 1711 Fax: 089 47 0052
Local contact	Mr Peter Wellings Kakadu Park Manager Andrew Skett Northern Supervisor Park Headquarters	Andrew Wellings Head Ranger Victor Cooper Sth Alligator Ranger Stn Ph: 089 790 194	Robert Egar Manager, Kapalga Research Stn Ph: 089 79 0101
Latitude	12° 41.1' S	12° 41.6' S	12° 41.6' S
Longitude	132° 48.4' E	132° 28.2' E	132° 22.4' E
Regional magnetic field value	46690 nT	46719 nT	46727 nT
Magnetic site variation	46760 nT Variations upto 200 nT over 10m	46690 nT Variation 20 nT over 200m	46660 nT Variations upto 100 nT over 10m
Geology (see Fig. 3)	Lateritic outcrop with ironstone pebbles	Alluvium	Alluvium but covered with lateritic pebbles

	PARK HEADQUARTERS	SOUTH ALLIGATOR RIVER	KAPALGA
Flooding	Free from flooding	Free from flooding	Free from flooding
Weather	Susceptible to lightning during during wet season.	Susceptible to Lightning during wet season. Wind and rain from the south.	Susceptible to lightning during wet season
Power	Ranger mine into NT water & power authority network. Outages average about 10-15 min/mth.	Station generator. Reliable supply. Serviced monthly with short breaks, never more than 2 hrs. Would have to run power 500m underground.	Station generator. Reliable supply. Serviced monthly with short breaks, never more than 2 hrs. Would have to run power 500m underground.
Phone lines	Telecom Darwin 008 089 155 (Judy Shellbrake) advise that lines are available.	Telecom Darwin 008 089 155 (Judy Shellbrake) advise that lines are available.	Currently radio link with only two lines, one of which is used. Availability of of lines doubtful with proposed increases in housing at the station.
Future encroachment	Development in the vicinity of the headquarters is most likely.	No plans to extend the station at this stage. If a magnetic station established then any expansion of ranger requirements can be away from a magnetic site.	Additional housing to be added within the settlement but sufficiently far away from site inspected.
Security	Considerable public access in the vicinity of park headquarters.	Public access restricted. The proposed site is buffered from the highway by the ranger station.	Public access restricted. Located about 4 km north of Arnhem Highway.
Service personnel	Rangers have a good level of education. In some cases with tertiary qualifications. More than one person who would be capable of carrying out weekly control observations	More than one person who would be capable of carrying out weekly control observations. One Ranger (Victor Cooper) have been there for about 10 yrs.	Only one permanent resident (Manager) who is responsible for caretaking and maintenance in the station.

	PARK HEADQUARTERS	SOUTH ALLIGATOR RIVER	KAPALGA
Long term stability	Good.	Good.	CSIRO has a 5 yr lease with ANP & WS. There is no reason why this should not be extended. ANP & WS control any development within the research station. The station operation is dependent on CSIRO maintaining an interest in operating a research facility in the park. They are currently proposing to commit funds to upgrade station facilities.

TABLE 1

OBSERVATORY STAFF 1991

Officer	Designation
P.J. Gregson	Senior Professional Officer Class C
B.A. Gaull	Senior Professional Officer Class C (to 20 June)
E.P. Paull	Professional Officer Class 2
V.F. Dent	Professional Officer Class 2
G. Woad	Technical Officer Grade 3 (to 30 August)
B.J. Page	Technical Officer Grade 3 (to 10 February)
Y.M. Moiler (Mrs)	Administrative Service Officer Grade 1 (25 hrs/week)
L.A. Van Reeken (Mrs)	Technical Officer Grade 1 (25 hrs/week)
O.D. McConnel	Technical Officer Grade 4 (from 4 November)
T. Sambell	Technical Officer Grade 1 (Temporary 13 May - 28 June)

TABLE 2

OBSERVATORY STAFF ABSENCES 1991

Nature of absences	No. of days
Sick leave	23
Special leave	2
Furlough	-
Oustation visits and field operations	79
Headquarters	45
Overseas	13
Counselling sessions (early retirement)	26
Total	162

TABLE 3

WORK EXPERIENCE STUDENTS 1991

Name	School	Dates	Duty
Stephen Britton	Swan View SHS	18-22 Mar	Geophysical Assistant
David Steed	Eastern Hills SHS	1-5 Jul	Geophysical Assistant

TABLE 4

ASSOCIATED PERSONNEL 1991

Name	Nature of Duties
P. Harvey	Daily attendant, Gnangara (to 1 Feb)
A. Annear	Daily attendant, Kununurra
P. Kildea	Daily attendant, Meekatharra
D. Hart	Daily attendant, Morawa (to 5 Sep)
J. Bartlet	Daily attendant, Nanutarra
C. Paget	Daily attendant, Warburton
R. Tregonning	Daily attendant, Marble Bar
S. Cameron	Daily attendant, Rocky Gully
P. Ryan	Daily attendant, Manton Dam
D. Schoch	Ground maintenance, Mundaring Observatory
S. Lozsan	Cleaning, Mundaring Observatory

TABLE 5

CONFERENCES, TRAINING AND COMMITTEES 1991

Officer	Date	Conference
		<u>Committees</u>
P.J. Gregson		Geophysics Advisory Committee, Western Australian Institute of Technology
		Working group on seismicity in mines in Western Australia (Mines Dept).
		<u>Conference</u>
P.J. Gregson	Oct 21-25	China International Symposium in geological hazards and prevention, Beijing, China.

TABLE 6

ADDRESSES

Officer	Date	Address
P.J. Gregson	Jul 29	Mt Hawthorn Rotary - Work at Mundaring Observatory.
P.J. Gregson	Oct 22	Geological Hazards Symposium, Bejing - "Seismic hazards in Australia".

TABLE 7

VISITORS 1991

Visitor	Institution
D. Edwards	Dept Primary Industries & Energy, Perth
R. Rutland	Bureau of Mineral Resources, Canberra
N. Williams	Bureau of Mineral Resources, Canberra
I. Everingham	
J. Eayrs	State Emergency Service
E. Van Rijnswoud	State Energy Commission
F. Leslie	Telecom
C. Swindells	Geological Survey of WA
S. Faulkner	Dept Primary Industries & Energy, Perth
I. Jackson	Dept Primary Industries & Energy, Perth
B. Smith	(CRA) - BMR Review team
B. Ellis	(University British Columbia) - BMR Review team
B. Olney	Telecom
G. Tresidder	Australian Construction Service
J. Rickards	Teledyne Geotech
K. Clevenger	Teledyne Geotech
L. Zeitlhofer	Bureau of Mineral Resources, Canberra
G. Ezzy	Bureau of Meteorology
T. Anagnos	San Jose State University
H. Kagami	Hokkaido University, Japan
K. Ovajack	Bureau of Mineral Resources, Canberra
G. Guyre	Alburquerque Seismological Laboratory
C.J. brewster	Alburquerque Seismological Laboratory
Geophysics Students (6)	Curtin University
Students, Year 11 (20)	Helena College
Members (12)	Women in Technology
Members (30)	Geological Society of Australia (WA Branch

TABLE 8

WESTERN AUSTRALIAN SEISMOGRAPH STATIONS

CODE	STATION NAME	LAT° S	LONG° E	ELEV	OPENED	CLOSED
BAL	Ballidu	30.6065	116.7072	300	82 Aug 27	
CLK	Clackline*	31.7230	116.4940	265	90 Nov 13	91 Feb 04
COOL	Coolgardie	30.8838	121.1447	500	88 Aug 10	
FORR	Forrest	30.7992	128.0673	530	88 Oct 07	
KLB	Kellerberrin	31.5923	117.7600	300	81 Sep 23	
KNA	Kununurra	15.7500	128.7667	150	72 Feb 28	
MBL	Marble Bar	21.1600	119.8333	200	76 Jun 21	
MEKA	Meekatharra	26.6142	118.5336	520	86 May 01	
MRWA	Morawa	29.2180	115.9960	300	84 Jun 21	
MTN	Manton Dam	12.8467	131.1300	80	72 Jun 01	
MGO	Mundaring Office	31.9033	116.1650	250	79 Jan 11	
MUN	Mundaring	31.9783	116.2083	253	62 Jun 01	
NANU	Nanutarra	22.5620	115.5290	300	87 Oct 22	
NOR	Northam*	31.6570	116.6650	155	90 Nov 13	91 Feb 04
NWAO	Narrogin	32.9267	117.2333	265	76 Mar 19	
ONG1	Ongerup*	33.8700	118.3190	300	91 Feb 05	91 Apr 16
ONG2	Ongerup*	33.8660	118.2950	300	91 Feb 18	91 Apr 16
ONG3	Ongerup*	33.8650	118.3700	300	91 Feb 05	91 Apr 03
ONG4	Ongerup*	33.8900	118.3160	300	91 Feb 18	91 Apr 16
ONG5	Ongerup*	33.8633	118.3265	320	91 Mar 22	91 Apr 16
RKG	Rocky Gully	34.5698	117.0103	300	83 Aug 03	
WARB	Warburton	26.1838	126.6430	460	87 Jun 28	
WOO	Wooroloo*	31.8070	116.3180	245	90 Nov 13	91 Feb 04

* Temporary station

TABLE 9

SEISMOGRAPH CALIBRATION DATA 1991

MAGNIFICATION (x1000)

SHORT PERIOD

PERIOD (Sec)	0.1	0.15	0.2	0.25	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
BAL Z	224	300	282	254	238	148	99	66	49	36	26	19
COOL Z	200		417		399	255	178	130	91	70	50	36
FORR	207	358	402	389	343	232	151	99	63	43	20	19
KLB Z	200	426	475	438	376	262	183	130	92	66	43	37
KNA Z	135	187	200	187	164	118	86	65	49	37	28	21
KNA N, E	36	54	61	62	58	48	39	32	27	22	19	16
MBL Z	481	748	828	794	711	500	380	293	220	177	140	116
MEKA Z	349	453	480	448	393	280	200	143	105	78	58	43
MRWA Z	650	878	974	926	808	556	364	240	156	105	72	47
MTN Z	34		180		246	240	200	157	118	87	55	40
MGO INS	2.60	3.03	2.98	2.97	2.97	2.87	2.59	2.25	1.89	1.70	1.40	1.11
MUN + ZNE	3	6	10	14.5	20	31	39	41	40	36	31	25
MUN HGZ	406	380	338	324	326	318	207	101	55	31	21	14
MUN WA	2.05		2.05		1.98	1.83	1.68	1.50	1.35	1.21	1.06	0.95
NANU Z	480	940	1010	954	823	520	348	190	115	76	53	40
NWAO *Z	30	110	193	238	260	242	190	150	120	90	70	50
RKG Z	544	632	616	540	408	246	160	104	68	48	32	22
WARB Z	900	1220	1300	1190	1010	673	430	265	176	116	78	55
WA (STANDARD)	2.77		2.75		2.65	2.43	2.25	2.03	1.82	1.61	1.43	1.27

LONG PERIOD

PERIOD (Sec)	8	9	10	15	20	25	30	40	50	60	80	100
MUN + Z	.62	.69	.72	.75	.67	.50	.55	.35	.29	.22	.15	.11
MUN + Z	.31	.34	.36	.37	.34	.25	.27	.18	.14	.11	.08	.06
MUN +NE	.31	.34	.36	.37	.34	.25	.27	.18	.14	.11	.08	.06
NWAO * ZNE	2.8	4.0	6.8	8.8	32.8	40.0	40.0	31.6	26.4	16.0	8.0	4.4
NWAO * ZNE	0.7	1.0	1.7	2.2	8.2	10.0	10.0	7.9	6.6	4.0	2.0	1.1

+	World Wide Standard Seismograph	SP-Z, N, E	LP-Z, N, E
*	Seismic Research Observatory	SP-Z	LP-Z, N, E
HG	High Gain Short Period Vertical		
WA	Wood Anderson Seismograph		

TABLE 10

WESTERN AUSTRALIAN EARTHQUAKES 1991

UT Date	UT Time	Lat°S	Long°E	Depth	Mag	Place
Jan 02	1144 58.4	31.82	116.92	14	ML 1.2	YORK, 16KM ENE
Jan 02	1500 36.2	31.20	117.52	3	ML 1.9	WYALKATCHEM, 14KM E
Jan 04	0217 16.1	33.89	118.31	1 C	ML 1.5	ONGERUP, 19KM NW
Jan 07	1141 58.8	30.72	121.33	1 C	ML 2.3	KALGOORLIE, 14KM W
Jan 07	1459 0.5	15.60	121.78	5 N	ML 2.5	BROOME, 270KM N
Jan 08	0436 7.4	30.61	117.05	5	ML 2.4	CADOUX, 19KM NW
Jan 08	0453 31.1	30.64	117.02	1 C	ML 1.9	CADOUX, 18KM NW
Jan 08	0527 8.1	30.62	117.07	3	ML 3.3	CADOUX, 18KM N
Jan 08	0545 42.9	30.58	117.06	6	ML 2.9	CADOUX, 22KM N
Jan 08	0550 16.6	30.63	117.04	3	ML 2.4	CADOUX, 18KM NW
Jan 09	1022 38.4	17.34	123.88	5 N	ML 3.7	DERBY, 26KM E
Jan 11	0746 58.1	32.13	117.21	19	ML 1.8	QUAIRADING, 22KM SW
Jan 11	2330 58.8	38.28	111.27	5 N	ML 3.1	ALBANY, 650KM SW
Jan 12	1703 48.8	30.62	117.03	0	ML 1.8	CADOUX, 19KM NW
Jan 12	2055 50.5	30.79	117.10	1 C	ML 1.9	CADOUX, 3KM SW
Jan 19	0221 24.9	31.71	116.99	4	ML 2.0	MECKERING, 9KM S
Jan 21	2137 21.2	33.79	118.21	1 C	ML 1.9	ONGERUP, 32KM NW
Jan 27	1139 2.5	31.70	116.98	0	ML 1.6	MECKERING, 9KM S
Jan 28	1207 36.9	18.13	118.93	5 N	ML 2.3	PORT HEDLAND, 245KM N
Jan 28	1347 7.1	31.33	118.19	5 N	ML 1.8	MERREDIN, 18KM NW
Feb 02	2342 9.0	30.09	119.40	4	ML 2.5	SOUTHERN CROSS, 127KM N
Feb 03	0039 36.3	33.30	118.68	1 C	ML 2.1	PINGRUP, 31KM NE
Feb 04	0827 34.3	18.72	115.71	5 N	ML 3.7	DAMPIER, 239KM NNW
Feb 05	0053 31.9	31.70	116.97	4	ML 1.7	MECKERING, 8KM SSW
Feb 06	0302 34.1	16.68	128.58	5 C	ML 2.4	KUNUNURRA, 101KM S
Feb 08	0015 7.6	24.64	114.25	5 N	ML 2.9	CARNARVON, 64KM ENE
Feb 08	1657 28.0	18.75	118.10	5 N	ML 2.7	PORT HEDLAND, 180KM NNW
Feb 10	1730 7.5	31.70	117.05	1 C	ML 1.7	MECKERING, 9KM SSE
Feb 11	1748 36.4	31.31	118.16	1	ML 1.8	MERREDIN, 21KM NNW
Feb 13	0735 7.2	29.77	125.65	1 C	ML 2.9	RAWLINNA, 140KM NNE
Feb 16	1114 31.2	30.74	117.16	3	ML 1.9	CADOUX, 4KM NE
Feb 20	0115 49.7	30.93	117.11	3	ML 1.7	CADOUX, 18KM S
Feb 21	0143 14.2	32.13	117.19	1 C	ML 1.9	QUAIRADING, 23KM SW
Feb 21	2052 38.9	17.78	116.84	5 N	ML 2.8	DAMPIER, 319KM N
Feb 22	2201 26.3	36.10	117.69	5 N	ML 2.4	ALBANY, 123KM S
Feb 24	1518 24.8	26.65	112.59	5 N	ML 2.5	CARNARVON, 225KM SSW
Mar 03	1601 46.0	32.12	117.43	10	ML 2.2	QUAIRADING, 12KM SSE
Mar 07	0809 32.9	29.59	117.19	1 C	ML 2.0	PAYNE'S FIND, 60KM SW
Mar 07	1352 23.2	31.22	117.33	1 C	ML 2.6	WYALKATCHEM, 5KM SW
Mar 09	0136 31.2	30.76	121.42	11	ML 4.2	KALGOORLIE, 5KM SSE
Mar 09	1522 24.9	20.57	120.75	5 N	ML 2.9	MARBLE BAR, 125KM NE
Mar 09	1752 9.8	30.79	117.09	3	ML 2.1	CADOUX, 4KM SW
Mar 12	1040 56.4	27.77	114.57	5 N	ML 2.7	KALBARRI, 38KM E
Mar 12	1218 14.1	30.75	117.12	5	ML 2.3	CADOUX, 4KM N
Mar 15	0429 39.3	29.36	124.65	1 C	ML 3.0	RAWLINNA, 195KM N
Mar 15	0600 46.2	31.70	116.98	7	ML 1.7	MECKERING, 8KM S
Mar 17	0938 26.5	28.09	114.01	5 N	ML 3.3	KALBARRI, 47KM SW
Mar 18	0043 15.9	30.91	116.34	1 C	ML 1.8	CALINGIRI, 21KM NW
Mar 24	0311 36.1	21.91	115.96	5 N	ML 3.0	KARRATHA, 160KM SW

TABLE 10 (Contd)

UT Date	UT Time		Lat°S	Long°E	Depth	Mag	Place
Mar 24	1613	33.6	31.60	117.06	7	ML 1.8	MECKERING, 5KM NE
Mar 26	0433	31.6	30.62	117.03	1 C	ML 2.1	CADOUX, 19KM NW
Mar 28	0625	49.7	30.63	117.02	1 C	ML 1.8	CADOUX, 19KM NW
Mar 28	1156	47.1	30.61	117.03	5 N	ML 1.8	CADOUX, 19KM NW
Mar 29	2254	16.7	30.63	117.02	1 C	ML 2.3	CADOUX, 18KM NW
Mar 30	0721	26.3	31.79	116.29	0 C	ML 1.8	WOOROLOO BLAST
Mar 30	0818	19.3	31.79	116.31	0 C	ML 1.6	WOOROLOO BLAST
Mar 31	1428	3.2	30.60	117.04	5	ML 1.7	CADOUX, 21KM NW
Apr 03	2158	54.7	31.71	116.98	0	ML 2.0	MECKERING, 9KM SSW
Apr 07	1536	43.9	30.63	117.03	5 N	ML 1.8	CADOUX, 18KM NW
Apr 07	1537	42.3	30.63	117.03	5 N	ML 2.0	CADOUX, 18KM NW
Apr 09	1400	8.0	20.65	116.99	5 N	ML 3.4	KARRATHA, 16KM NE
Apr 10	0606	34.2	30.72	121.42	5 N	ML 3.1	KALGOORLIE, 6KM NW
Apr 10	0635	22.0	30.82	121.47	5 N	ML 2.4	KALGOORLIE, 8KM S
Apr 12	2014	3.3	31.70	117.04	5 N	ML 1.6	MECKERING, 8KM SE
Apr 14	0746	22.2	26.79	111.53	5 N	ML 3.7	CARNARVON, 300KM SW
Apr 19	0340	5.0	18.00	115.70	5 N	ML 2.5	DAMPIER, 314KM N
Apr 20	1508	58.9	27.38	112.51	5 N	ML 3.1	CARNARVON, 300KM SW
Apr 26	0359	40.2	31.29	119.44	5 N	ML 2.1	SOUTHERN CROSS, 13KM SE
Apr 30	1848	25.1	32.35	117.05	9	ML 1.6	BROOKTON, 4KM E
Apr 30	1904	51.4	32.34	117.07	7	ML 2.4	BROOKTON, 7KM E
May 01	0957	45.1	33.33	118.21	1 C	ML 2.1	NYABING, 26KM NNE
May 01	1944	24.0	32.35	117.06	3	ML 2.2	BROOKTON, 5KM E
May 02	0556	21.7	33.74	115.89	2	ML 2.7	KIRUP, 2KM SW
May 02	1622	20.7	32.35	117.05	1	ML 2.2	BROOKTON, 4KM ESE
May 04	0144	12.9	34.53	117.66	5 N	ML 2.1	CRANBROOK, 27KM SSE
May 06	0457	19.0	31.03	116.39	1 C	ML 2.0	CALINGIRI, 7KM NW
May 06	0610	0.5	31.85	116.34	8	ML 1.6	WOOROLOO, 7KM SSE
May 06	0709	1.4	13.91	130.99	5 N	ML 3.0	DARWIN, 163KM S
May 07	0107	18.3	32.36	117.05	5 N	ML 2.0	BROOKTON, 4KM ESE
May 07	0522	56.2	32.34	117.08	5 N	ML 1.5	BROOKTON, 7KM E
May 07	0528	39.7	18.80	118.41	5 N	ML 3.0	PORT HEDLAND, 168KM N
May 12	2119	12.9	32.03	117.31	5 N	ML 1.6	QUAIRADING, 9KM W
May 15	0906	43.6	22.32	113.04	35 C	ML 3.0	LEARMONTH, 107KM W
May 16	0202	49.1	25.46	116.09	9	ML 2.9	ERONG SPRINGS, 59KM W
May 18	1823	6.6	32.13	117.21	13	ML 1.9	QUAIRADING, 22KM SW
May 19	2015	31.2	30.79	117.10	1 C	ML 1.8	CADOUX, 4KM SW
May 21	0125	41.4	31.98	117.26	3	ML 1.6	QUAIRADING, 14KM WNW
May 21	0212	54.7	15.45	125.49	5 N	ML 3.0	KUNUNURRA, 354KM W
May 22	0445	41.8	34.50	129.31	5 N	ML 2.5	EUCLA, 320KM SSE
May 26	1119	2.9	33.87	118.35	3	ML 1.8	ONGERUP, 16KM NW
Jun 01	1515	54.5	23.26	114.73	5 N	ML 2.3	NANUTARRA, 113KM SW
Jun 06	0008	45.5	31.98	117.29	1 C	ML 2.0	QUAIRADING, 11KM WNW
Jun 14	1222	52.4	32.60	122.32	5	ML 3.6	NORSEMAN, 68KM SE
Jun 17	0452	45.3	19.97	121.68	5 N	ML 3.1	BROOME, 230KM SSW
Jun 17	0549	1.8	31.87	116.37	5 N	ML 1.9	WOOROLOO, 10KM SE
Jun 19	0101	33.2	32.53	116.92	7	ML 2.5	PINGELLY, 15KM W
Jun 20	0342	13.5	31.66	117.04	5 N	ML 1.3	MECKERING, 4KM SE
Jun 20	0707	40.3	32.23	117.42	15	ML 2.0	QUAIRADING, 23KM S
Jun 22	1951	48.3	24.42	115.58	5 N	ML 2.6	GASCOYNE JN, 79KM NNE
Jun 23	1520	35.1	27.43	113.15	5 N	ML 2.7	KALBARRI, 108KM WNW

TABLE 10 (Contd)

UT Date	UT Time	Lat°S	Long°E	Depth	Mag	Place
Jun 26	0909 40.6	30.61	117.03	4	ML 2.0	BURAKIN, 16KM SW
Jun 29	2339 4.6	30.61	117.05	1 C	ML 2.5	BURAKIN, 15KM SW
Jul 02	0648 56.4	26.95	111.27	5 N	ML 3.6	CARNARVON, 333KM SW
Jul 04	0355 6.3	30.63	117.04	1 C	ML 1.7	BURAKIN, 16KM SW
Jul 10	0054 36.0	30.61	117.03	1 C	ML 2.0	BURAKIN, 17KM S
Jul 11	1642 53.9	32.78	119.75	1 C	ML 2.0	LAKE KING, 34KM N
Jul 14	0720 40.4	30.61	117.05	1 C	ML 2.0	BURAKIN, 16KM SW
Jul 20	0207 44.0	31.00	121.54	5 N	ML 2.6	KALGOORLIE, 28KM S
Jul 24	0205 47.3	30.61	117.60	3	ML 2.4	KOORDA, 27KM NE
Jul 25	2357 39.8	33.65	118.07	1 C	ML 2.5	NYABING, 13KM SW
Jul 27	0351 31.6	33.40	117.85	1 C	ML 2.2	DUMBLEYUNG, 14KM SE
Jul 27	1226 23.6	30.85	117.07	2	ML 2.3	CADOUX, 11KM SW
Jul 28	0531 59.3	17.72	122.31	5 N	ML 3.1	BROOME, 29KM NNE
Jul 31	0812 40.6	33.77	118.25	5 N	ML 1.9	NYABING, 26KM S
Aug 04	0655 31.9	31.78	119.59	23	ML 1.8	SOUTHERN CROSS, 66KM SE
Aug 05	1800 52.3	22.21	109.14	5 N	ML 3.5	EXMOUTH, 515 KM W
Aug 06	1100 0.4	30.71	117.07	1 C	ML 1.6	CADOUX, 9KM NW
Aug 08	2016 54.8	30.98	116.90	5 N	ML 1.7	WONGAN HILLS, 20KM SE
Aug 09	1859 17.2	35.23	123.67	5 N	ML 2.6	ESPERANCE, 220KM SE
Aug 11	2204 18.6	33.68	117.96	5 N	ML 2.3	NYABING, 22KM SW
Aug 17	0008 43.6	29.13	115.70	5 N	ML 2.9	MINGENEW, 26KM E
Aug 18	1156 57.4	16.61	128.61	5 N	ML 3.9	KUNUNURRA, 90KM S
Aug 18	1205 26.9	16.56	128.59	5 N	ML 3.0	KUNUNURRA, 88KM S
Aug 18	2125 11.1	33.87	118.01	5 N	ML 1.7	GNOWANGERUP, 7KM N
Aug 19	2203 33.4	16.49	128.43	5 N	ML 2.4	KUNUNURRA, 90KM S
Aug 20	0221 0.2	33.43	116.31	3	ML 2.0	COLLIE, 17KM E
Aug 20	0744 40.1	32.94	116.10	5 N	ML 1.9	BODDINGTON, 38KM SW
Aug 20	1452 5.2	32.88	111.10	5 N	ML 2.7	PERTH, 458KM W
Aug 22	0916 36.5	16.57	123.76	5 N	ML 2.8	DERBY, 85KM N
Aug 25	0104 23.1	33.98	117.93	1 C	ML 1.6	GNOWANGERUP, 9KM SW
Aug 27	1556 42.2	33.66	118.03	1 G	ML 2.1	NYABING, 16KM SW
Aug 28	0104 27.3	16.60	128.60	5 C	ML 2.0	KUNUNURRA, 90KM S
Aug 28	2021 10.8	32.99	111.56	5 N	ML 2.3	PERTH, 419KM W
Aug 30	1404 23.8	20.53	119.67	5 N	ML 3.3	MARBLE BAR, 71KM N
Aug 30	2217 40.1	33.65	117.95	5 N	ML 1.6	NYABING, 22KM SW
Aug 31	0406 52.8	20.64	119.57	5 N	ML 3.0	MARBLE BAR, 61KM N
Sep 02	0559 55.1	31.86	116.36	1	ML 1.4	WOOROLOO BLAST
Sep 03	1746 53.8	30.72	117.10	1 G	ML 1.8	CADOUX, 6KM NNW
Sep 05	0611 45.4	25.09	112.68	5 N	ML 3.0	CARNARVON, 103KM WSW
Sep 06	1303 5.7	34.37	113.16	5 N	ML 2.5	AUGUSTA, 183KM W
Sep 08	0045 7.3	31.75	116.95	3	ML 1.7	MECKERING, 14KM SSW
Sep 08	0717 40.1	31.14	117.30	5 N	ML 1.8	WYALKATCHEM, 9KM WNW
Sep 09	1447 25.1	23.99	113.27	5 N	ML 2.3	CARNARVON, 106KM NNW
Sep 10	1815 19.7	35.14	123.65	5 N	ML 2.6	ESPERANCE, 214KM SE
Sep 11	0212 28.6	22.54	114.04	5 N	ML 2.9	LEARMONTH, 32KM S
Sep 11	0408 9.9	34.82	118.85	5 N	ML 2.5	ALBANY, 92KM ENE
Sep 11	0604 43.0	31.87	116.36	5 N	ML 1.7	WOOROLOO, 9KM SE BLAST
Sep 12	1101 53.4	32.01	117.28	5	ML 1.5	QUAIRADING, 12KM W
Sep 14	1153 17.4	33.26	116.55	5 N	ML 1.6	DARKAN, 19KM WNW
Sep 16	0755 45.0	20.35	118.92	5 N	ML 2.3	PORT HEDLAND, 36KM E

TABLE 10 (Contd)

UT Date	UT Time	Lat°S	Long°E	Depth	Mag	Place
Sep 17	0207 15.1	31.86	117.85	5	ML 2.0	KELLERBERRIN, 28KM SSE
Sep 19	2101 29.7	31.62	117.03	1	ML 2.0	MECKERING, 3KM NE
Sep 21	1339 43.6	16.89	121.58	23	ML 3.1	BROOME, 138KM NNW
Sep 21	1808 17.6	35.30	123.65	34	ML 2.7	ESPERANCE, 226KM SE
Sep 22	1701 36.9	35.09	117.83	1 C	ML 2.4	ALBANY, 10KM SSW
Sep 23	2119 58.1	20.72	120.71	5 N	ML 4.0	MARBLE BAR, 111KM ENE
Sep 25	0220 45.8	31.18	117.29	1	ML 1.9	WYALKATCHEM, 9KM W
Sep 30	1022 26.4	21.07	121.01	5 N	ML 2.6	MARBLE BAR, 132KM E
Oct 02	0628 4.7	31.65	117.04	5 N	ML 1.9	MECKERING, 3KM SE
Oct 03	1329 33.0	31.69	116.98	5 N	ML 1.7	MECKERING, 8KM SW
Oct 04	1030 27.1	33.61	117.61	5 N	ML 1.9	KATANNING, 10KM NE
Oct 04	1746 2.5	27.92	114.13	5 N	ML 2.7	KALBARRI, 25KM S
Oct 06	2259 8.3	16.86	129.09	5 N	ML 3.2	KUNUNURRA, 125KM S
Oct 06	2259 37.3	16.88	129.09	5 N	ML 3.6	KUNUNURRA, 129KM S
Oct 08	1429 32.2	22.10	126.46	5 N	ML 2.1	TOBIN LAKE, 39KM SE
Oct 08	2232 42.8	33.67	118.00	5 N	ML 2.0	NYABING, 19KM SW
Oct 09	1646 15.6	16.55	128.57	5 N	ML 3.7	KUNUNURRA, 87KM S
Oct 10	0224 11.1	31.16	117.26	5 N	ML 1.5	WYALKATCHEM, 11KM W
Oct 11	1209 22.5	29.79	117.01	5 N	ML 1.8	WUBIN, 50KM NE
Oct 18	0907 27.6	20.50	114.13	5 N	ML 4.3	EXMOUTH, 158KM N
Oct 20	2347 16.3	31.17	117.26	5 N	ML 1.6	WYALKATCHEM, 12KM W
Oct 21	1944 25.6	35.21	123.49	5 N	ML 2.8	ESPERANCE, 208KM SE
Oct 23	0503 20.9	38.11	112.33	5 N	ML 2.8	AUGUSTA, 500KM SW
Oct 24	0457 1.1	20.34	116.14	5 N	ML 2.7	DAMPIER, 70KM NW
Oct 25	0505 56.0	20.46	119.91	5 N	ML 3.0	MARBLE BAR, 81KM N
Oct 27	1130 31.5	33.90	117.68	5 N	ML 2.0	TAMBELLUP, 16KM N
Oct 31	0323 45.3	20.28	120.99	5 N	ML 2.6	MARBLE BAR, 163KM NE
Nov 02	0909 18.3	33.67	118.02	1 G	ML 2.0	NYABING, 18KM SW
Nov 03	1536 18.3	31.70	116.99	4	ML 1.9	MECKERING, 9KM S
Nov 05	0926 49.8	32.84	122.10	5 N	ML 3.8	SALMON GUMS, 45KM ENE
Nov 07	0147 16.7	32.15	117.18	5 N	ML 2.0	BEVERLEY, 23KM E
Nov 09	0024 35.2	30.41	117.75	1	ML 1.8	BEACON, 12KM WNW
Nov 14	1843 52.1	21.09	118.93	5 N	ML 2.7	MARBLE BAR, 85KM W
Nov 15	0223 35.0	21.60	111.89	5 N	ML 2.6	EXMOUTH, 234KM W
Nov 15	2239 42.2	31.63	117.05	7	ML 1.8	MECKERING, 2KM E
Nov 16	0452 10.4	30.76	117.14	4	ML 2.6	CADOUX, 3KM NE
Nov 17	1504 29.1	35.17	123.39	5 N	ML 2.3	ESPERANCE, 200KM SE
Nov 18	0449 29.2	20.40	119.42	5 N	ML 3.4	PORT HEDLAND, 88KM E
Nov 19	0553 3.4	33.30	118.13	5 N	ML 2.6	NYABING, 28KM N
Nov 20	1625 41.6	33.35	118.54	5 N	ML 1.7	PINGRUP, 20KM N
Nov 20	1904 21.2	31.72	117.00	4	ML 2.0	MECKERING, 10KM S
Nov 20	1940 9.0	31.69	116.98	1 G	ML 1.8	MECKERING, 8KM SSW
Nov 23	0615 9.4	37.94	112.60	5 N	ML 2.5	WALPOLE, 495KM SW
Nov 24	1438 46.7	19.37	117.00	5 N	ML 3.1	DAMPIER, 145KM N
Nov 24	1704 35.0	32.09	117.15	1 C	ML 2.4	BEVERLEY, 21KM E
Nov 25	0133 7.0	30.78	117.13	1	ML 2.6	CADOUX, 2KM SSW
Nov 25	0142 54.3	30.77	117.14	2	ML 3.2	CADOUX, 0KM ESE
Dec 04	0121 25.1	34.24	117.28	5 N	ML 2.2	CRANBROOK, 26KM W
Dec 04	1602 28.6	33.66	118.09	1 C	ML 1.9	NYABING, 13KM SW
Dec 04	1955 27.7	33.65	118.03	1 C	ML 2.1	NYABING, 16KM SW

TABLE 10 (Contd)

UT Date	UT Time	Lat°S	Long°E	Depth	Mag	Place
Dec 06	1458 41.9	26.76	112.17	5 N	ML 3.3	CARNARVON, 256KM SW
Dec 06	2117 33.0	24.07	113.03	5 N	ML 2.5	CARNARVON, 111KM NW
Dec 08	2143 39.4	31.74	117.01	1	ML 2.2	MECKERING, 12KM S
Dec 09	0721 30.5	33.37	113.46	5 N	ML 2.2	PERTH, 274KM SW
Dec 11	0839 38.2	30.54	116.79	5 N	ML 1.9	BALLIDU, 7KM N
Dec 11	1759 55.6	30.39	117.74	2	ML 3.2	BEACON, 14KM NW
Dec 11	2333 27.5	30.10	117.72	5 N	ML 1.5	BEACON, 41KM N
Dec 13	0448 17.6	34.39	117.36	1 G	ML 4.3	CRANBROOK, 20KM WSW
Dec 17	0546 49.2	35.19	123.45	5 N	ML 2.6	ESPERANCE, 205KM SE
Dec 20	0110 26.8	31.32	128.87	5 N	ML 2.3	EUCLA, 40KM N
Dec 20	1139 32.4	30.80	117.10	5	ML 1.8	CADOUX, 5KM SW
Dec 21	0631 17.3	31.13	121.46	5 N	ML 2.2	KALGOORLIE, 42KM S
Dec 22	0412 19.5	32.18	117.17	5 N	ML 1.8	BEVERLEY, 24KM E
Dec 22	1601 45.1	16.38	128.55	5 N	ML 2.8	KUNUNURRA, 70KM S
Dec 24	2006 23.3	17.29	126.20	5 N	ML 2.5	KUNUNURRA, 323KM SW
Dec 26	1314 41.1	30.40	117.77	8	ML 2.2	BEACON, 10KM NW
Dec 30	0357 47.8	33.66	118.06	1 C	ML 2.2	NYABING, 15KM SW

Western Standard Time (WST) = Universal Time (UT) + 8 hours
N = Nominal depth
C = Constrained depth
ML = Richter Magnitude
MM = Maximum Reported Modified Mercalli Intensity

TABLE 11

WESTERN AUSTRALIAN ACCELEROGRAPH LOCATIONS 1991

LOCALITY	CODE	LAT°S	LONG° E	ELEV	FOUNDATION	OWNER
BALLIDU						
Mailey T.	BA-M	30.607	116.707	300	Granite	BMR
CADOUX						
Avery C.	CA-A	30.851	117.160	300	Alluvium/Granite	BMR
Emmott J.	CA-E	30.895	117.123	320	Laterite	BMR
Kalajzic C.	CA-K	30.718	117.141	300	Granite	BMR
Kalajzic M.	CA-A	30.746	117.151	300	Weathered Granite	BMR
Robb A.	CA-R	30.781	117.138	300	Alluvium-Granite	BMR
Shankland	CA-S	30.810	117.132	300	Alluvium-Granite	BMR
CANNING DAM						
Lower Gallery	CD-L	32.154	116.126	142	Granite	WAWA
Upper Gallery	CD-U	32.154	116.126	202	Granite	WAWA
DOWERIN						
Uberin Rock	DO-W	31.010	116.982	300	Granite	BMR
GOOMALLING						
Lamb	GO-O	31.394	116.852	250	Granite	BMR
KUNUNURRA						
Dam Abutment	KN-A	16.113	128.737		Phyllite	WAWA
Dam Wall	KN-W	16.113	128.738		Rock fill, 3m clay 90 m quartzite	WAWA
MECKERING						
Elliot	ME-3	31.714	117.054	200	Alluvium/Granite	BMR
Kelly	ME-K	31.694	116.982	200	Alluvium/Granite	BMR
MUNDARING						
Weir	MU-W	31.958	116.164	140	Concrete wall 42m	WAWA
O'Connor Museum	MU-C	31.957	116.162	106	Concrete floor	WAWA
NORTH DANDALUP						
Downstream	ND-D	32.52	116.01	205	Granite	WAWA
PERTH						
Telecom)	PT-B	31.953	115.850	10	Perth Basin Sediment	TEL
Exchange)	PT-M	31.953	115.850	40	Perth Basin Sediment	TEL
Building)	PT-T	31.953	115.850	70	Perth Basin Sediment	TEL
SERPENTINE DAM						
Basement	SE-B	32.40	116.10		Granite	WAWA
Wall	SE-W	32.40	116.10		Earthfill	WAWA
VICTORIA DAM						
Survey marker	VI-D	32.04	116.06		Granite	WAWA

OWNERS

BMR	Bureau of Mineral Resources, Mundaring Geophysical Observatory
WAWA	Water Authority of Western Australia
TEL	Telecom

ABLE 12

ACCELEROGRAPH CALIBRATION DATA

CODE	DATE OF OPERATION	INST. NO.	BLOCK NO.	CALIBRATION DATA g-cm and azimuth Ia	Ib	Ic
BA-M	Fm 1990 May 08	MO2 291	1196	0.590 090	0.560 000	0.394 Up
CA-A	Fm 1986 Jul 02	A700 033	ID002	1.159V 090	1.172V 000	1.167V Up
CA-C	Fm 1986 Oct 03 To 1990 May 07	MO2 291	1196	0.590 090	0.560 000	0.394 Up
CA-E	Fm 1987 Jan 21	A700 030	ID003	1.178V 090	1.216V 000	1.187V Up
CA-I	Fm 1987 Dec 11 To 1989 Jun 23	MO2 245	448	0.602 090	0.628 000	0.409 Up
CA-K	Fm 1985 Dec 18	MO2 289	1166A	0.582 090	0.548 000	0.348 Up
CA-R	Fm 1986 Jul 01 To 1986 Aug 05	MO2 291	1196	0.540 090	0.560 000	0.394 Up
	Fm 1986 Aug 05	MO2 290	651	0.631 090	0.659 000	0.433 Up
CA-S	Fm 1985 Dec 18	MO2	1462	0.609	0.597	0.417
CD-L	Fm 1987 Jan 16	A700 072	ID032	2.339V 090	2.400V 000	2.308V Up
CD-U	Fm 1987 Jan 16	A700 056	ID033	2.436V 090	2.396V 000	2.420V Up
DO-W	Fm 1989 Sep 13	Kelungi		2×10^6 counts/g		
GO-O	Fm 1988 Dec 20	Kelungi 057		2×10^6 counts/g		
KN-A	Fm 1989 Jul 04	A700 244	ID040	1.200V 090	1.217V 000	1.221V Up
KN-W	Fm 1989 Jul 04	A700 203	ID041	1.209V 090	1.247V 000	1.233V Up
ME-K	Fm 1989 Jul 01	MO2 245	837	0.625 090	0.642 000	0.443 Up

Table 12 (Cont'd)

CODE	DATE OF OPERATION	INST. NO.	BLOCK NO.	CALIBRATION DATA g-cm and azimuth Ia	Ib	Ic
ME3	Fm 1991 Jul 11 To 1991 Nov 07	A700 030	ID003	1.178V 090	1.1216V 000	1.187V Up
	Fm 1991 Nov 07	A700 033	ID002	1.159V 090	1.172V 000	1.167V Up
MU-C	Fm 1987 Aug 21	MO2 244	423			
MU-W	Fm 1979 Apr 24	SMA-1 1072		0.510 000	0.526 Up	0.568 090
ND-D	Fm 1989 Dec 28	A700 200	ID044	2.443V 090	2.450V 000	2.413V Up
PT-B	Fm 1981 Sep 21	SMA-1 4271		0.148 300	0.138 Up	0.135 210
PT-M	Fm 1981 Sep 21	SMA-1 4272		0.138 300	0.144 Up	0.135 210
PT-T	Fm 1981 Sep 21	SMA-1 4273		0.151 300	0.136 Up	0.136 210
SE-B	Fm 1987 May 05	A700 069	ID036	2.339V 090	2.395V 000	2.314V Up
SE-W	Fm 1987 May 05	A700 078	ID037	2.377V 090	2.395V 000	2.314V Up
VI-D	Fm 1989 Dec 30	A700 201	ID047	2.378V 090	2.424 000	2.421 Up

TABLE 13

ACCELEROGRAM DATA - 1991

Date UTC	Time	Lat°S	Long°E	ML	Site	H/E km	C	T sec	Acc mms^{-2}
01 08	0527	30.62	117.07	3.3	CA-K	14/13	SZ	0.030	26.0
							SN	0.037	27.0
							SE	0.037	29.0
02 16	1114	30.74	117.16	1.9	CA-A	3/1	SZ	0.018	187.0
							SN	0.022	323.0
							SE	0.014	294.0
03 09	1752	30.79	117.09	2.1	CA-A	8/7	SZ	0.030	21.0
							SN	0.030	120.0
							SE	0.030	93.0
03 14	1218	30.75	117.12	2.3	CA-A	5/3	SZ	0.042	30.0
							SN	0.022	140.0
							SE	0.022	85.0
04 25	2310	UNLOCATED			CA-A		SZ	—	20.0
							SN	0.018	196.0
							SE	0.021	235.0
09 19	2101	31.62	117.03	2.0	GOO	30/30	SZ	0.035	8.0
							SN	0.035	10.0
							SE	0.035	130.0
10 02	0628	31.62	117.04	1.9	GOO	33/33	SZ	0.040	8.0
							SN	0.040	16.0
							SE	0.040	13.0
11 03	1536	31.70	116.99	1.9	GOO	37/37	SZ	0.040	1.0
							SN	0.040	3.0
							SE	0.040	3.0
11 15	2239	31.63	117.05	1.8	GOO	32/32	SZ	0.035	2.0
							SN	0.035	5.0
							SE	0.035	3.0
11 16	0452	30.76	117.14	2.6	CA-K	5/4	SZ	0.030	17.0
							SN	0.037	10.0
							SE	0.024	29.0
11 25	0133	30.78	117.13	2.6	CA-K	7/7	SZ	0.033	60.0
							SN	0.033	67.0
							SE	0.037	114.0

TABLE 13 (Cont'd)

Date UTC	Time	Lat°S	Long°E	ML	Site	H/E km	C	T sec	Acc mms^{-2}
11 25	0142	30.77	117.14	3.2	CA-S	5/5	SZ	0.040	61.0
S-P 0.53s							SN	0.030	73.0
							SE	0.043	149.0
					CA-K	6/6	SZ	0.037	65.0
							SN	0.030	94.0
							SE	0.037	171.0
					GOO	5/75	SZ	0.040	4.0
							SN	0.040	6.0
							SE	0.040	6.0
12 08	2143	31.74	117.01	2.2	ME-3	5/5	SZ	0.025	225.0
							SN	0.036	225.0
							SE	0.030	225.0
					GOO	42/42	SZ	0.035	3.0
							SN	0.035	6.0
							SE	0.035	6.0

TABLE 14

GNANGARA - ABSOLUTE INSTRUMENTS, 1991

Used from	Component	Instrument	Ser. No.	Correction
1986 Jan 01	H	PVM MNS-2	B/5/Z#	0 nT
1986 Jan 01	D	Askania Circle	509319 580135	0.5'
1986 Jan 01	Z	PVM MNS-2	B/5/Z#	0 nT
1991 Jan 01	D & I	DIM	313837	0.0'
1991 Jan 01	F	PPM Elsec	215	0 nT

PVM serial number coil/magnetometer/sensor

TABLE 15

GNANGARA - INSTRUMENT COMPARISONS, 1991

Date	Instruments	Difference	No. of Obs.
<u>Through baseline values</u>			
Jun to Jul	D.DIM 313837 - D.DIM 353758	0.05'	18
Jun to Jul	I.DIM 313837 - I.DIM 353758	-0.03'	18
Aug to Sep	D.DIM 313837 - D.DIM 311847	0.1'	14
Aug to Sep	I.DIM 313837 - I.DIM 311847	0.07'	14

TABLE 16
GNANGARA - AZIMUTHS OF REFERENCE MARKS

	E	SE	SW	N
	Datum#	Temporary	Permanent	Permanent
Distance from	70m	30m	85m	130m
Resolution 1mm	0.05'	0.09'	0.04'	0.25'
Date	Azimuth from NE pier			
1982 Aug 11	77° 23.6	150° 28.4	198° 59.0	03° 10.4
1982 Sep 20	77° 23.6	150° 28.4	198° 59.4	03° 10.6
1982 Oct 07	77° 23.6	150° 28.4	198° 59.4	03° 10.4
1983 Aug 21	77° 23.6		198° 59.3	03° 10.3
1985 Aug 21	77° 23.6		198° 59.2	03° 10.3
1987 Jan 16	77° 23.6		198° 59.2	03° 10.4
1989 Nov 24	77° 23.6		198° 53.3	03° 10.4
Adopted	77° 23.6	150° 28.4	198° 59.3	03° 10.4

Azimuth determined by Australian Survey Office. All other azimuths are relative to this value.
Azimuths read from NE pier

TABLE 17

GNANGARA - ESCHENHAGEN VARIOMETER TEMPERATURE COEFFICIENTS

Used from Yr	Mn Dy	Hr	Component	Coefficient nT/°C
1981	Jan 01	00	H	0.0
1981	Jan 01	00	Z	3.2
1987	Jan 16	06	Z	2.0
1988	Aug 26	00	Z	1.0

TABLE 18

GNANGARA - ESCHENHAGEN ORIENTATION TESTS

Date	Component	Reference	Magnet	Orientation	N Pole
1985 Jul 09	H	23247 nT	East	0.2°	South
1987 Jan 16	H	23241 nT	East	0.3°	South
1989 Feb 28	H	23204 nT	East	0.8°	South
1985 Jul 09	D	3°17.5' W	North	0.2°	West
1986 Jan 16	D	3°15.0' W	North	0.1°	West
1989 Feb 28	D	3°10.0' W	North	0.2°	West
1985 Jul 09	Z	53771 nT	North	0.5°	Up
1989 Feb 28	Z	53809 nT	North	0.3°	Up

TABLE 19

GNANGARA - STANDARD DEVIATION OF OBSERVATIONS

Year	H Scale Value nT/mm	Z Scale Value nT/mm	D Base Value nT(min)	H Base Value nT	Z Base Value nT
1981	0.02	0.04	0.7 (0.1)	1.1	1.2
1982	0.02	0.03	1.5 (0.2)	1.4	1.7
1983	0.01	0.03	1.7 (0.25)	0.9	1.3
1984	0.02	0.04	1.4 (0.20)	1.4	1.0
1985	0.013	0.033	1.4 (0.19)	1.14	1.43
1986	0.012	0.019	1.5 (0.22)	1.06	1.87
1987	0.015	0.023	1.3 (0.20)	1.49	1.90
1988	0.014	0.025	1.8 (0.26)	1.04	1.73
1989	0.014	0.026	1.4 (0.19)	1.00	0.91
1990	0.019	0.031	1.6 (0.22)	0.89	0.89
			D Base Value nT/(min)	F Base Value nT	I Base Value nT
1991	-	-	1.3 (0.18)	1.7	0.2 (0.012)

TABLE 20

GNANGARA - AMO ADOPTED CONTROL VALUES 1991

		Year	Mn	Dy	Hr	Min	Value	Remarks
GNA	MD	1991	1	1	0	0	-185.0	
GNA	MF	1991	1	1	0	0	58600.0	
GNA	MI	1991	1	1	0	0	-4001.0	
GNA	SD	1991	1	1	0	0	-0.01483	
GNA	SF	1991	1	1	0	0	0.10000	
GNA	SI	1991	1	1	0	0	-0.00587	
GNA	OD	1991	1	1	0	0	5000.0	
GNA	OF	1991	1	1	0	0	5000.0	
GNA	OI	1991	1	1	0	0	5000.0	
GNA	BD	1991	1	1	0	0	-199.4	
GNA	BD	1991	1	5	23	0	-183.8	
GNA	BD	1991	1	21	0	0	-183.9	
GNA	BD	1991	1	26	0	0	-184.0	
GNA	BD	1991	2	1	0	0	-184.1	
GNA	BD	1991	6	1	0	0	-184.0	
GNA	BD	1991	7	26	0	0	-184.1	
GNA	BD	1991	11	11	0	0	-184.0	
GNA	BD	1991	11	21	0	0	-183.9	
GNA	BF	1991	1	1	0	0	58491.0	
GNA	BF	1991	12	1	0	0	58492.0	
GNA	BI	1991	1	1	0	0	-3995.3	
GNA	BI	1991	1	5	23	0	-3998.8	
GNA	BI	1991	2	1	0	0	-3998.7	
GNA	BI	1991	3	1	0	0	-3998.8	
GNA	BI	1991	4	11	0	0	-3998.7	
GNA	BI	1991	4	21	0	0	-3998.6	
GNA	BI	1991	5	6	0	0	-3998.7	
GNA	BI	1991	5	11	0	0	-3998.8	
GNA	BI	1991	5	16	0	0	-3998.9	
GNA	BI	1991	5	21	0	0	-3999.0	
GNA	BI	1991	5	26	0	0	-3999.1	
GNA	BI	1991	6	1	0	0	-3999.2	
GNA	BI	1991	6	6	0	0	-3999.3	
GNA	BI	1991	8	1	0	0	-3999.2	
GNA	BI	1991	8	6	0	0	-3999.1	
GNA	BI	1991	12	1	0	0	-3999.0	
GNA	BI	1991	12	15	0	0	-3998.9	

TABLE 21
PRELIMINARY MONTHLY MEAN GEOM[illegible]ETIC VALUES, 1991

Month	D (West)	H, nT	Z, nT	F, nT
January	3 03.6	23203	-53777	58569
February	03.0	200	784	574
March	02.9	172	788	567
April	02.2	163	797	571
May	02.0	167	795	572
June	02.1	147	803	571
July	01.8	160	799	572
August	01.3	169	797	571
September	01.1	176	793	572
October	01.5	164	795	569
November	01.3	159	800	573
December	2 58.1	193	796	574
Mean	3 01.7	23173	53794	58571

TABLE 22
GNANGARA - GEOMAGNETIC ANNUAL MEAN VALUES, 1981-1991
(AND SECULAR VARIATION)

Year	D	I	H, nT	X, nT	Y, nT	Z, nT	F, nT	Notes
1980	3° 17.8'	66° 25.7'	23409	23370	-1346	-53652	-58536	C
	(-2.1)	(-3.2)	(-45)	(-45)	(-12)	(-33)	(+14)	
1981	19.9	28.9	364	325	-1358	685	550	D
	(+0.4)	(-3.0)	(-43)	(-43)	(-29)	(-29)	(+8)	
1982	19.5	31.9	321	282	-1353	714	558	D
	(+0.2)	(-1.8)	(-27)	(-27)	(+3)	(-16)	(+4)	
1983	19.3	33.7	294	255	-1350	730	562	D
	(+0.3)	(-1.6)	(-21)	(-21)	(+4)	(-22)	(+14)	
1984	19.0	35.3	273	234	-1346	752	574	D
	(+1.1)	(-1.7)	(-15)	(-15)	(+8)	(-20)	(+13)	
1985	17.9	37.0	258	219	-1338	772	587	D
	(+2.4)	(-1.1)	(-19)	(-18)	(+18)	(-20)	(+10)	
1986	15.5	38.1	239	201	-1320	792	597	D
	(+2.0)	(-0.9)	(-11)	(-10)	(+13)	(-14)	(+09)	
1987	13.5	39.0	228	191	-1307	806	606	D
	(+1.8)	(-0.9)	(-14)	(-13)	(+13)	(-05)	(-02)	
1988	11.7	39.9	214	1788	-1294	811	604	D
	(+3.1)	(-0.9)	(-17)	(-16)	(+22)	(-02)	(-04)	
1989	08.6	40.8	197	162	-1272	813	600	D
	(+2.5)	(+0.1)	(-02)	(-01)	(+17)	(-11)	(-41)	
1990	06.1	40.7	195	161	-1255	802	589	D
	(+4.4)	(-1.0)	(-22)	(-20)	(+31)	(-8)	(-18)	
1991	01.7	41.7	173	141	-1224	794	571	E

Notes: C Preliminary values = Mean daily values, 10 days
D Preliminary values = Mean daily values, 5 days
E Preliminary values = Mean of all days

TABLE 23

LEARMONTH - ABSOLUTE INSTRUMENTS

Used From	Component	Instrument	Serial No.	Correction
1986 Nov 30	D	DIM	311847	0
1986 Nov 30	I	DIM	311847	0
1986 Nov 30	F	PPM Elsec	E770/189	0
1991 Aug 14	D	DIM	353758	0
1991 Aug 14	I	DIM	353758	0

TABLE 24

LEARMONTH - TEMPERATURE COEFFICIENTS

Data Set	Component	Coefficient (nT/ C)
1986 Nov	X	0.77
1986 Nov	Y	0.04
1986 Nov	Z	-0.65
1987 Jan - Oct	X	0.682
1987 Jan - Dec	Z	-0.506
1988 Mar - Dec	X	0.568
1988 Jan - Dec	Z	-0.498
1991 Jan - Dec	X	1.19
1991 Jan - Dec	Y	-0.31
1991 Jan - Dec	Z	1.74

Adopted values from

Year Mn Dy Hr		
1986 11 26 00	X	0.6
1986 11 26 00	Y	0.0
1986 11 26 00	Z	-0.5
1991 01 01 00	X	1.19
1991 01 01 00	Y	-0.31
1991 01 01 00	Z	1.74

TABLE 25

LEARMONTH - ADOPTED CONTROL VALUES 1991

Stn	Comp	Year	Mn	Dy	Hr	Min	Value	Remark
LRM	MX	1991	1	1	0	0	29500.0	
LRM	MY	1991	1	1	0	0	-247.0	
LRM	MZ	1991	1	1	0	0	-44441.0	
LRM	TS	1991	1	1	0	0	25.0	
LRM	ST	1991	1	1	0	0	0.0204	
LRM	BT	1991	1	1	0	0	4.43	
LRM	QX	1991	1	1	0	0	-1.19	
LRM	QY	1991	1	1	0	0	0.31	
LRM	QZ	1991	1	1	0	0	-1.74	
LRM	OX	1991	1	1	0	0	4997	
LRM	OX	1991	12	1	0	0	4996	
LRM	OY	1991	1	1	0	0	4998	
LRM	OY	1991	2	1	0	0	4999	
LRM	OY	1991	3	1	0	0	4998	
LRM	OY	1991	5	16	0	0	4997	
LRM	OY	1991	6	16	0	0	4998	
LRM	OY	1991	8	1	0	0	4999	
LRM	OY	1991	9	16	0	0	4998	
LRM	OY	1991	10	1	0	0	4997	
LRM	OZ	1991	1	1	0	0	5018	
LRM	OZ	1991	3	1	0	0	5017	
LRM	OZ	1991	4	1	0	0	5063	
LRM	SX	1991	1	1	0	0	0.1956	
LRM	SX	1991	1	25	0	0	0.1998	
LRM	SX	1991	3	21	0	0	0.1996	
LRM	SX	1991	5	1	0	0	0.1998	
LRM	SX	1991	5	11	0	0	0.2000	
LRM	SX	1991	6	1	0	0	0.1998	
LRM	SY	1991	1	1	0	0	0.1990	
LRM	SY	1991	1	6	0	0	0.2000	
LRM	SY	1991	1	11	0	0	0.2010	
LRM	SY	1991	1	16	0	0	0.2020	
LRM	SY	1991	2	1	0	0	0.2030	
LRM	SY	1991	3	1	0	0	0.1960	

Table 25 (cont'd)

Stn	Comp	Year	Mn	Dy	Hr	Min	Value	Remark
LRM	SY	1991	3	11	0	0	0.1970	
LRM	SY	1991	3	16	0	0	0.1980	
LRM	SY	1991	3	21	0	0	0.1990	
LRM	SY	1991	3	26	0	0	0.2000	
LRM	SY	1991	4	16	0	0	0.1990	
LRM	SY	1991	5	1	0	0	0.1980	
LRM	SY	1991	5	16	0	0	0.1970	
LRM	SY	1991	6	6	0	0	0.1980	
LRM	SY	1991	6	11	0	0	0.1990	
LRM	SY	1991	7	1	0	0	0.1980	
LRM	SY	1991	10	1	0	0	0.1970	
LRM	SY	1991	10	3	0	0	0.1960	
LRM	SY	1991	10	5	0	0	0.1950	
LRM	SY	1991	10	7	0	0	0.1940	
LRM	SY	1991	10	9	0	0	0.1930	
LRM	SY	1991	10	16	0	0	0.1940	
LRM	SY	1991	10	21	0	0	0.1950	
LRM	SY	1991	10	26	0	0	0.1960	
LRM	SY	1991	11	1	0	0	0.1970	
LRM	SY	1991	11	11	0	0	0.1980	
LRM	SY	1991	11	21	0	0	0.1990	
LRM	SZ	1991	1	1	0	0	-0.1978	
LRM	SZ	1991	2	1	0	0	-0.1980	
LRM	SZ	1991	5	1	0	0	-0.1978	
LRM	SZ	1991	12	1	0	0	-0.1980	
LRM	BX	1991	1	1	0	0	29501.0	
LRM	BX	1991	3	21	0	0	29502.0	
LRM	BX	1991	4	1	0	0	29503.0	
LRM	BX	1991	4	11	0	0	29504.0	
LRM	BX	1991	4	21	0	0	29503.0	
LRM	BX	1991	5	1	0	0	29502.0	
LRM	BX	1991	5	16	0	0	29501.0	
LRM	BX	1991	6	1	0	0	29500.0	
LRM	BX	1991	9	10	0	0	29505.0	
LRM	BX	1991	10	1	0	0	29506.0	
LRM	BX	1991	11	1	0	0	29507.0	
LRM	BX	1991	12	1	0	0	29508.0	
LRM	BY	1991	1	1	0	0	178	
LRM	BY	1991	2	1	0	0	180	
LRM	BY	1991	3	1	0	0	188	
LRM	BY	1991	7	1	0	0	186	
LRM	BY	1991	10	1	0	0	188	
LRM	BY	1991	11	1	0	0	190	
LRM	BY	1991	12	1	0	0	192	
LRM	BZ	1991	1	1	0	0	44399	

TABLE 26
LEARMONTH - STANDARD DEVIATION OF OBSERVATIONS, 1991

Year	Scale values			Base values			Zero values		
	X	Y	Z	X	Y	Z	X	Y	Z
1987	0.00035	0.0023	0.00013	2.27	2.63	1.72	0.5	1.4	0.6
1988	0.00023	0.0012	0.00018	2.27	2.59	2.46	0.5	0.5	0.5
1989	0.00034	0.0017	0.00031	1.89	2.90	2.25	0.7	0.4	0.4
1990	0.00027	0.0016	0.00030	0.26	0.49	0.75	0.6	0.2	2.1
1991	0.00010	0.0023	0.00018	2.1	2.4	4.1	0.3	0.5	0.3

TABLE 27
LEARMONTH - PRELIMINARY MONTHLY MEAN GEOMAGNETIC VALUES, 1991

Month	D (West)	H, nT	Z, nT	F, nT
January	00 26.9	29538	-44424	53348
February	26.9	529	424	343
March	27.3	517	426	338
April	26.7	527	419	338
May	26.5	518	418	332
June	26.3	500	428	330
July	26.1	526	422	339
August	26.2	512	427	336
September	25.6	535	417	340
October	25.1	543	421	348
November	25.5	527	428	345
December	25.6	547	420	349
Mean	00 26.2	29526	-44423	53341

TABLE 28
LEARMONTH - GEOMAGNETIC ANNUAL MEAN VALUES, 1991
(AND SECULAR CHANGES)

Year	D	I	H, nT	X, nT	Y, nT	Z, nT	Z, nT
1987	-00 37.4	-56 25.6	29483	29481	-321	-44421	53314
	(+1.0)	(-0.2)	(+1)	(+1)	(+9)	(-7)	(+6)
1988	-00 36.4	-56 25.8	29484	29482	-312	-44428	53314
	(+2.1)	(-0.4)	(-3)	(-3)	(+18)	(-5)	(+4)
1989	-00 34.3	-56 26.2	29481	29479	-294	-44433	53324
	(+5.6)	(+1.7)	(+35)	(+36)	(+48)	(-6)	(+24)
1990	-00 28.7	-56 24.5	29516	29515	-246	-44422	53348
	(+2.5)	(+1.1)	(+10)	(+10)	(+19)	(+1)	(-7)
1991	-00 26.2	-56 23.4	29526	29525	-225	-44423	53341

TABLE 29

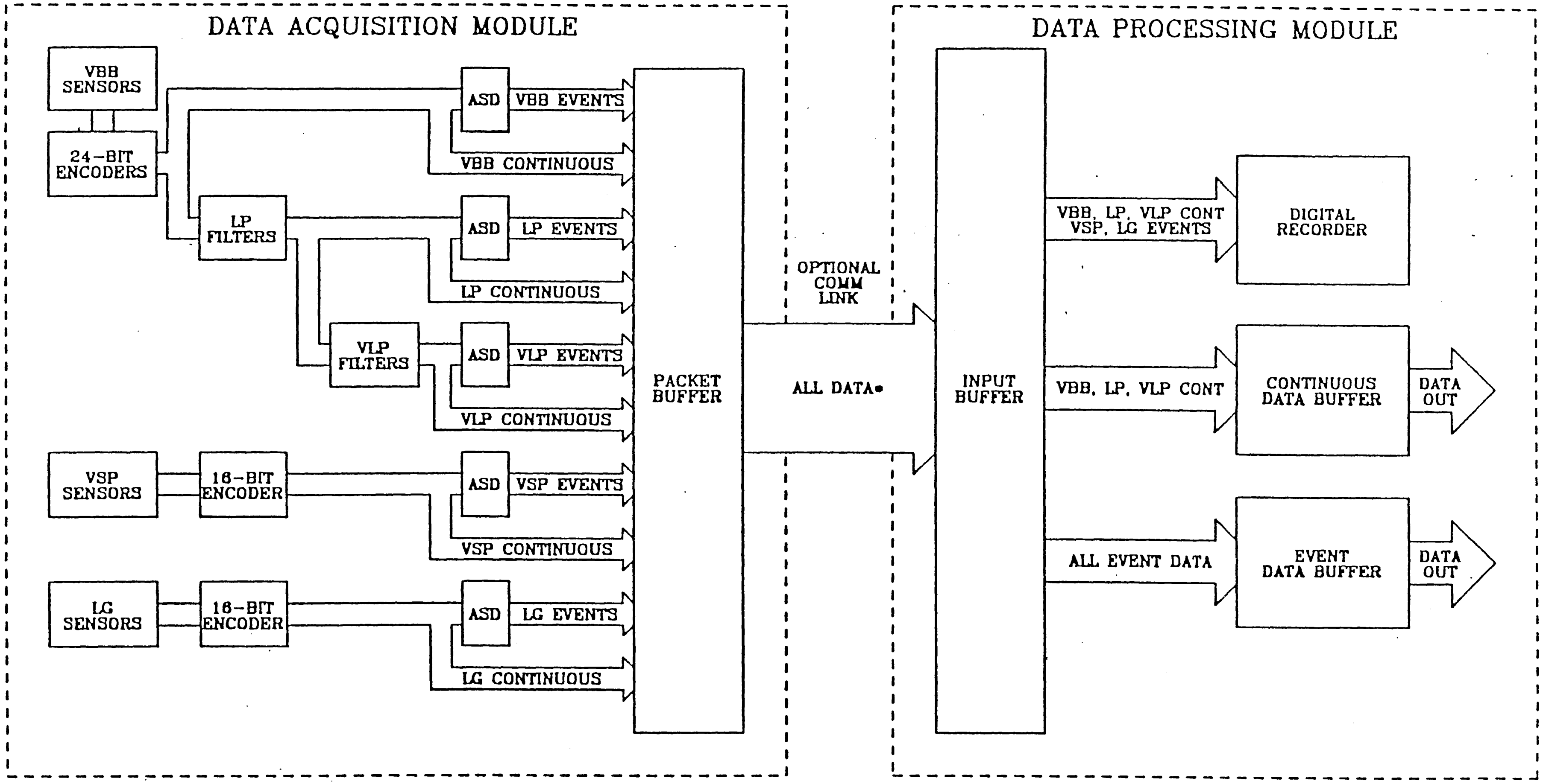
ROUTINE DISTRIBUTION OF GEOMAGNETIC DATA

Weekly	K-indices
Gnangara	Ionospheric Prediction Service for distribution to their recipients

Monthly	K-Indices	Rapid Variations	Principal Storms	Preliminary Mean Values	Magnetogram 16mm copy
Gnangara					
BMR, Canberra	*1	*1	*1	*1	
IPS, Sydney	*	*			
WDC A, Washington	*	*	*		*
WDC C1, Denmark	*	*	*		
WDC C2, Kyoto	*	*	*		
Observatory de Ebro		*2			
Institute de Physiques du Globe	*				
Learmonth					
BMR, Canberra				*1	

Data Published

1. Geophysical Observatory Report, Bureau of Mineral Resources, Geology and Geophysics
2. IAGA Bulletin, Geomagnetic data



ASD -- AUTOMATIC SIGNAL DETECTOR •OR A SELECTED SUBSET OF DATA, DEPENDING ON LINK BANDWIDTH

FIGURE 1 - IRIS data acquisition system

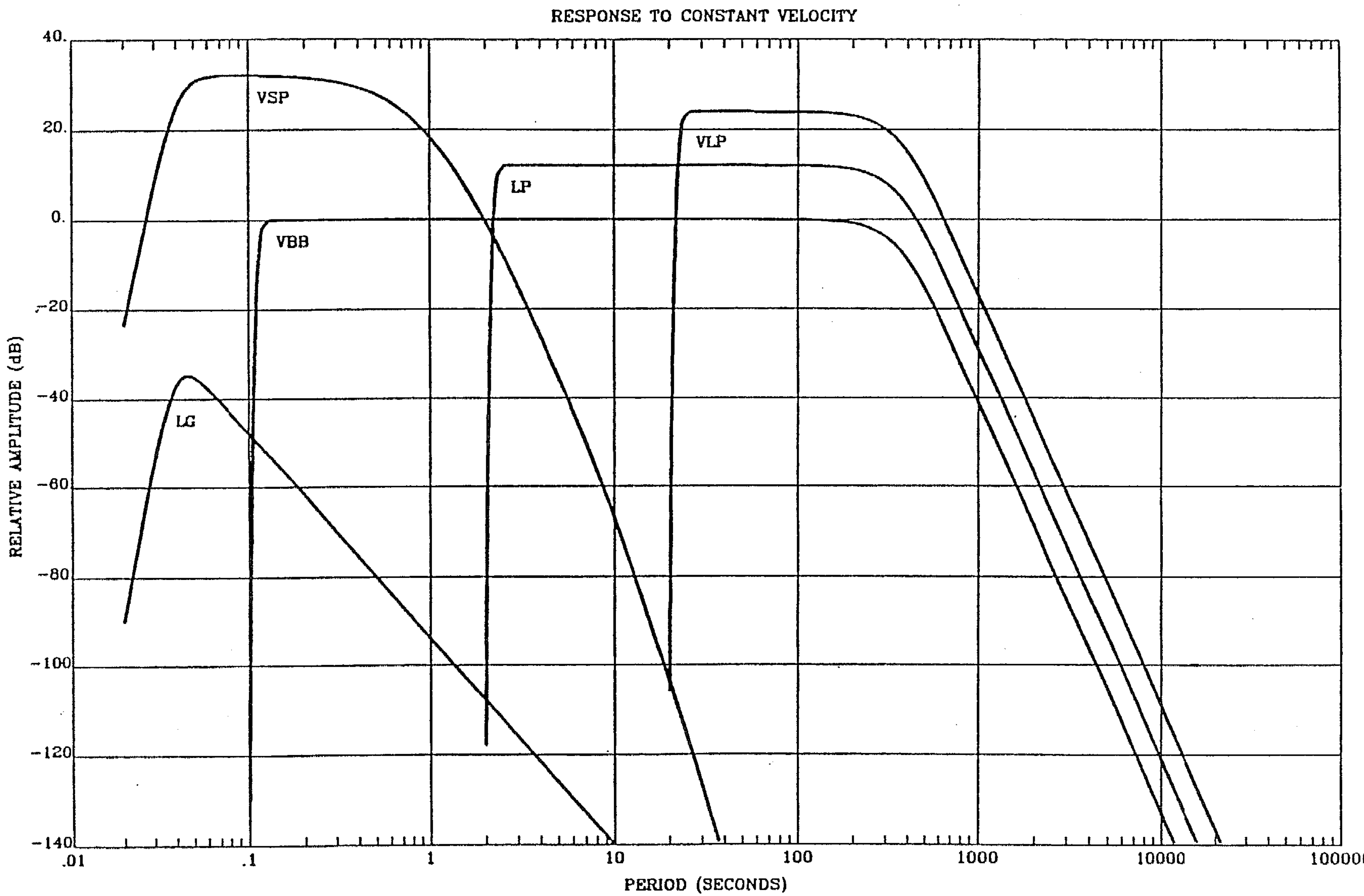


FIGURE 2 - IRIS response curves

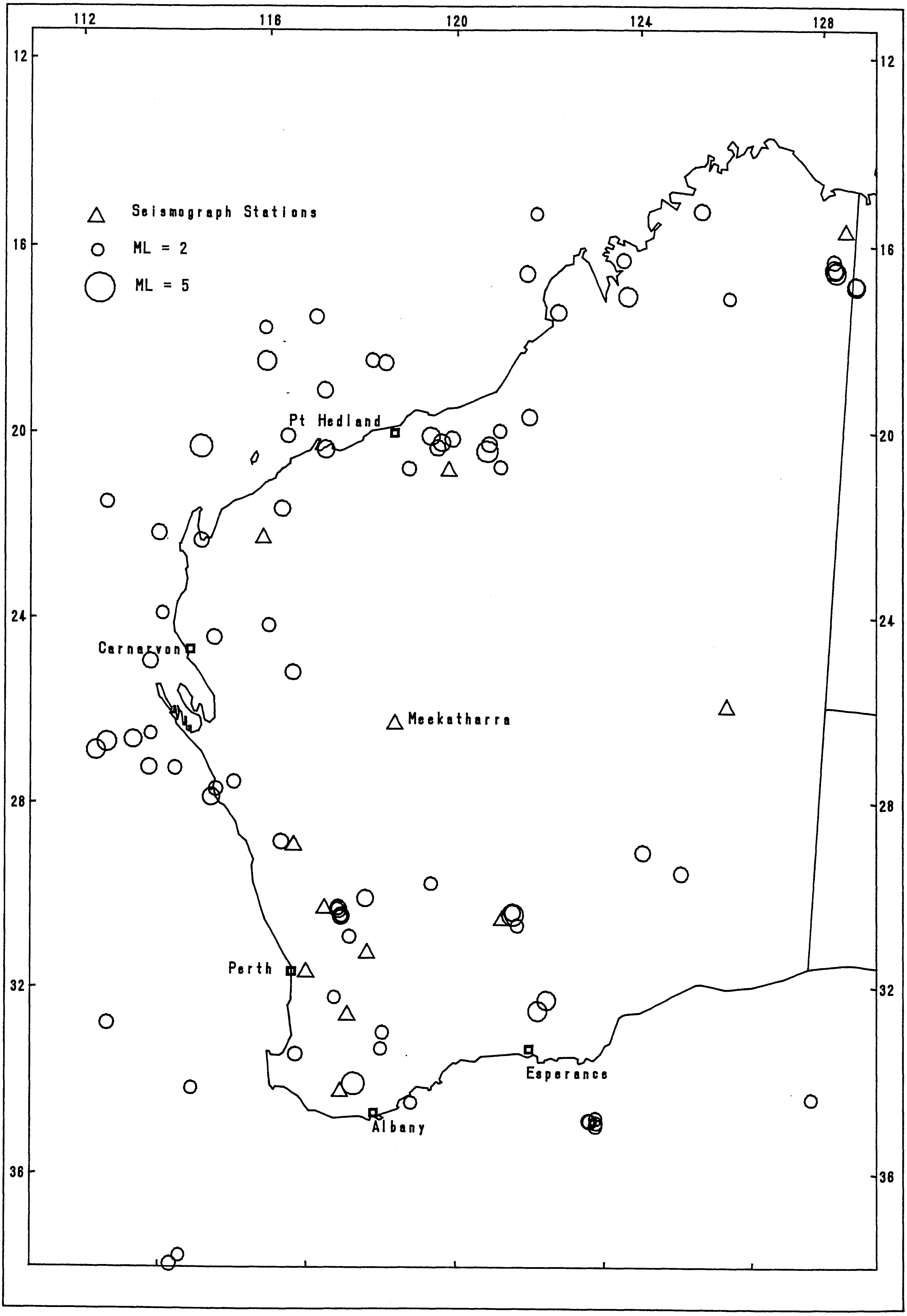


FIGURE 3 - Earthquakes in the region of Western Australia ML>2.4, 1991

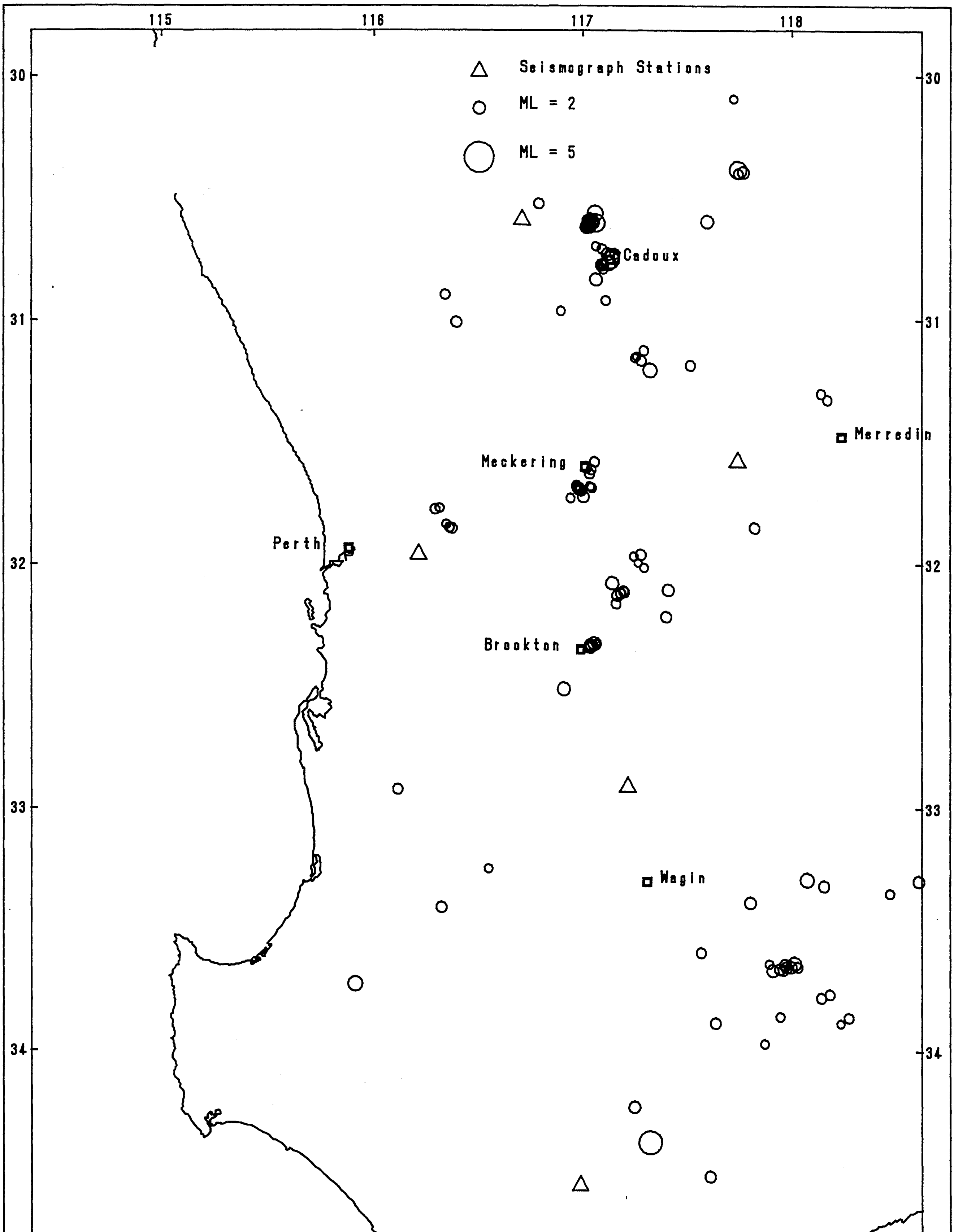
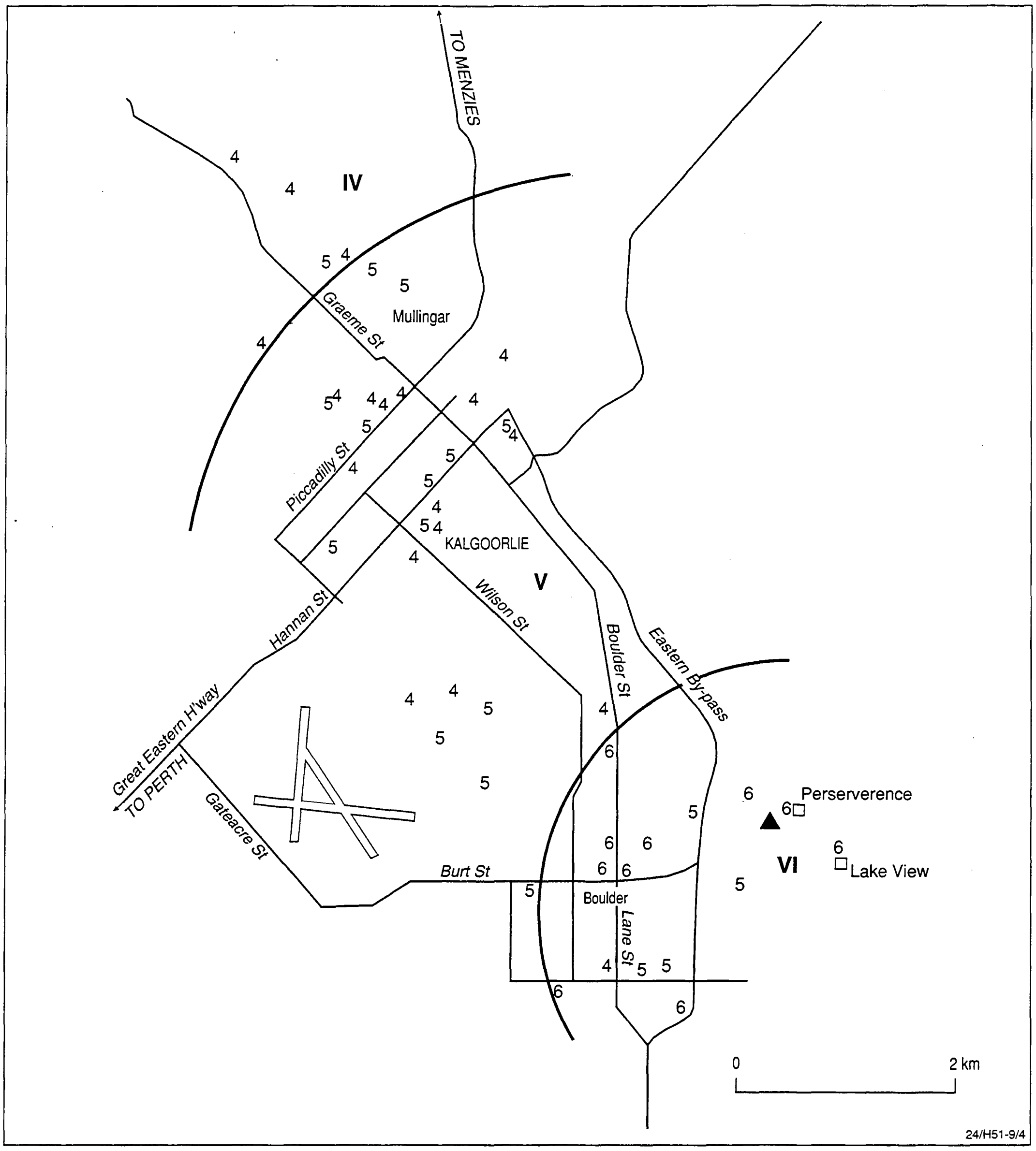


FIGURE 4 - Earthquakes in the region 30.0°-35.0°S and 114.5°-118.5° E, 1991

ISOSEISMAL MAP OF THE KALGOORLIE ROCKBURST, WESTERN AUSTRALIA
9 MARCH 1991



DATE: 9 MARCH 1991
TIME: 01:36:30.4 UTC
MAGNITUDE: 4.2 ML (MUN)
EPICENTRE: 30.78°S, 121.50°E
DEPTH 1 km

▲ *Epicentre*
IV *Zone intensity designation*
6 *Earthquake felt (MM)*
0 *Earthquake not felt*

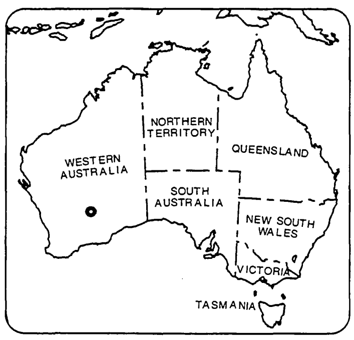
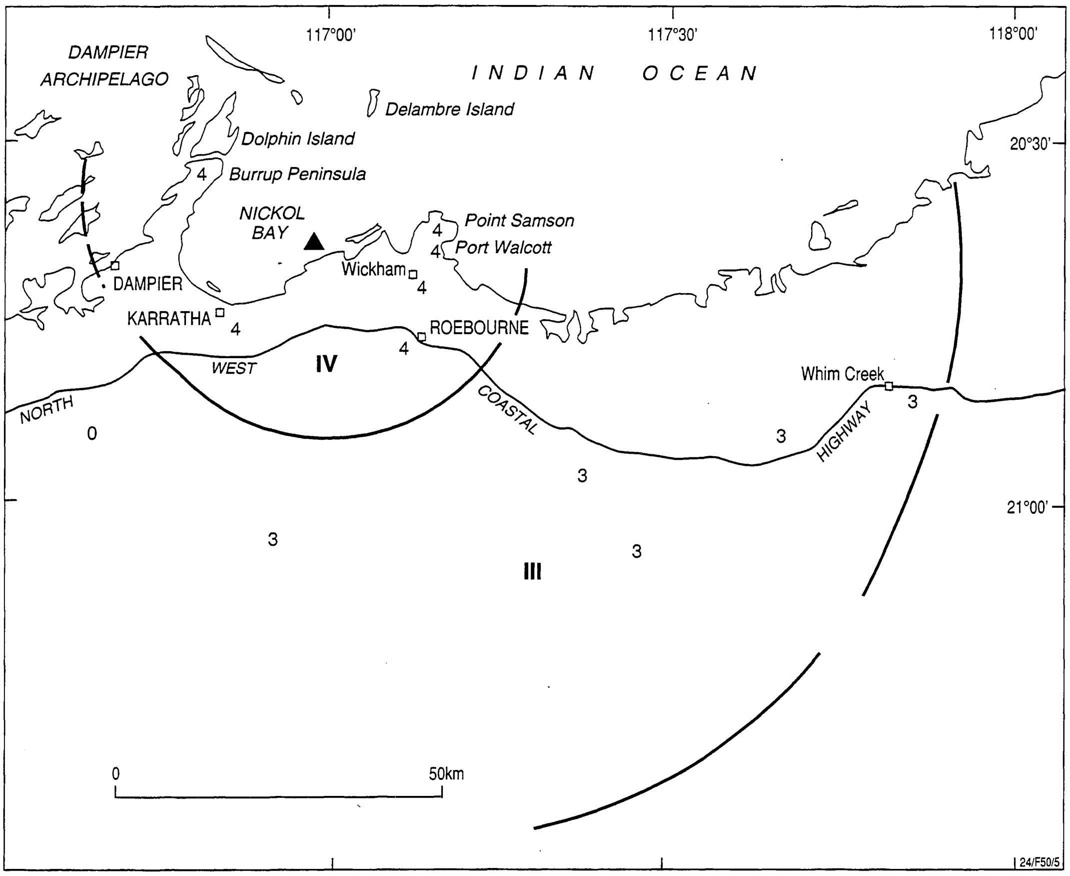


Figure 5

ISOSEISMAL MAP OF THE KARRATHA EARTHQUAKE, WESTERN AUSTRALIA
9 APRIL 1991



DATE: 9 APRIL 1991
TIME: 14:00:08.0 UTC
MAGNITUDE: 3.5 ML (MUN)
EPICENTRE: 20.65°S, 116.99°E

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

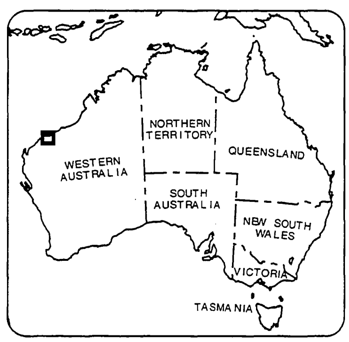
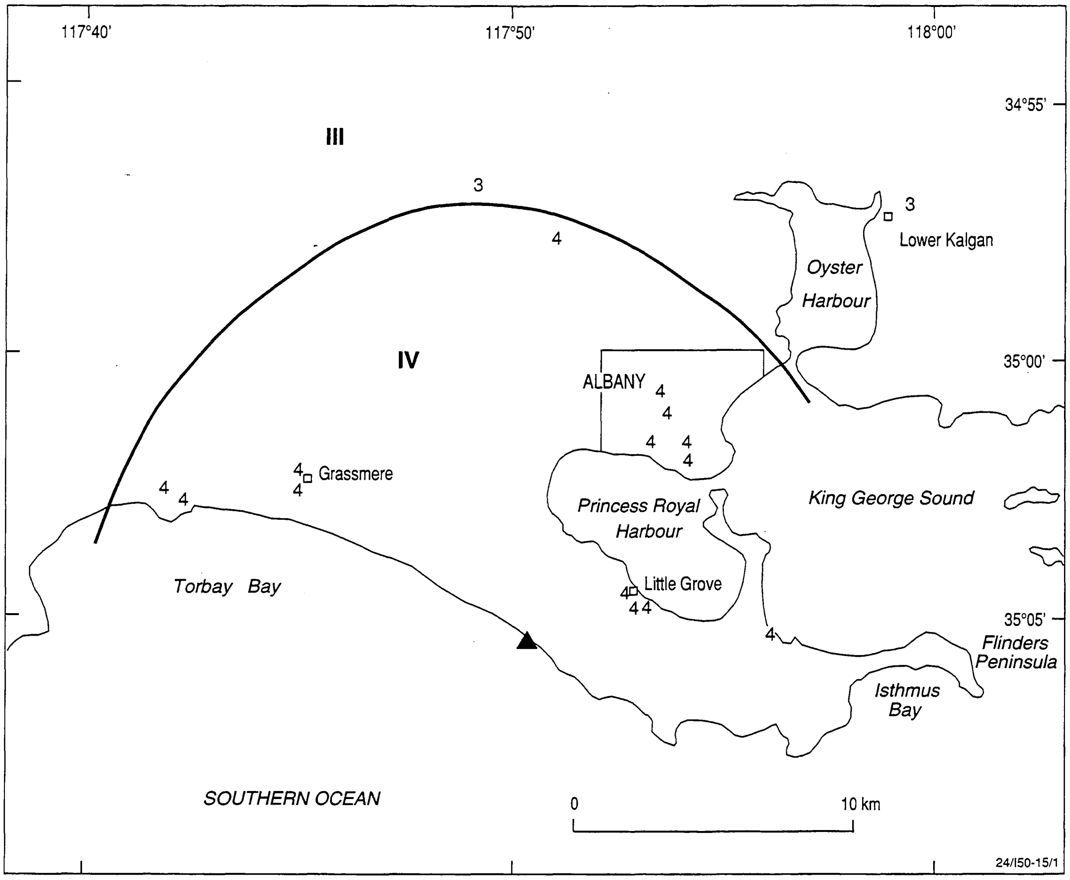


Figure 6

ISOSEISMAL MAP OF THE ALBANY EARTHQUAKE, WESTERN AUSTRALIA
22 SEPTEMBER 1991



DATE: 22 SEPTEMBER 1991
TIME: 17:01:36.9 UTC
MAGNITUDE: 2.4 ML (MUN)
EPICENTRE: 35.09°S, 117.83°E

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

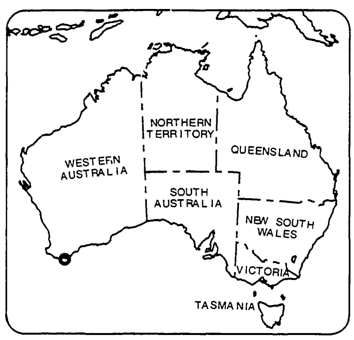
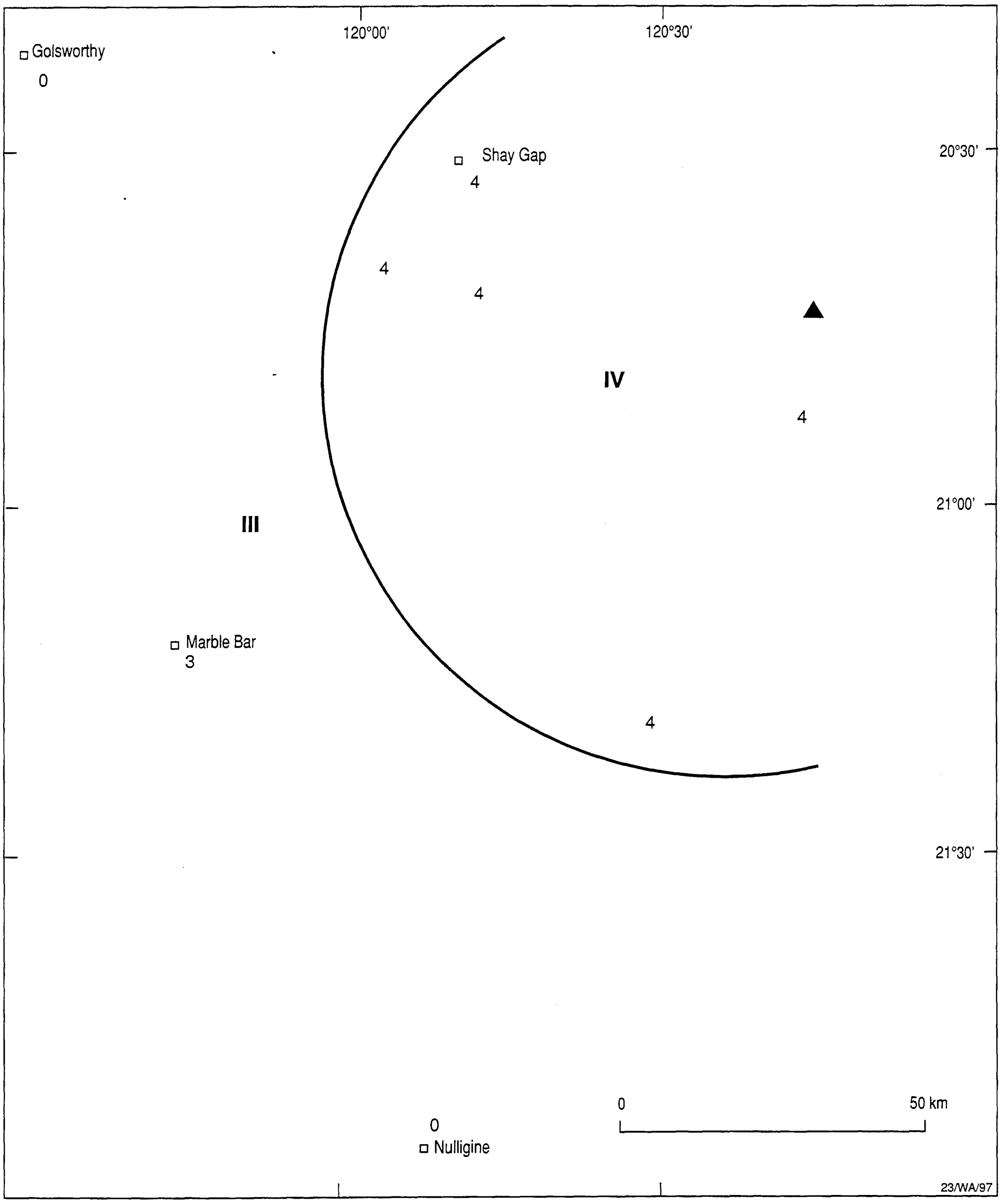


Figure 7

ISOSEISMAL MAP OF THE SHAY GAP EARTHQUAKE, WESTERN AUSTRALIA
23 SEPTEMBER 1991



DATE: 23 SEPTEMBER 1991
TIME: 21:19:58.1 UTC
MAGNITUDE: 4.0 ML (MUN)
EPICENTRE: 20.72°S, 120.71°E

▲	*Epicentre*
IV	*Zone intensity designation*
4	*Earthquake felt (MM)*
0	*Earthquake not felt*

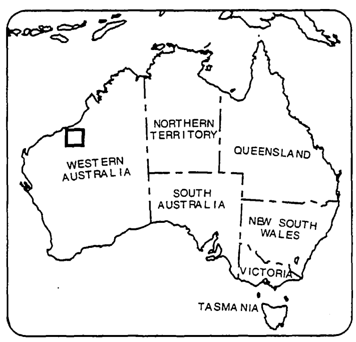
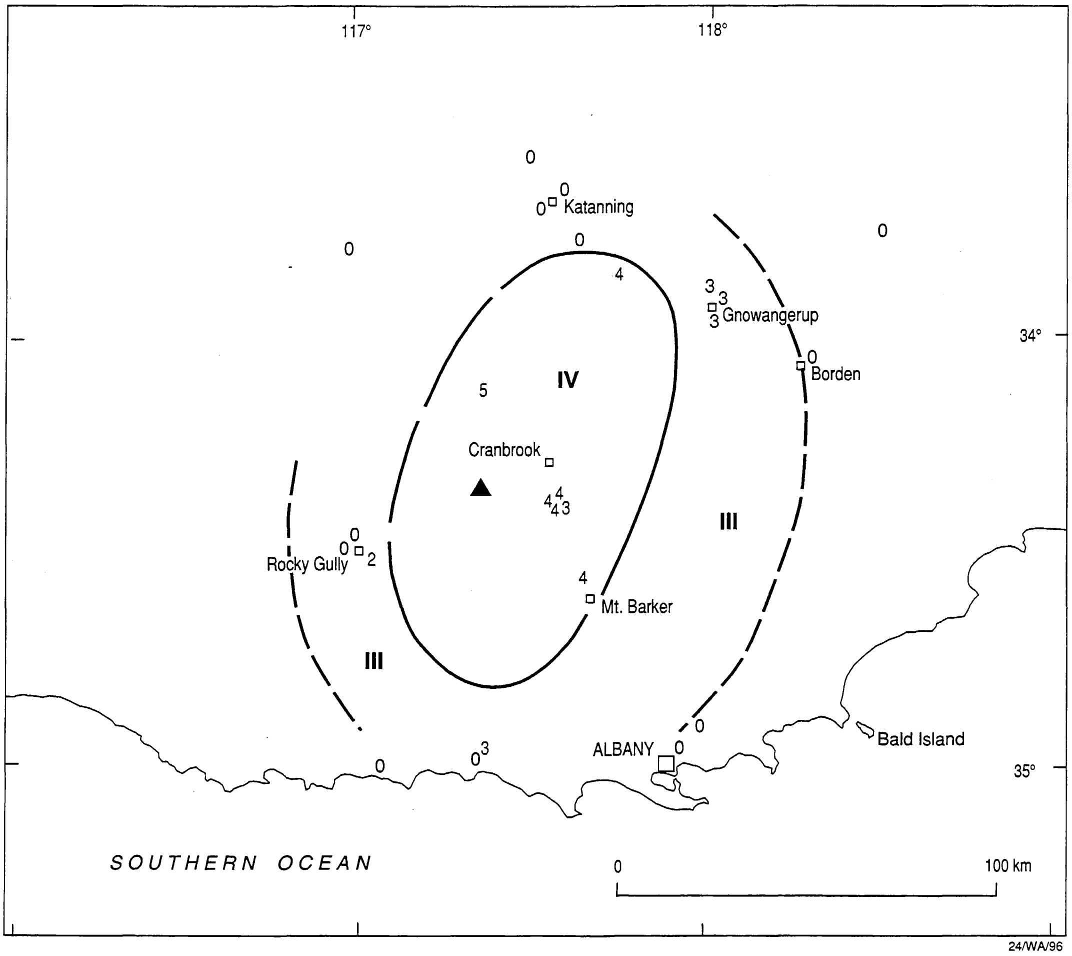


Figure 8

ISOSEISMAL MAP OF THE CRANBROOK EARTHQUAKE, WESTERN AUSTRALIA 13 DECEMBER 1991



DATE: 13 DECEMBER 1991
TIME: 04:48:17.6 UTC
MAGNITUDE: 4.3 ML (MUN)
EPICENTRE: 34.39°S, 117.36°E

▲ *Epicentre*
IV *Zone intensity designation*
4 *Earthquake felt (MM)*
0 *Earthquake not felt*

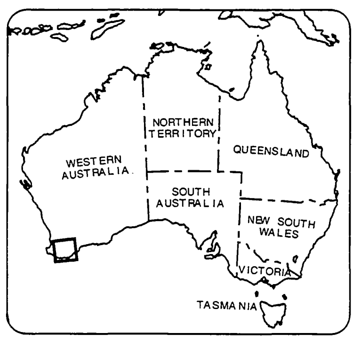
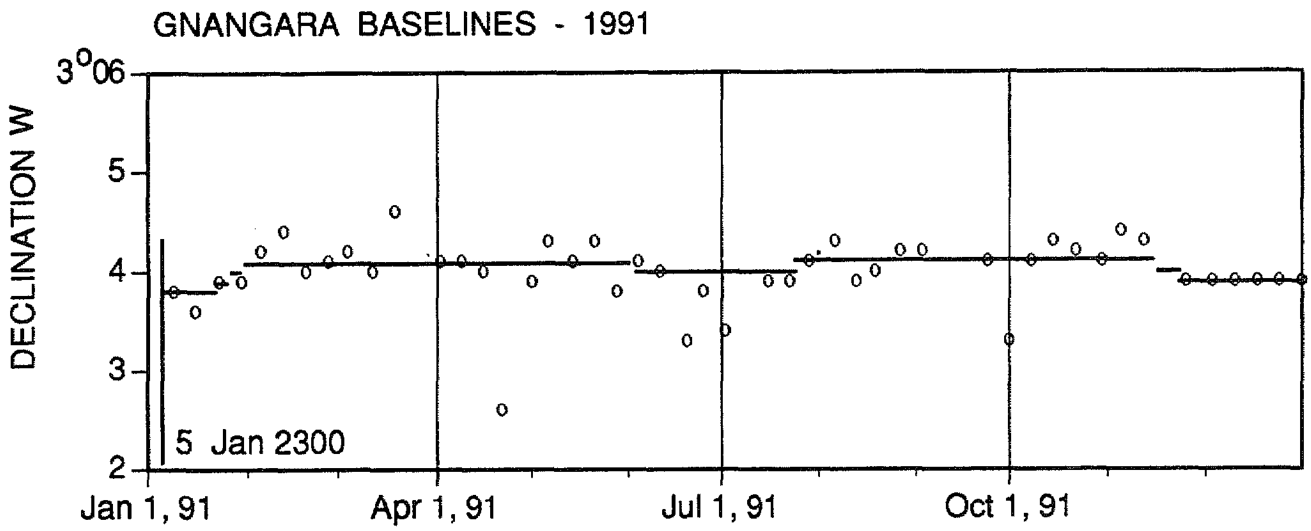
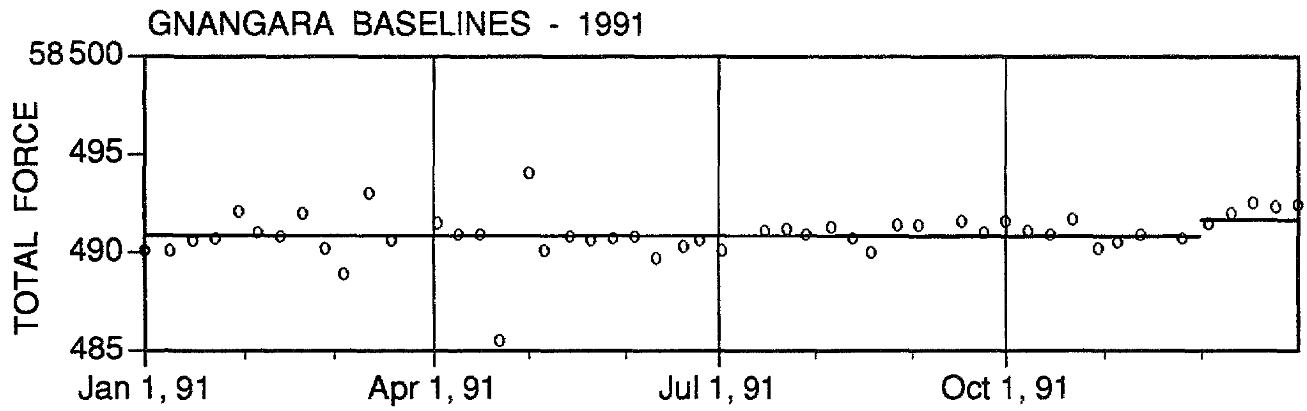


Figure 9





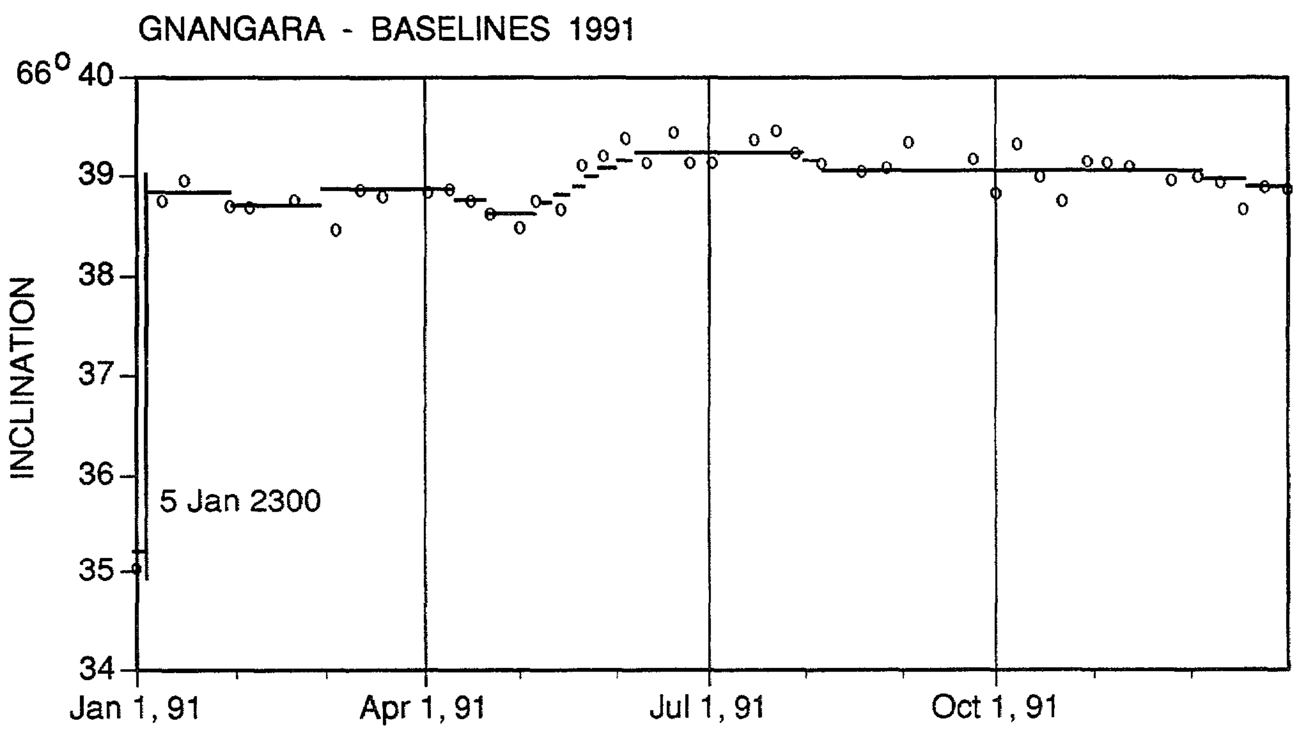


FIGURE 10 - Gnangara - observed and adopted baseline values

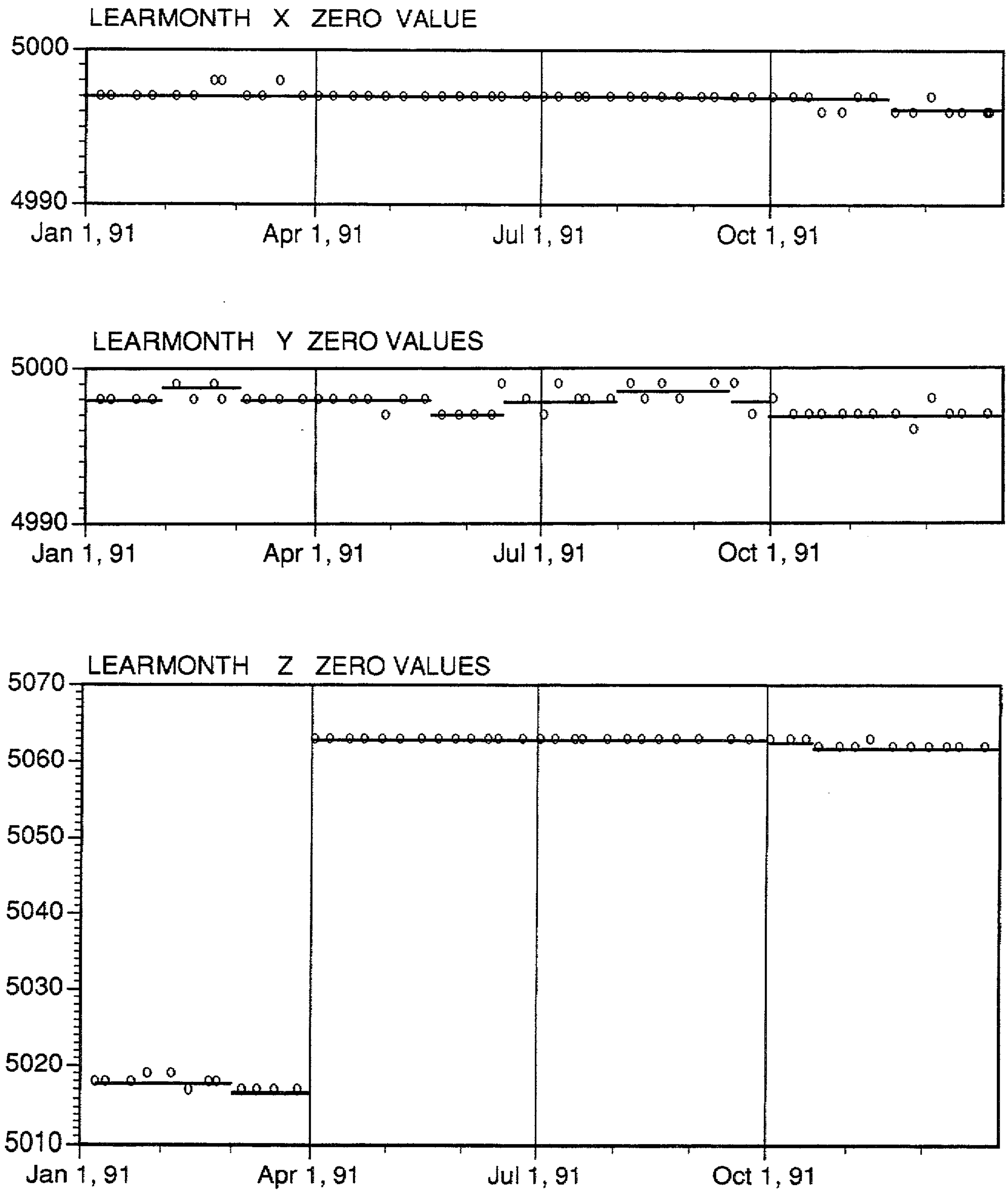


FIGURE 11 - Learmonth - observed and adopted zero values

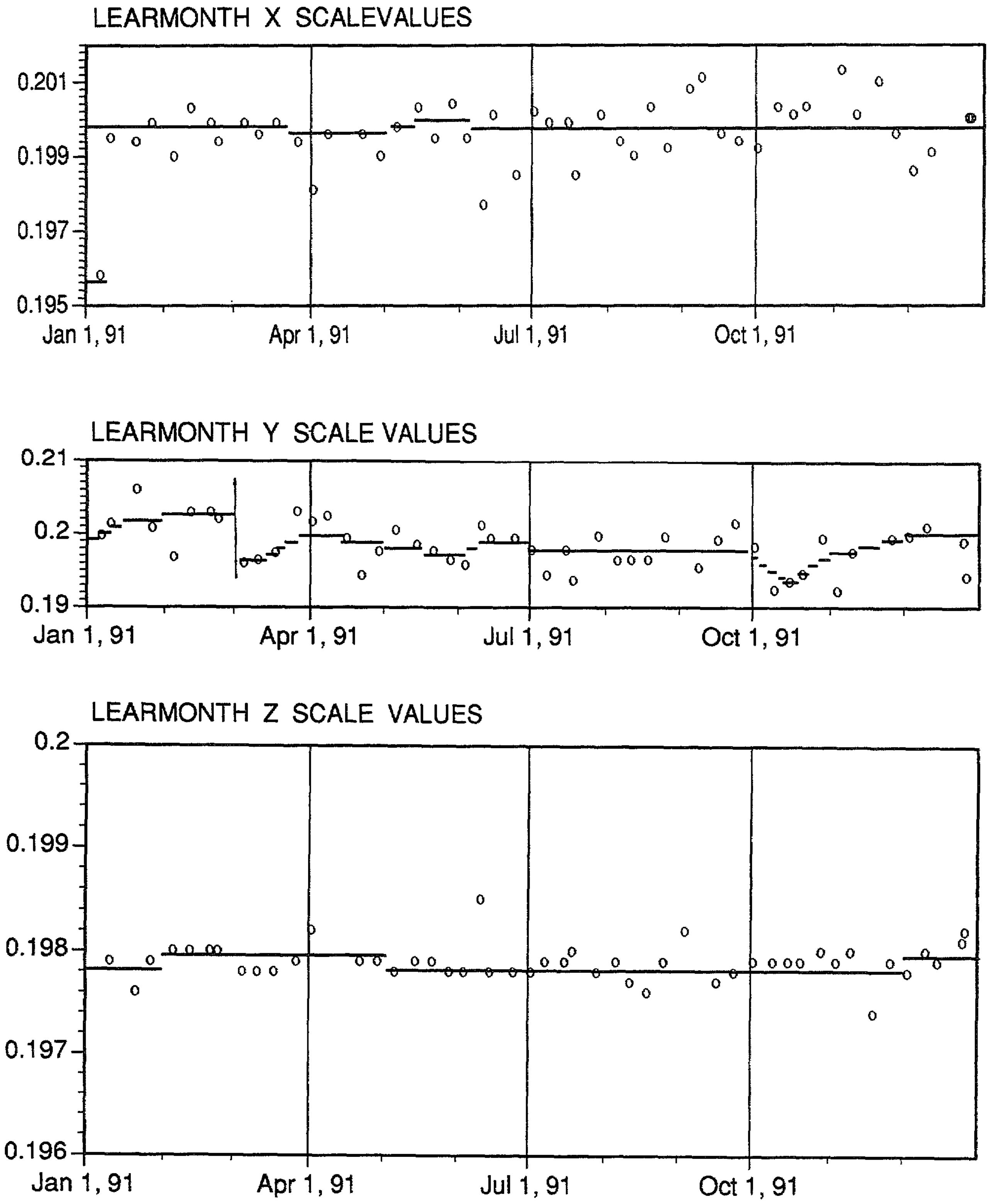


FIGURE 12 - Learmonth - observed and adopted scale values

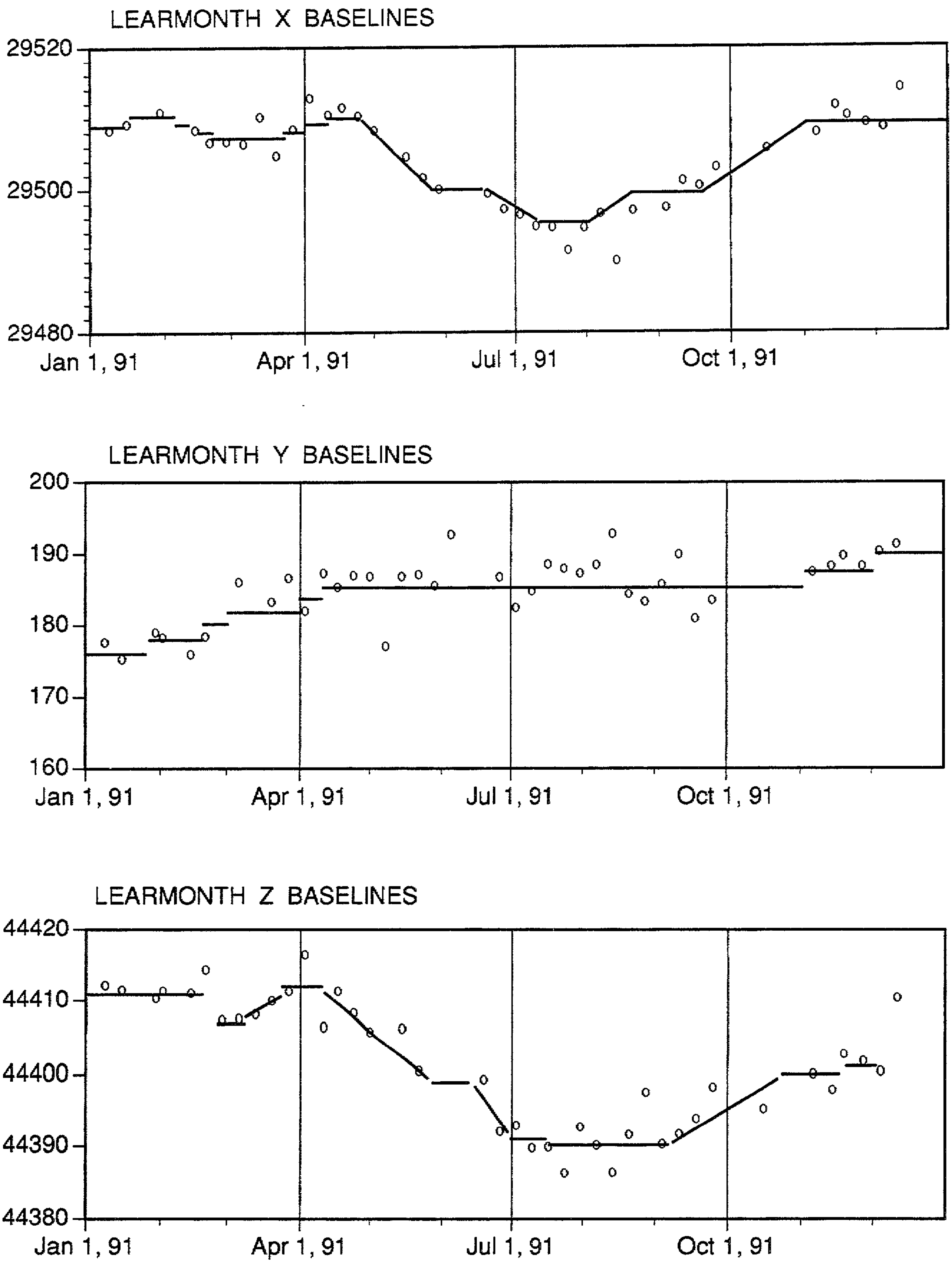


FIGURE 13 - Learmonth - observed and adopted baseline values at temperature

LEARMONTH BASLINE VALUES AT 25 °C

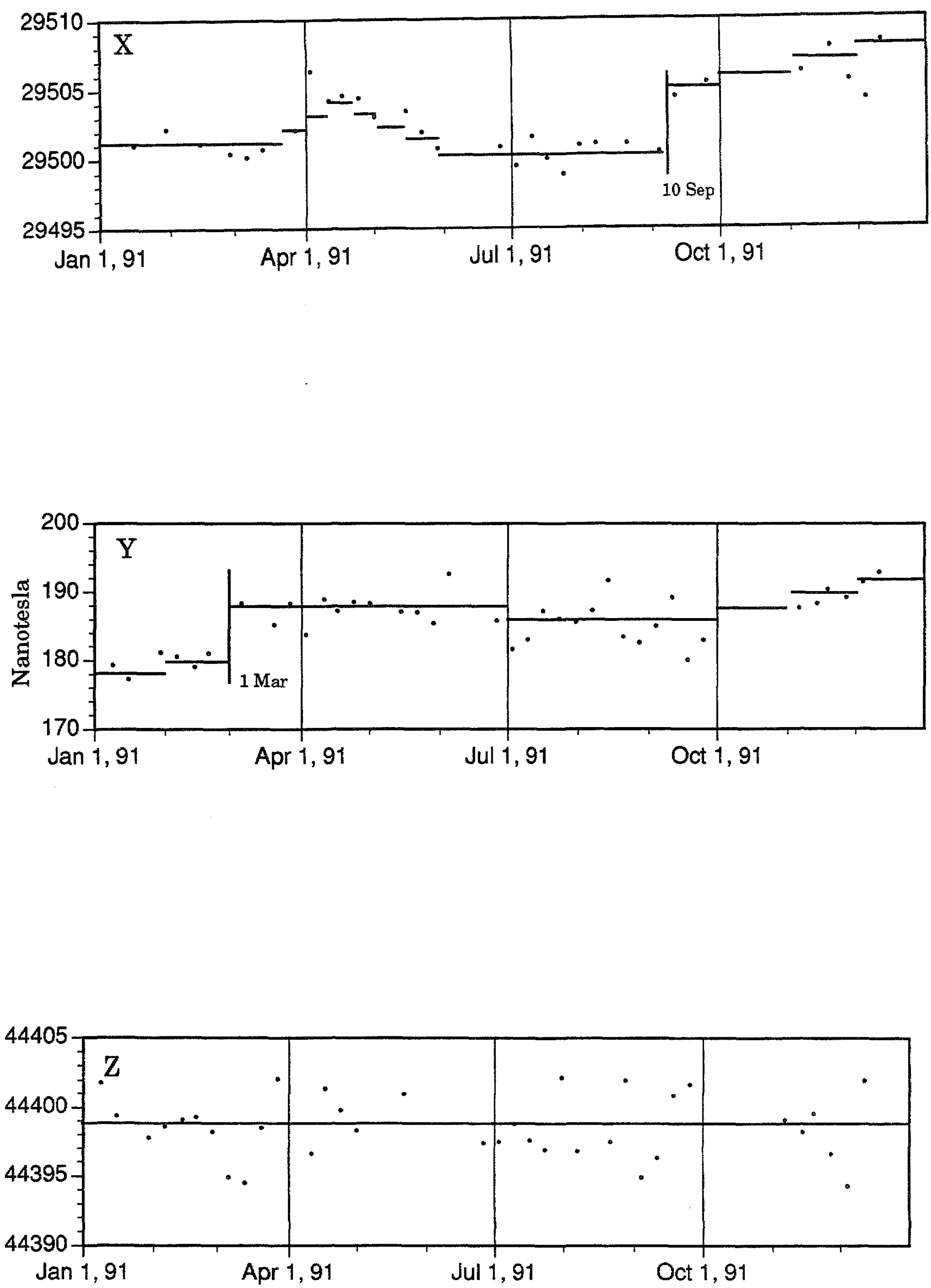


FIGURE 14 - Learmonth - observed and adopted baseline values at 25oC

THERMOGRAPH TEMPERATURE - LEARMONTH,

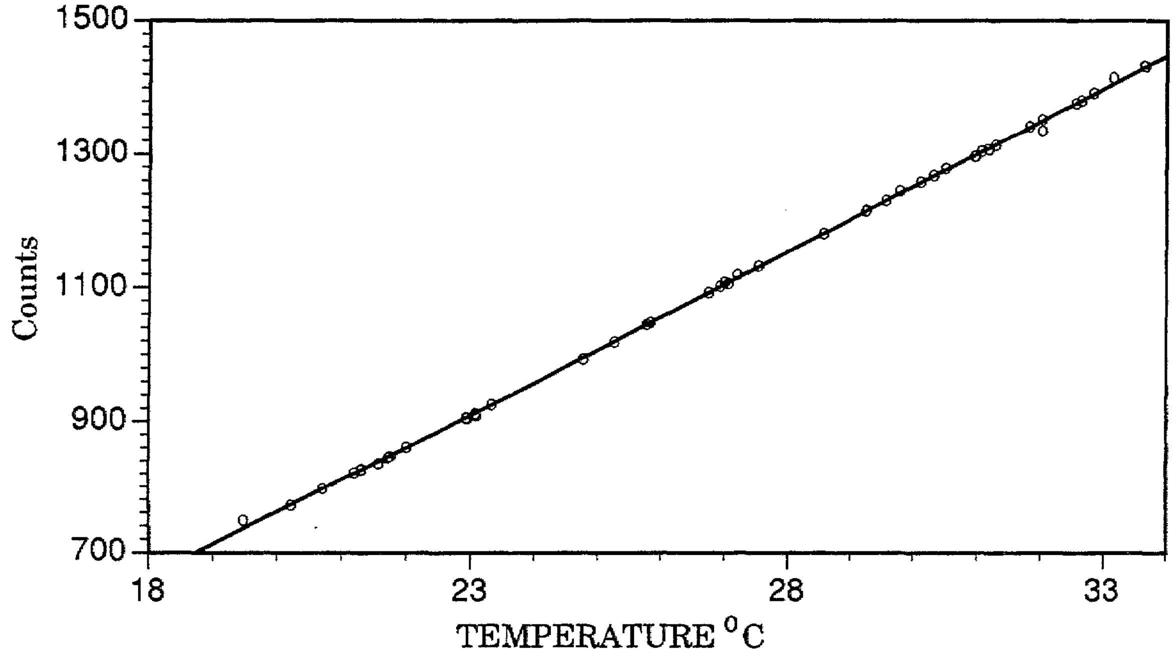


FIGURE 15 - Learmonth - thermograph temperature

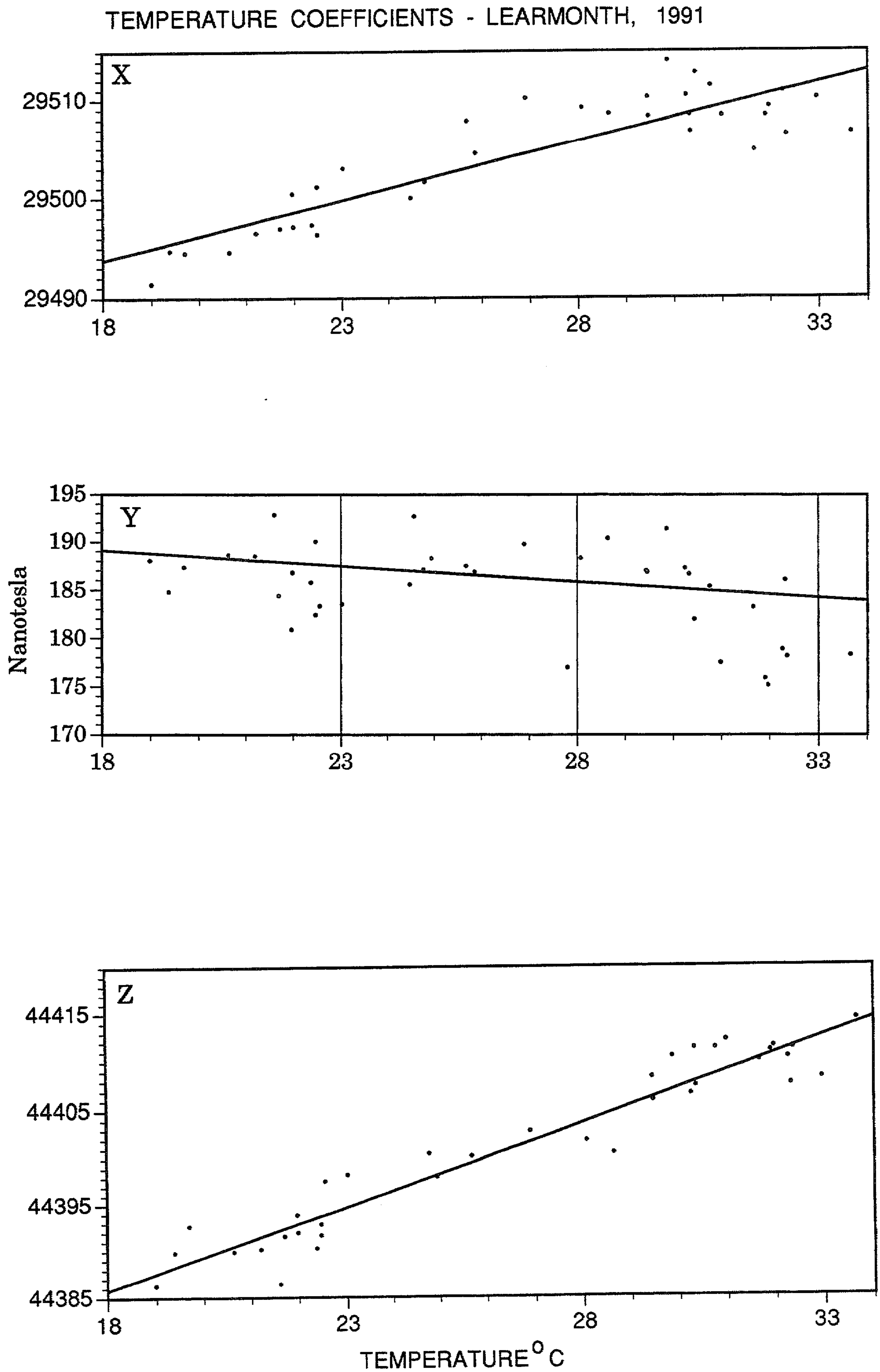


FIGURE 16 - Learmonth - temperature coefficients

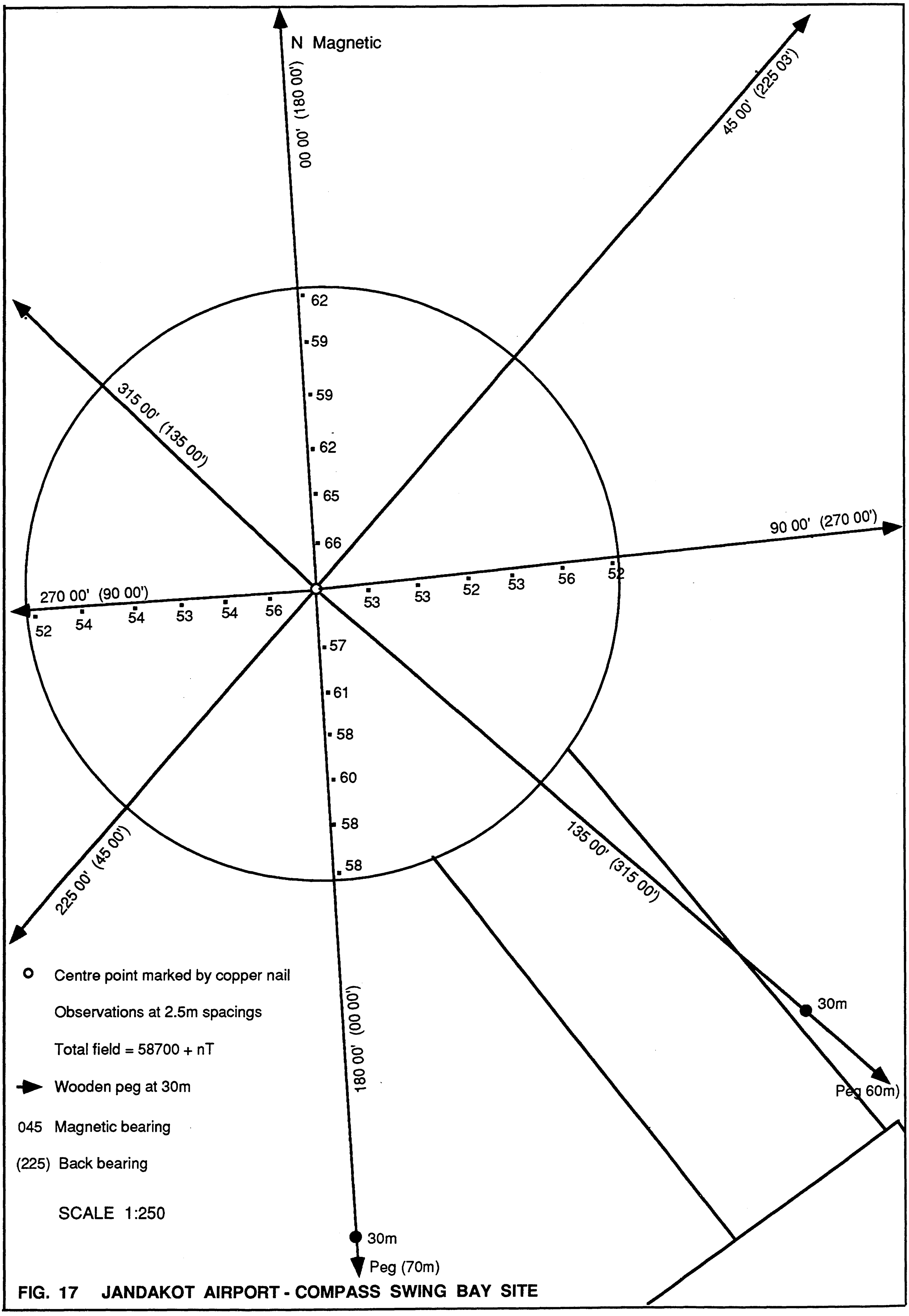


FIG. 17 JANDAKOT AIRPORT - COMPASS SWING BAY SITE

MAGNETIC OBSERVATORY SITE SELECTION - NORTHERN TERRITORY

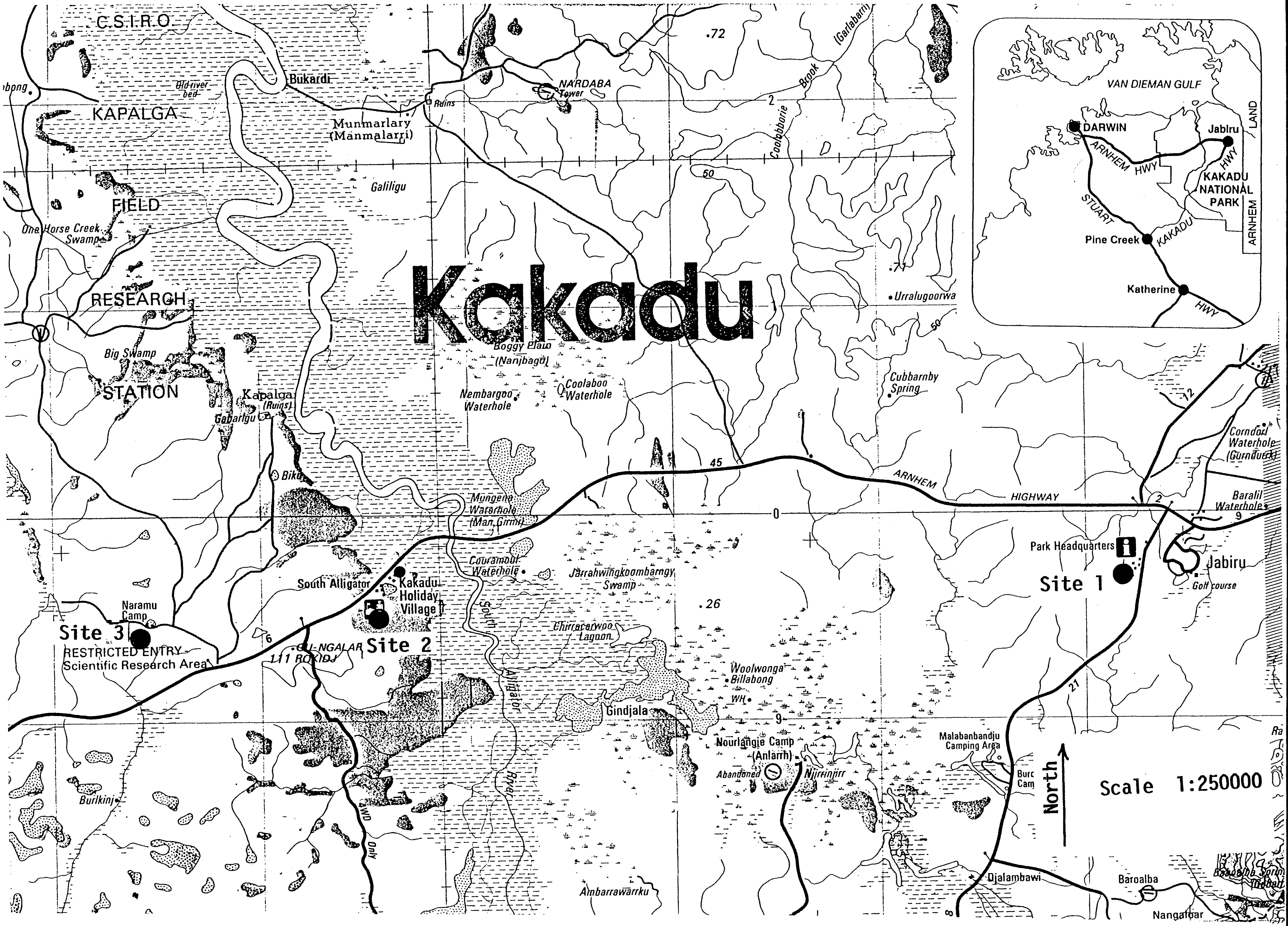


FIGURE 18

SITE LOCATIONS

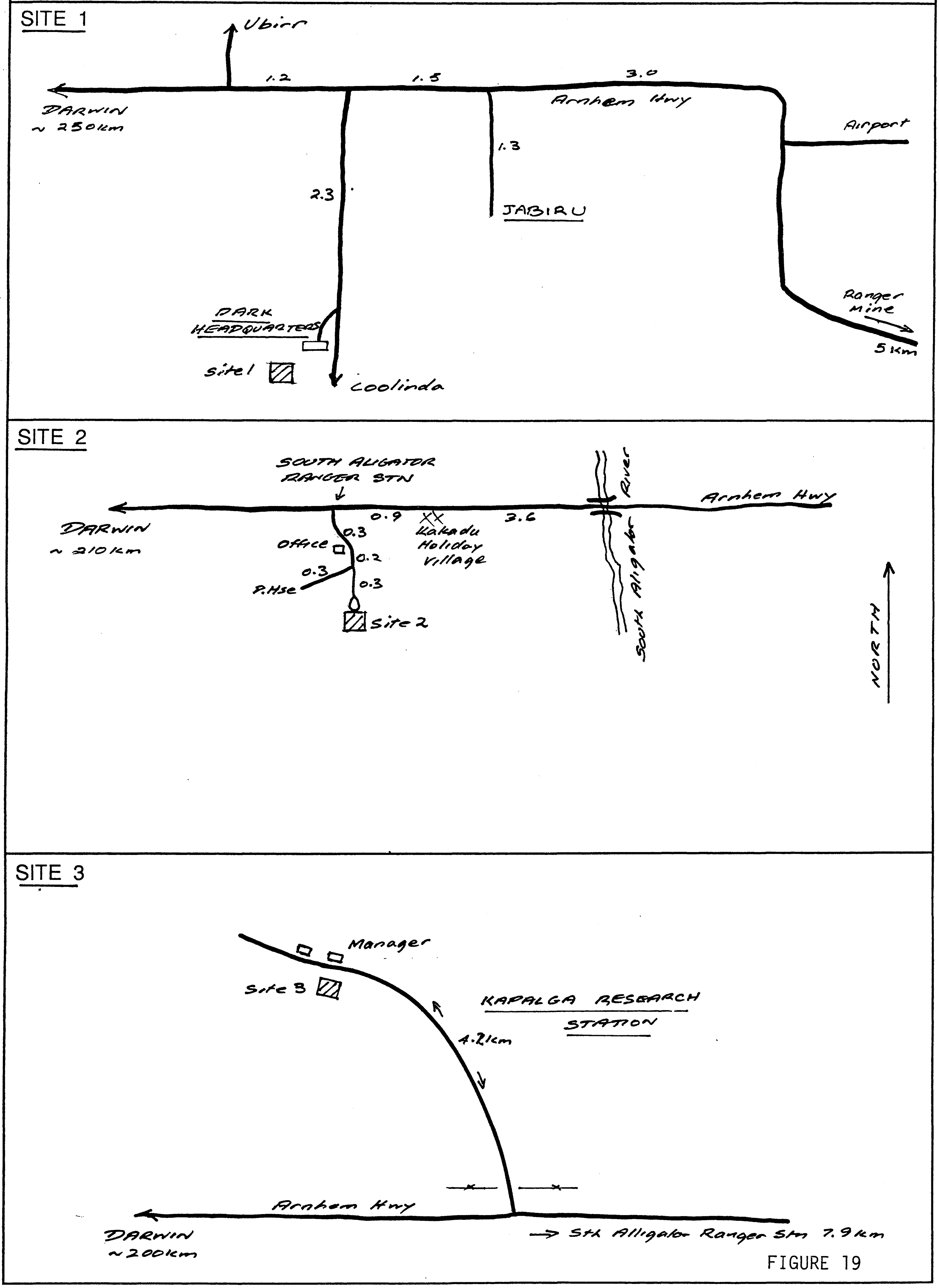


FIGURE 19

GEOLOGICAL MAP OF THE KAKADU AREA

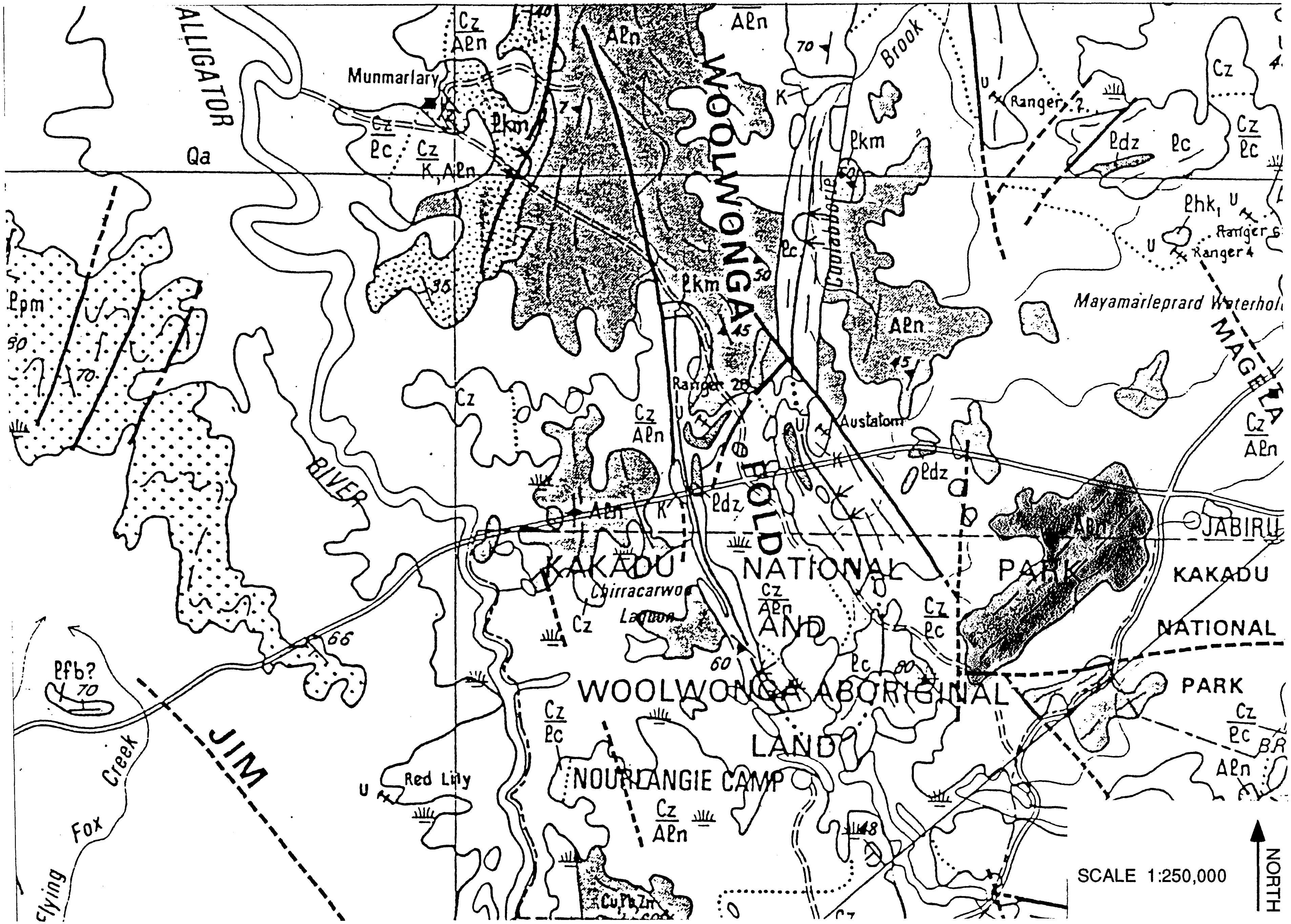


FIGURE 20