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Wire-line Logged Waterbores in the Great Artesian Basin —

Digital Data of Logs and Waterbore Data Acquired by AGSO

M.A. Habermehl

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AGRICULTURE, FISHERIES AND FORESTRY - AUSTRALIA

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A report to the National Landcare Program

M A Habermehl

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The Land & Water Sciences Division is part of the Bureau of Rural Sciences (BRS), the science agency within the Commonwealth Department of Agriculture, Fisheries and Forestry – Australia.

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FOREWORD

The Bureau of Rural Sciences Land and Water Sciences Division provides information and advice on Australia's land and water resources to governments and the community.
Through our geological and environmental research, and information management, we facilitate the productive and sustainable management of these resources. We give particular emphasis to:

- Research into land and water resources processes and environmental responses;
- Developing innovative geoscientific survey techniques and applying them to land management and risk mitigation;
- Cross jurisdictional land and water geoscience issues;
- Facilitating and developing national guidelines and standards for geoscientific data and information; and
- Developing improved national land and water resource databases.

This report provides data on geophysically logged waterbores in the Great Artesian Basin. The information in the form of digital data and maps will enable a better understanding of the geology and hydrogeology of the Great Artesian Basin, and contribute to enhanced exploration, development and management of the artesian groundwater resources and other natural resources of the Great Artesian Basin.

Peter O'Brien
Executive Director
Bureau of Rural Sciences

Contents

Figures	**page**

Maps (in back pocket)

M.A. Habermehl, A.G. Tucker, A.L. Sedgmen & N.G. Revell, 1997 - Wire-line logged waterbores in the Great Artesian Basin (Logs acquired by AGSO) - (set of 3 maps at scale 1 : 2 500 000)
Australian Geological Survey Organisation, Canberra

- Map 1 - Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO)
  Map 1 (1 of 3) at scale 1 : 2 500 000

  Waterbores with:

  - natural gamma ray logs
  - neutron-gamma ray logs
  - lithostratigraphy data
  - hydrochemistry data

- Map 1 - Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO)
  Map 2 (2 of 3) at scale 1 : 2 500 000

  Waterbores with:

  - temperature logs
  - differential temperature logs
  - caliper logs
  - flowmeter (down) logs
  - flowmeter (up) logs

- Map 3 - Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO)
  - Map 3 (3 of 3) at scale 1 : 2 500 000

  Waterbores with:

  - spontaneous potential logs
  - single point resistance logs
  - short normal resistivity logs
  - long normal resistivity logs
  - lateral resistivity logs

CD-ROM (in back pocket)

- CD-ROM contains the text of this report, digital log data, database description and database with data on type of logs, data on waterbores logged, lithostratigraphic units in waterbores and hydrochemistry results

ABSTRACT

The acquisition of wire-line logs from selected waterbores in the Great Artesian Basin, Australia, the digitising of the logs, the log data, the data on the waterbores logged and the database containing these data are described in this report. The use of the wire-line logs is discussed within the context of an overview of the geology and hydrogeology of the Great Artesian Basin. The geophysical logs allow the definition of geological ie. lithostratigraphic units and hydrogeological units ie. aquifers and confining beds, and their characteristics, and provide an accurate and reliable data set.

AGSO's collection of wire-line logs from flowing and non-flowing artesian waterbores in the Great Artesian Basin comprises natural gamma-ray, neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs from approximately 1250 waterbores in the Queensland, New South Wales and Northern Territory parts of the Great Artesian Basin. The waterbores were geophysically logged by the Bureau of Mineral Resources, Geology and Geophysics (BMR), now the Australian Geological Survey Organisation (AGSO) between 1960 and 1975.

Digitising of the analog, paper based, wire-line logs was carried out using PC-based semi-automatic (oil) well log digitising software during the 1990s. A total of 3875 logs were digitised, and they include natural gamma-ray logs for each of the logs from 1235 waterbores, and one or several of the following types of logs: neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs.

Included in this report is a CD-ROM, which contains the digital log data as a dataset, together with a database comprising data on the type of logs available, data on the waterbores logged, lithostratigraphy units encountered in the waterbores and hydrochemistry results from watersamples of selected waterbores, and a description of the structure of the database.
A set of 3 maps at scale 1 : 2 500 000 are included in the report, and show the locations and Registered Numbers of the waterbores logged, and the availability of each type of log, and the availability of lithostratigraphy and hydrochemistry data for each waterbore logged by BMR (now AGSO) in the Great Artesian Basin.

The digital dataset of the log data and the waterbore data on CD-ROM, together with the set of 3 maps, provides for improved access of the wire-line log information. The wire-line logs and their interpreted data have given a better understanding of the geology and hydrogeology, and contribute to enhanced exploration, development and management of the artesian groundwater resources and other natural resources of the Great Artesian Basin.

Introduction

The Bureau of Mineral Resources, Geology and Geophysics (BMR), now the Australian Geological Survey Organisation (AGSO), and its contractors geophysically logged flowing and non-flowing artesian waterbores in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory from 1960 to 1975.
The objective of the wire-line logging program was to apply borehole geophysics to existing waterbores to obtain information on the subsurface geology and hydrogeology of the Great Artesian Basin and its constituent sedimentary basins, which include the Eromanga, Surat and Carpentaria Basins, and parts of the Bowen and Galilee Basins (Figures 1 and 16; Habermehl, 1980a, Habermehl & Lau, 1997, Habermehl, 2001a, b, c).

The wire-line logs obtained comprise natural gamma-ray, neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs from approximately 1250 waterbores in the Great Artesian Basin (Figure 2). Existing waterbores in the Great Artesian Basin contain steel casing for most or all of their depths, and wire-line logs obtainable from these waterbores are therefore restricted to nuclear logs.
Natural gamma-ray logs were acquired from all of the waterbores logged during 1960 to 1975. Neutron-gamma ray logs were obtained from a small number of waterbores in the early 1970s. Temperature, differential temperature and casing collar locator logs were acquired from most waterbores logged, and flow meter logs were obtained from a limited number of flowing artesian waterbores. Spontaneous potential, resistivity and caliper logs were run in a small number of waterbores, which had sufficient length of uncased hole, usually at least 100 m of open hole.

Extensive use has been made of the wire-line logs (including by the author), in particular the natural gamma-ray logs, to define lithostratigraphic (geological) units in the Great Artesian Basin, and to delineate aquifers (hydrogeological units) as part of the geological mapping and the hydrogeological studies, and for the search for petroleum and other economic commodities during the 1960s, 1970s, 1980s and 1990s. The logs continue to be used by AGSO and State Water and Geological Authorities and by petroleum exploration, mining and other companies and geological and groundwater consultants. Copies of the logs were available to government authorities, industry and the public from BMR (now AGSO), and copies could be purchased for the cost of copying prior to the release of the data in this report.

Part or all of the Cretaceous Rolling Downs Group sedimentary sequence and part of the underlying Lower Cretaceous - Jurassic sedimentary sequence is shown by most of the logs obtained from the flowing and non-flowing artesian waterbores in the Great Artesian Basin. This is because almost all of the waterbores logged have been completed in the upper parts of the Lower Cretaceous - Jurassic sedimentary sequence, including the aquifer sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone. Only a limited number of waterbores extend into deeper, underlying stratigraphic units.

Figure 1 - Location and extent of the Great Artesian Basin, Australia

The artesian groundwater supplies in most of the flowing artesian waterbores are obtained from the aquifers in the upper part of the Lower Cretaceous - Jurassic sedimentary sequence. In some areas, in particular near the eastern and northeastern margin of the Basin, deeper aquifers in lower lithostratigraphic units in the Jurassic and in the Triassic are encountered in waterbores, and logs were obtained from a larger part of the sedimentary sequence.
Care was taken to select as many deep waterbores as possible during the planning and operational stages of the logging program, and to include waterbores penetrating the maximum number of lithostratigraphic units. The waterbores logged represent a close network in areas where sufficient numbers of waterbores were available.

Time independent data is shown by most of the wire-line logs acquired by BMR (now AGSO) during the logging program in the Great Artesian Basin in the 1960s and 1970s, including the natural gamma-ray, neutron-gamma-ray, spontaneous potential and resistivity logs, from which geological and hydrogeological information can be interpreted. Other logs, including the temperature, differential temperature, flowmeter, caliper and casing collar locator logs are time dependent, as information obtained from these logs will change with the time of data collection. Different or changed conditions of the waterbore during its lifetime, eg. deepening of the waterbore or changes in the aquifers tapped, eg. by penetration of the casing against aquifers, which previously were cased off, will also lead to different results. The casing collar locator logs for instance can be interpreted to show the amount of corrosion of the casing at the time of logging, and casing collar locator logs obtained one or several decades apart could give different results.

The wire-line logs acquired as part of the logging program were all produced in analog form, as ink traces on transparent paper (film) at scales 1 inch to 100 feet (1:1200) and at a scale of 1 inch to 20 feet (1:240). A complete set of originals and duplicate paper print copies has been held in BMR (now AGSO) for storage, retrieval and access purposes, and for duplication and work purposes. Use of the log information for analyses and interpretation has been based on the paper print copies during the 1960s to 1990s.
Access, retrieval, copying and storage of the large number of paper (film) based logs, which can be up to several metres long, and the preparation and processing of log data, has been difficult and therefore restricted. The availability of Personal Computers (PCs) and log digitising software since the 1980s provided the opportunity to convert the logs into digital data, greatly improving access and data interpretation, and also enhancing the storage and distribution of the datasets.

Digitising of the analog wire-logs at scale 1 inch : 100 feet (1 : 1200) commenced early in 1991, using PC-based semi-automatic (oil) well log digitising software. The natural gamma-ray logs, which are present for all waterbores logged, were completed in early 1992. All neutron-gamma-ray logs, and any available temperature, flowmeter, caliper, spontaneous potential and resistivity logs for the waterbores were digitised, and a total of 3875 logs were completed by 1993/4. The casing collar locator logs could not be digitised for technical reasons, and are not included in the digital dataset of the logs.
The digital dataset of the logs acquired by BMR (now AGSO) from 1235 waterbores in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975, and data on the types of logs, the logged intervals, date of logging and data on the waterbores logged, is included on a CD-ROM disk in the back of this report.

Data on the waterbores logged are in a database on CD-ROM in the back of this report, and include the identification, location, elevation, depth and year of completion of the waterbores, the lithostratigraphic units encountered in the waterbores and their depths. Also included are the hydrochemical laboratory analyses results such as pH, electrical conductivity, total dissolved solids, alkalinity and the detailed analyses results of 8 or 9 major ions, which were obtained from the watersamples of selected logged waterbores.

The locations of the waterbores from which wire-line logs were acquired by BMR (now AGSO) in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975 are shown in Figures 2 and 3. The waterbore locations and the type of logs obtained from each of the 1235 waterbores, as well as the availability of lithostratigraphic and hydrochemistry data for each of the waterbores is shown on a set of 3 maps –

> **Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000 (Habermehl & others, 1997)**,

which are included in the back of this report.

Wire-line logs obtained by other organisations from waterbores in the Great Artesian Basin during the 1960s to 1990s have not been included. The South Australian Department of Mines logged 17 flowing artesian waterbores, mostly along the Birdsville Track in South Australia during the 1960s, the New South Wales Geological Survey logged 235 waterbores in the Great Artesian Basin in New South Wales during the early 1970s.
The Queensland Department of Natural Resources (previously the Queensland Department of Primary Industries, the Queensland Water Resources Commission and the Queensland Irrigation and Water Supply Commission) logged waterbores in the Great Artesian Basin in Queensland during the late 1980s and 1990s. The New South Wales Department of Land and Water Conservation (previously the New South Wales Department of Water Resources and the New South Wales Water Conservation and Irrigation Commission) logged waterbores in the Great Artesian Basin in New South Wales during the late 1980s and 1990s. The Department of Primary Industries and Resources South Australia (previously the South Australian Department of Mines and Energy and the South Australian Department of Mines) logged waterbores in the Great Artesian Basin in South Australia during the late 1980s and 1990s, and waterbores drilled for the Olympic Dam Borefields in the Great Artesian Basin were logged by contractors during the 1980s and 1990s. The Northern Territory Department of Lands, Planning and Environment (previously the Northern Territory Power and Water Authority and also the Northern Territory Administration Water - Resources Branch) logged waterbores in the Great Artesian Basin in the Northern Territory during the 1990s.
In addition, wire-line logs have been obtained by petroleum companies from all the petroleum exploration and production wells drilled in the Great Artesian Basin area since the early 1960s, but none of these logs have been included.

The Australian Government transferred the functions and staff of the Land and Water Sciences Division from the Australian Geological Survey Organisation (AGSO) into the Bureau of Rural Sciences (BRS, previously the Bureau of Resource Sciences) in late 1998. The work for the Great Artesian Basin Wire-line Logging Program was carried out in AGSO as part of the Great

Artesian Basin Hydrogeological Project, but the present report is published by BRS.
This publication also appears as Australian Geological Survey Organisation Bulletin 245.

AGSO and BRS aim to provide reliable and accessible geological, hydrogeological and geophysical information to Commonwealth and State Water and Geological Agencies and other government agencies, industry and the general community, and in this way assist resource developers and planners to improve the management of Australia's groundwater resources.
The digitising of the wire-line logs from waterbores in the Great Artesian Basin, and the preparation of the CD-ROM containing the digital dataset of the log data and associated data of the waterbores, and the production of the set of 3 maps - Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), formed part of the project aimed at refinement, enhancement and maintenance of AGSO's Great Artesian Basin Hydrogeological Database, which has been supported by funding to AGSO from the Federal Water Resources Assistance Program and the National Landcare Program during the 1980s and 1990s.

Logging of waterbores in the Great Artesian Basin

The Bureau of Mineral Resources, Geology and Geophysics (BMR), (now the Australian Geological Survey Organisation - AGSO), commenced the wire-line logging of waterbores in the Great Artesian Basin in 1960 and continued this work until 1975. During that period approximately 1250 waterbores in the Great Artesian Basin were geophysically logged (Figure 2).

The aim of the wire-line logging of waterbores in the Great Artesian Basin was to apply borehole geophysics to existing flowing and non-flowing artesian waterbores and to improve the available information on the subsurface geology of the Basin for the purpose of a better understanding of the artesian groundwater resources and to assist petroleum exploration.

Hahn & Fisher (1963) reviewed the available information on the Great Artesian Basin and referred to the results of some of the early BMR logging activities. These authors considered information on the Great Artesian Basin in 1963 for its availability, completeness and usefulness and looked at ways to overcome any deficiencies in the data in order to advance the knowledge of the Basin.

The Australian Water Resources Council - Technical Committee on Underground Water (AWRC - TCUW) - Sub-Committee for the Hydrogeological Study of the Great Artesian Basin - included the geophysical logging of waterbores as an item for the Program of Great Artesian Basin Hydrogeological Studies, prepared in 1966. In its Specific Recommendations for the Program it concluded ... "that a representative proportion of existing water bores be gamma-ray logged"..., as it had been shown that the work by BMR on the gamma-ray logging of waterbores in Queensland led to conclusive positive stratigraphic correlations between bores, and that lithological changes in individual units could be traced by gamma logging. The AWRC - TCUW Sub-Committee stated that this was the only method by which the stratigraphy could be established in cased bores, and strongly recommended the continuation by BMR of the gamma-ray logging of existing bores and electric and gamma-ray logging of bores being drilled, with the objective to achieve as uniform a coverage as possible by selecting bores at suitable intervals throughout the Great Artesian Basin.

The AWRC - TCUW Sub-Committee for the Hydrogeological Study of the Great Artesian Basin recommended several related items, including geological mapping, stratigraphic studies, stratigraphic drill-holes and geophysical surveys.

The report by the AWRC - TCUW Sub-Committee for the Hydrogeological Study of the Great Artesian Basin, which included the above recommendation and the recommendation that the study be undertaken by a single authority was followed by the recommendation by TCUW in 1969 that BMR should carry out the Hydrogeological Study of the Great Artesian Basin (Habermehl, 1980a, 1982, 2001c).

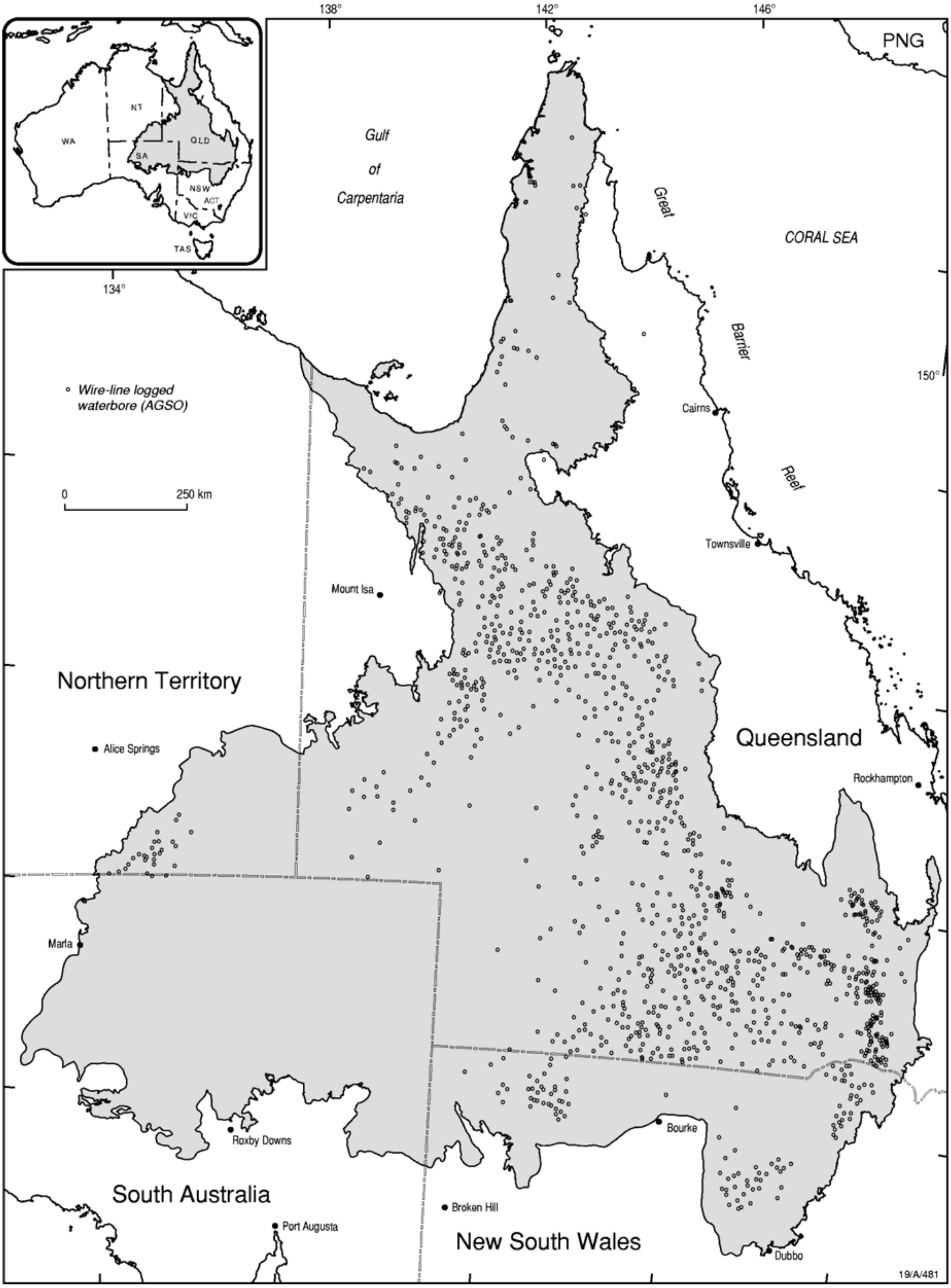

Figure 2 - Location of the wire-line logged waterbores in the Great Artesian Basin

Field operations

BMR carried out the initial logging operations from 1960 to 1964, and engaged contractors to undertake most of the logging from 1965 onwards. Logging operations by BMR during the second half of the 1960s and early 1970s were partly restricted to selected and difficult waterbores, which for various reasons could not be logged by the contractors. More extensive logging was done again by BMR during the early and mid 1970s.
The BMR logging operations during the 1960s and 1970s were carried out with BMR owned truck mounted logging units. A large part of the logging program since 1965 was carried out under contract for BMR by the following companies - Down Under Well Services Pty Ltd (Down Under Well Services), Schlumberger Seaco Inc., Agnew-Go-Western Pty Ltd and Bendix-Australia United Geophysical Pty Ltd with truck mounted logging units provided by these operators (see Appendix 1, and Habermehl, 1980b).

Most of BMR's logging activity during the 1970s was performed with a BMR-modified, truck-mounted Gearhart Owen logging unit with a 3050 m (10 000 feet) cable and Gearhart Owen logging probes. During the 1960s, Failing Logmaster and Widco equipment was used.
All of the logs obtained by BMR and its contractors were recorded at a scale of 1 inch to 100 feet (1 : 1200) and at a scale of 1 inch to 20 feet (1 : 240). Instrument-equipment data, types of probes used, log calibration (API) units, and other log and waterbore details are shown in the log headings of the original wire-line logs. The originals (transparent paper/film copies) of both sets of logs and a collection of paper prints of the logs at a scale of 1 inch to 100 feet (1 : 1200) are stored in AGSO. A set of paper prints of the logs at a scale of 1 inch to 100 feet (1 : 1200) is kept as a reference set within the Land and Water Sciences Division in the Bureau of Rural Sciences since 1999.

The logging program was a large scale and long term program, involving extensive activities, carried out jointly by the BMR Geological and Geophysical Branches. The program partly coincided with the extensive program of geological mapping at scale 1 : 250 000 (and at scale 1 : 1 000 000) of the Great Artesian Basin by BMR.
The planning phase of the Great Artesian Basin Wire-line Logging Program included the compilation of waterbore data, the selection of waterbores to be logged based on their location, available data, depths, casing integrity and the geological units expected to be encountered in the waterbores. Field operations involved the geophysical logging of the waterbores, and were preceded by scouting to check the location and condition of the waterbores, check access for the logging truck into the area and near the waterbore, obtain the written permission from the landholders and/or waterbore owners, carry out the removal of the bore headworks prior to the logging in the case of flowing artesian waterbores to make the borehole accessible for the logging tools. Following the logging the headworks had to be reinstalled. In the case of non-flowing artesian waterbores, the majority of which are pumped by windmills, various activities had to be carried out on the windmills to remove and replace their pumprods and pumpvalves, to make the hole accessible for logging. Engine pumps and submersible pumps had to be removed, and reinstalled after logging. Most of these activities (ie. work on the headworks and windmills) were undertaken by qualified drilling personnel from the Queensland Irrigation and Water Supply Commission for the waterbores located in Queensland and by the New South Wales Water Conservation and Irrigation Commission for waterbores located in New South Wales, and

partly by licensed contractors.

Many of the flowing artesian waterbores have high artesian pressures, and discharge small to medium to large volumes of warm to hot (up to 100^0 C) artesian groundwater, making any operations on the waterbores complex and potentially dangerous. In addition, the work on and the removal of older headworks and pumping installations was quite difficult, as some waterbore headworks and casings are corroded or poorly maintained. Some waterbores are located in large pools of (warm to hot) water and are difficult to access with a large logging truck because of the number of boredrains originating from the waterbores (small, unlined open earth drains, which can be many tens of kilometres long (up to 80 km), and which are used for the distribution of the artesian groundwater from flowing artesian waterbores).

Problems encountered during the logging operations of the waterbores were numerous. Basic problems included the total depths of the waterbores recorded by the driller being different from the actual depths, because the waterbore was deepened at a later date. Some waterbores were partly filled in as a result of casing collapse, or the waterbores had obstructions as a result of a broken casing or foreign material in the casing, which caused the logging probes being unable to be lowered below the obstruction.

The logs acquired were forwarded from the field operations to BMR for inspection, checking and approval by geologists and geophysicists, and subsequently handled in BMR to prepare copies for interpretation and storage. Copies of all logs obtained were forwarded to the State water and geological agencies shortly after the field operations.
Watersamples obtained by the logging operators during the logging were forwarded to the State analytical laboratories for analyses.
The State Water and Geological Authorities provided data on the waterbores logged and on the driller's logs and hydrological data from the bores, which were usually added to copies of the wire-line logs.

The wire-line logs obtained comprise natural gamma-ray, neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs from approximately 1250 waterbores. Because all or nearly all existing waterbores in the Great Artesian Basin contain steel casing for most or all of their depths, only nuclear wire-line logs (as well as temperature, differential temperature, flowmeter, caliper and casing collar locator logs) could be obtained from most of the waterbores, and few electrical logs have been run.

Natural gamma-ray logs were obtained from nearly all of the waterbores logged during 1960 to 1975. The number of natural gamma-ray logs in the dataset is 1212. Neutron-gamma ray logs were obtained from 345 waterbores in the early 1970s. Temperature (763), differential temperature (742) and casing collar locator logs were acquired from most waterbores logged. Flow meter logs (180 logged downhole, 160 logged uphole) were obtained from a limited number of flowing artesian waterbores. Spontaneous potential (41), resistivity (62) and caliper (208) logs were run in a small number of waterbores, which had sufficient length of uncased hole, usually at least 100 m.

Watersamples from the logged waterbores were generally forwarded to the State Government

Laboratories. Watersamples from logged waterbores in Queensland were analysed by the Queensland Government Chemical Laboratory, in New South Wales by the New South Wales Department of Mines Chemical Laboratory and in the Northern Territory by the Northern Territory Administration Water Resources Branch Laboratory.
Details on the conditions of the watersample collection, the type of sample containers and other aspects of the watersampling are poorly documented. The analyses by the State Laboratories were usually carried out several months after the receipt of the watersamples, and show the (laboratory) pH, electrical conductivity, hardness and alkalinity and 8 or 9 major ions.
The results of analytical laboratory analyses of the (412) watersamples were collated by BMR, and have been included in the dataset on the CD-ROM in this report. Interpretation of part of the hydrochemical data is included in Habermehl (1980a, 1983), Ransley & others (1998), Radke & others (2000).

Lithostratigraphy data has been interpreted using mostly the natural gamma-ray logs for 1170 waterbores, and this information is included in the dataset on the CD-ROM in this report.

Logging operation results and reports

The results of the early logging operations in the Great Artesian Basin during the early 1960s, including the logs produced, some details on the equipment used, and some interpretations, waterbore correlations and contour maps are recorded in Jewell (1960), Jesson & Radeski (1961), Jewell & Jesson (1961), Radeski & Jewell (1963), Jesson, Radeski & Jewell (1963), Jewell, Radeski & Jesson (1964), Jesson & Radeski (1964, 1966).

From 1960 to 1964 BMR carried out the logging operations, and from 1965 onwards contractors were engaged to undertake most of the logging. From 1965 onwards BMR logging activities were largely restricted to selected and difficult waterbores, which for various reasons could not be logged by the contractors. During the 1970s BMR carried out more extensive logging programs again, until the end of the program in 1975.

Logging activities during later years until 1975, and the compilation of the log and waterbore data during the 1970s and 1980s, and the digitising of the wire-line logs between 1991 and 1994, were reported in the BMR Geological Branch and Geophysical Branch Annual Reports (BMR Report and Record Series 1960 - 1980), and in BMR Annual Reports (1971 - 1976) and BMR and AGSO Yearbooks 1977 - 1994 (see list at the end of References).

Wire-line logs and log interpretations, showing tops and bottoms of geological formations and cross-sections based on the correlations and interpretations of wire-line logs from waterbores are included in: Senior & others (1975), Exon (1976), Exon & Senior (1976), Senior & others (1978), Burger & Senior (1979), Smart & others (1980), Andrews and Leys (1984) and Burger (1989).

Logs from petroleum exploration wells with detailed geological (lithological) and geophysical logs can be correlated with the wire-line logs from waterbores in the Great Artesian Basin. Wire-line logs and log interpretations, showing tops and bottoms of geological formations and cross-sections based on the correlations and interpretations of wire-line logs from petroleum exploration wells in the central Eromanga Basin in southwestern Queensland are included in Green & others (1989a, b), and from petroleum exploration wells in the Eromanga Basin in South Australia in Alexander & Hibburt (1996).

Polak & Horsfall (1979) provided an interpretation of the temperature logs and the data derived from those logs, and interpreted geothermal gradients in the Great Artesian Basin. The geothermal gradients obtained have values ranging from 15.4 ^{0}C/km to 102.6 ^{0}C/km, and have a mean of 48 ^{0}C/km. More than 75 percent of these values exceed the world representative average value of 33 ^{0}C/km, which suggests that the Great Artesian Basin is an area of higher than normal geothermal gradients (Polak & Horsfall, 1979).
Cull & Conley (1983) used several different assumptions on the groundwater data, aquifer models and temperature corrections, and determined a mean geothermal gradient of 38.6 (± 0.1) ^{0}C/km, which is closer to the world average of 33 ^{0}C/km than the results of Polak & Horsfall (1979). Estimates of the heat flow from the Great Artesian Basin are consistent with the configuration of the major aquifer systems, with low values of heat flow observed along the recharge areas in the eastern part, and corresponding highs in the western discharge areas of the Basin. Anomalies in other areas might be generated by vertical groundwater flow along geological faults and near basement structures (Habermehl, 1980a, Cull & Conley, 1983).

Wire-lined logged waterbores are shown on maps in Exon (1976), Senior & others (1978), and Smart & others (1980), which deal respectively with the geology of the Surat Basin, Eromanga Basin and Carpentaria Basin. Several of the maps in these publications, including structure contour maps and isopach maps of lithostratigraphic units in the Cretaceous and Jurassic sedimentary sequences are based on the data obtained from the geophysical logs from waterbores.

The Cretaceous oil shale bearing Toolebuc Formation, which occurs throughout most of the Great Artesian Basin (Eromanga Basin) shows a marked gamma-ray anomaly. The presence of this distinctive anomaly has been used as a marker bed for correlations throughout the Basin (Senior & others, 1978). The gamma-ray anomaly is related with uranium associated with organic matter and phosphatic fish remains in the Toolebuc Formation (Senior & others, 1978, Ozimic, 1986).

Exon & Morrissey (1974), Smart & others (1975) prepared listings of the waterbores logged respectively in the Surat Basin and Carpentaria Basin areas of the Great Artesian Basin as part of the geological mapping activities in these basins.

Habermehl & Morrissey (1980) produced a map at scale 1 : 2 500 000 showing the location and Registered Numbers of the waterbores in the Great Artesian Basin from which wire-line logs had been acquired by BMR, the Geological Survey of New South Wales and the South Australian Department of Mines and Energy.

Habermehl & Morrissey (1983) provided an index of the logs acquired by BMR from waterbores in the Great Artesian Basin between 1960 and 1975, a list of the waterbores logged, the type and depth intervals of the logs recorded, maximum depth reached by the logger, year of logging, basic data on the waterbores logged, including locations (latitude and longitude), ground elevation, total depth, year of completion, availability of driller's log, and availability of chemical analyses results of watersamples collected from the waterbore at the time of geophysical logging.

The work recorded in the present report included the compilation, review and checking of all available data on the logs and the waterbores logged.
Digitising of the analog, paper based, wire-line logs was carried out using PC-based semi-automatic (oil) well log digitising software during the 1990s. A total of 3875 logs were digitised, and they include natural gamma-ray logs for each of the logs from 1235 waterbores, and one or several of the following types of logs: neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs.

Included in the present report is a CD-ROM, which contains the digital log data as a dataset, together with a database comprising data on the type of logs available, data on the waterbores logged, lithostratigraphy units encountered in the waterbores and hydrochemistry results from watersamples of selected waterbores, and a description of the structure of the database.
A set of 3 maps at scale 1 : 2 500 000 are included in the report, and show the locations and Registered Numbers of the waterbores logged, and the availability of each type of log, and the availability of lithostratigraphy and hydrochemistry data for each waterbore logged by BMR (now AGSO) in the Great Artesian Basin.

The digital dataset of the log data and the waterbore data on CD-ROM, together with the set of 3 maps, provides for improved access of the wire-line log information. The wire-line logs and their interpreted data have given a better understanding of the geology and hydrogeology, and contribute to enhanced exploration, development and management of the artesian groundwater resources and other natural resources of the Great Artesian Basin.

Digitising of wire-line logs - Methodology

Access, retrieval, copying and storage of the large number of film and paper based wire-line logs from waterbores in the Great Artesian Basin, acquired by BMR during the 1960s and 1970s, and the preparation and processing of log data, has been difficult and therefore restricted.
The availability of the combination of Personal Computers (PCs) and log digitising software since the 1980s enabled the conversion of the analog logs into digital data, and so led to a great improvement in the access to the log data and in data interpretation, and also enhanced the storage and distribution of the log datasets.

The wire-line logs acquired by BMR's logging program from waterbores in the Great Artesian Basin during the 1960s and 1970s were all in analog form. The analog logs are present as ink traces on transparent paper (film) at scales 1 inch to 100 feet (1 : 1200) and at a scale of 1 inch to 20 feet (1 : 240). A complete set of originals and duplicate paper print copies has been held in BMR (now AGSO) for storage, retrieval and access purposes, and for duplication and work purposes. A set of paper print copies has been the main source of the log information for geological and hydrogeological studies in BMR/AGSO during the 1960s to 1990s. A reference set of paper print copies of the logs at scale 1 inch to 100 feet (1 : 1200) is held in the Land and Water Sciences Division in the Bureau of Rural Sciences (LWSD - BRS).
Most of the wire-line logs acquired by BMR (now AGSO) during the logging program in the Great Artesian Basin in the 1960s and 1970s show time independent data, including the natural gamma-ray, neutron-gamma-ray, spontaneous potential and resistivity logs, from which geological and hydrogeological information can be interpreted. Other logs, including the temperature, differential temperature, flowmeter, caliper and casing collar locator logs are time dependent, as information obtained from these logs will change with the age and the different or changed conditions of the waterbore during its lifetime. The casing collar locator logs for instance can be interpreted to show the amount of corrosion of the casing at the time of logging.

The logs, data on the logs and data on the waterbores logged were collated and compiled during the late 1970s and early 1980s (Habermehl, 1980b), and the results of the compilation produced as a map showing the location of the waterbores logged (Habermehl & Morrissey, 1980) and as an index, listing the wire-line logs acquired by BMR from waterbores in the Great Artesian Basin 1960 - 1975 (Habermehl & Morrissey, 1983).

Digitising of the analog wire-logs of the waterbores at scale 1 inch : 100 feet (1 : 1200) commenced early in 1991, using PC-based semi-automatic (oil) well log digitising software.
LogSCAN® software was used (LogSCAN® is a registered trademark of Briere Engineering Ltd, Canada, versions 1.0 - 1989 and 1.2 - 1990), which has the capability in combination with a PC and a connected facsimile machine to raster scan logs into a PC. The paper copy of the log is scanned by the fax machine and transferred to the hard disk of the PC, following the definition of the log grid on the PC visual display unit using the mouse. The log traces and the log grid are visible on the PC monitor. The operator can subsequently use the PC based LogSCAN® software, to filter out the log grid leaving only the log traces (one or more) or curve(s) to be

vectorised (digitised). LogSCAN® follows the exact centre of the raster curve(s) automatically, and no hand tracing is required. The software distinguishes between different types of curves that cross each other, and adjusts for paper skew, paper stretch and scale changes both vertically and horizontally on the log. The log traces or curves are converted and presented as traces for verification and editing if necessary by the operator, using a mouse. If the traces are satisfactory, LogSCAN® can write the digital values onto disk, after the output resolution has been defined, in the format specified (ASCII).

The digital data of the logs has been presented in ASCII format on the CD-ROM in the present report, as data in this format will be accessible by all users. Specific (petroleum industry) log formats have not been used, as this would allow limited access to the data by users, many of which, particularly in the water industry, will not have access to specific (petroleum industry) log format software.

Digitising of the natural gamma-ray logs, which are present for all waterbores logged, was completed in early 1992, and all neutron-gamma-ray logs, and any available temperature, flowmeter, caliper, spontaneous potential and resistivity logs for the waterbores were digitised and a total of 3875 logs were completed by late 1993/early 1994. The casing collar locator logs could not be digitised for technical reasons, and are not included in the digital dataset of the logs. Casing collar locator logs are present on most original copies of the natural gamma-ray logs obtained as part of the Great Artesian Basin Wire-line Logging Program, but are not available in the digitised versions. A technical problem prevented the digitising (vectorising) of the horizontal marks of the casing collar locator log, as the log digitising software assumed these marks to be part of the original log grid, and during the removal of the grid, the marks from the casing collar locator log were also filtered out.

CD-ROM

The CD-ROM included in the back of this report contains:

- text of this report
- digital data of the wire-line logs
- database description
- database with data on :

    - data on the wire-line logs available for each waterbore,
    - data on the waterbores logged,
    - lithostratigraphic units encountered in the waterbores
    - hydrochemistry results.

The digital dataset of the logs and data on the types of logs acquired by BMR (now AGSO) from 1235 waterbores in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975 are included on a CD-ROM in the back of this report. The data is in ASCII format, and this allows for easy access to the log data and the waterbore data by users. The digital log data can be used to prepare prints or plots of the logs by the users. The basic digital log dataset can also be used for digital data processing of the log data and subsequent analysis and interpretation.

Data on the waterbores logged, including the identification, location, elevation, depth and year of completion of the waterbores, the lithostratigraphic units encountered in the waterbores and their depths, and the hydrochemical laboratory analyses results obtained from watersamples taken at the time of logging, showing pH, electrical conductivity, total dissolved solids, alkalinity and the detailed analyses results of 8 or 9 major ions are included in a database on CD-ROM in the back of this report.
Also included on the CD-ROM is a description of the structure of the Great Artesian Basin Wire-line Log Database (see also Tucker & Ivkovic, 1997).

Data on the waterbores logged were obtained at the time of logging from the State Water and Geological Authorities by BMR. These data were enhanced and/or completed during the digitising and data compilation stages using the BMR/AGSO Great Artesian Basin Hydrogeological Data Base and/or data obtained from State Water and Geological Authorities during the BMR/AGSO Hydrogeological Study of the Great Artesian Basin (Habermehl, 1980a, 1985, 1996, 2001c).

Maps of wire-line logged waterbores

A set of 3 maps is included in the back of this report:

> **Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000 (Habermehl & others, 1997).**

The maps show the locations of the waterbores from which wire-line logs were acquired by BMR (now AGSO) in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975, the (State Water Authority) Registered Number, and the type of logs obtained from each of the 1235 waterbores, as well as the availability of lithostratigraphic and hydrochemistry data for each of the waterbores.

Database of Log and Waterbore Data

Database

The Great Artesian Basin Wire-line Logged Borehole Database - GABLOG consists of datatables, which contain the data on the waterbores logged, the types of wire-line logs available for each waterbore, hydrochemical analyses results and lithostratigraphic data for each logged waterbore. The description and layout of the GABLOG Database is included in Tucker & Ivkovic (1997) and on the CD-ROM in this report. The database was implemented with ORACLE RDBMS, version 7, and is set up as 5 tables.

Data Tables

The Data Tables include:

- GLGEN	- general information about each waterbore, including waterbore location data
- GLLOG	- information describing each of the digitised wire-line logs
- GLFLOW	- stationary flow data measured during impeller flow meter tests
- GLSTRAT	- stratigraphic data
- GLCHEM	- hydrochemical data

All data sets in the data tables include the State in which the waterbore is located and the Registered Number of the waterbore.
The State abbreviations used in the GABLOG data tables and on the set of 3 maps - Wire-line logged waterbores in the Great Artesian Basin (Logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000, are:

Queensland	- q
New South Wales	- n
South Australia	- s
Northern Territory	- t

Lookup Tables

The Lookup Tables are related to the data tables, and are useful in providing consistency checks on values in the data tables:

- GLSTATE	- State names and abbreviations for States within the Great Artesian Basin
- GLMAP_250	- map sheet names and codes for 1 : 250 000 map sheets within the Great Artesian Basin boundary

- GLELEV - methods for measurement of the elevation of the logged waterbores
- GLLOGTYPE - list of the valid types of geophysical logs held in the database
- GLLOGUNITS - list of the valid units for each type of geophysical log
- GLSTRATCODE - list of names and abbreviations of lithostratigraphic units in the Great Artesian Basin
- GLCHACCU - list of codes representing the accuracy of the data
- GLCONUNITS - list of allowable concentration units
- GLLAB - list of valid laboratory names and abbreviations

To maintain consistency with the existing log originals, all depth measurements have been given in feet.
The original chemical concentration units listed in the analytical laboratory result sheets have also been maintained.

Waterbore Data - GLGEN

The waterbore data in the Great Artesian Basin Wire-line Logged Borehole Database GABLOG - data table GLGEN includes the identification and location data of the waterbores, the registered number of the bore, State, 1 : 250 000 map sheet, latitude, longitude, UTM zone, name, elevation, year of completion of the waterbore, total depth of the waterbore, the greatest depth of any of the logs available for the waterbore, and the greatest depth of digital copies of any of the logs for the waterbore, measured from the groundsurface.

Waterbore data were derived from the records on flowing artesian waterbores in the Great Artesian Basin present in the BMR/AGSO Great Artesian Basin Hydrogeological Database PARADOX RDBMS - GABMT, and data on flowing and non-flowing artesian waterbores in the BMR/AGSO Great Artesian Basin Hydrogeological Database ORACLE RDBMS - GABMOD. The data in these databases has been obtained during the 1970s, 1980s and 1990s from the State Water and Geological Authorities in Queensland, New South Wales, South Australia and the Northern Territory as part of the BMR/AGSO Hydrogeological Study of the Great Artesian Basin. In addition, data obtained during the logging program and BMR/AGSO data has been incorporated.

Types of Logs - GLLOG

The data on the logs in the GABLOG Database data table GLLOG include the type of log, name of the log, the top and bottom depths of the log, log unit, year of logging, the direction of the logging (up or down), the temperature at the top and bottom, availability of transparent and/or paper copy of the log, scale of the available log copy (1 inch to 100 feet or 1 inch to 20 feet), the scale of the hardcopy from which the wire-line log was digitised, the owner of the log, the file name of the digitised log data, any problems encountered during the geophysical logging of the waterbore and any problems encountered during the digitising of the wire-line log.

GLLOGTYPE - The types of logs which are available in the AGSO Great Artesian Basin Wire-line Log collection include:

- natural gamma-ray
- neutron-gamma
- temperature
- differential temperature
- caliper
- flowmeter (logged down)
- flowmeter (logged up)
- resistivity - long normal
- resistivity - lateral
- resistivity - short normal
- spontaneous potential
- single point resistance

GLLOGUNITS - The units for the different types of logs include:

- natural gamma-ray	gr	- API	- American Petroleum Institute
	gr	- COUNTS/MIN	- counts per minute
	gr	- CPS	- counts per second
	gr	- mR/hr	- milliroentgen per hour
- neutron-gamma	neu	- API	- American Petroleum Institute
	neu	- CPS	- counts per second
- temperature	t	- ^{0} C or celsius	- degrees Celsius
- differential temperature	dt	- diff_t	- differential temperature units
- caliper	cal	- inches	- inches
- flowmeter (logged down)	fld	- RPS	- rotations per second
- flowmeter (logged up)	flu	- RPS	- rotations per second
- resistivity - long normal	rtn	- ohm.m	- ohm metres
- resistivity - lateral	rtl	- ohm.m	- ohm metres
- resistivity - short normal	rsn	- ohm.m	- ohm metres
- spontaneous potentialsp	- mV		- millivolts
- single point resistance	spr	- ohms	- ohms

Map sheets and wire-line logged waterbores locations - GLMAP250

Map sheets at scale 1 : 250 000 that cover the area of the Great Artesian Basin are listed in the lookup table GLMAP250 in the GABLOG Database

.

In the list of map sheets at scale 1 : 250 000 covering the Great Artesian Basin, maps marked * indicate that wire-line logged waterbores are present on the map sheets (Appendix 2).
The map sheets are also shown in Figure 3, and (with their map number and map sheet name) on the set of 3 maps:

Wire-line logged waterbores in the Great Artesian Basin (Logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000 (Habermehl & others, 1997),

which are included in the back of this report.

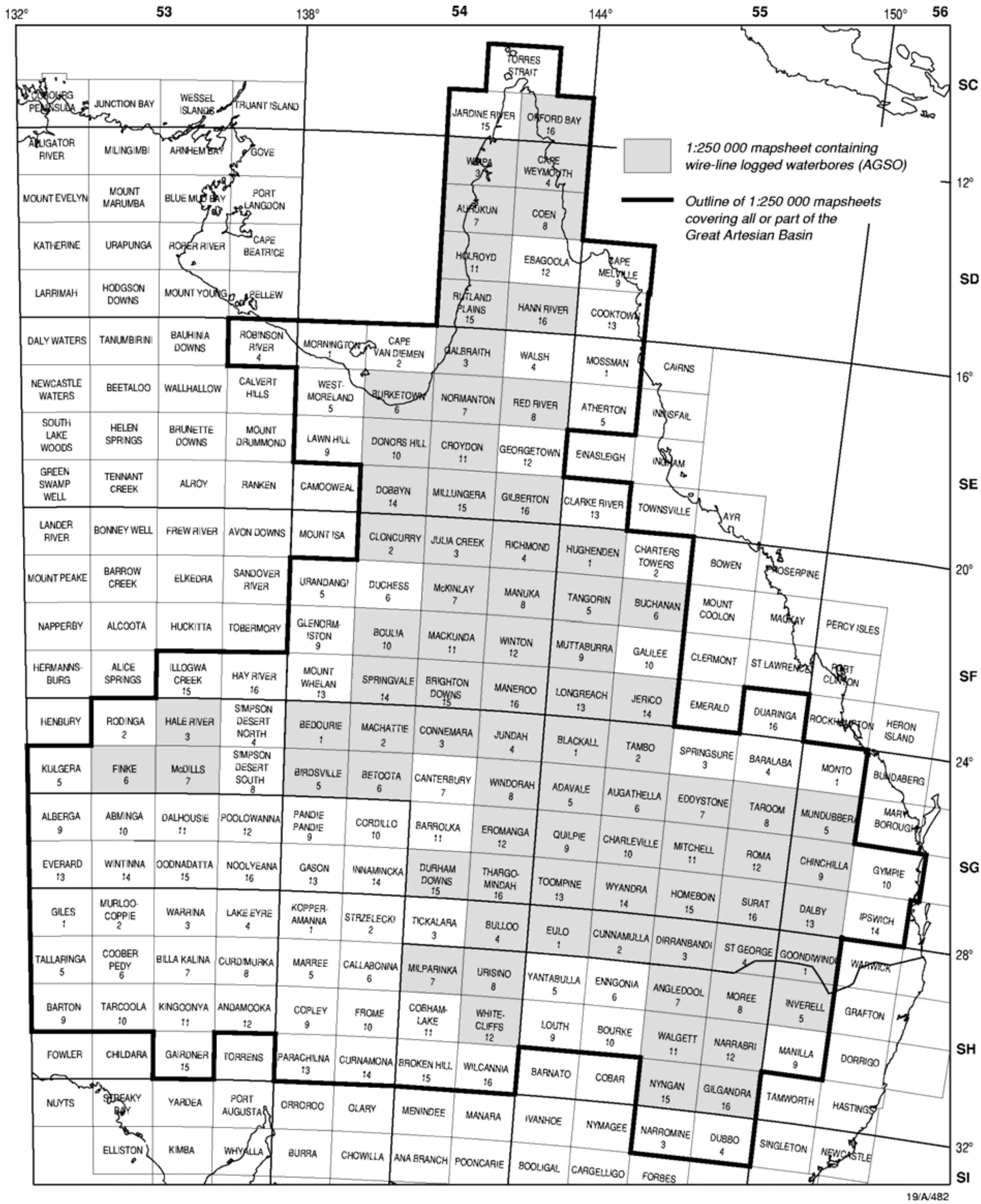

Figure 3 - Index map showing 1 : 250 000 map sheets in the Great Artesian Basin on which wire-line logged waterbores are located

Lithostratigraphic Units - GLSTRAT

The lithostratigraphic units (geological formations) encountered in the waterbores logged are recorded in the Great Artesian Basin Wire-line Logged Borehole Database GABLOG data table GLSTRAT, including the top and bottom depths of the units. The list of lithostratigraphic units in the Great Artesian Basin is given in the lookup table GLSTRATCODE.

The lithostratigraphy of the waterbores has been interpreted by a number of geologists and hydrogeologists during the 1960s, 1970s, 1980s and 1990s, as part of the geological mapping by BMR/AGSO and State Geological Authorities, and as part of the hydrogeological studies of the Great Artesian Basin by BMR/AGSO and State Water and Geological Authorities. Most of the earlier interpretations and datasets are only available as working copies, and these are not accessible in database or digital form.
Log interpretations, showing tops and bottoms of geological formations and cross-sections based on the log interpretations from waterbores in specific regions of the Great Artesian Basin are also given in: Senior & others (1975), Exon (1976), Exon & Senior (1976), Senior & others (1978), Burger & Senior (1979), Smart & others (1980), Andrews & Leys (1984) and Burger (1989).

The lithostratigraphy of the waterbores included in the Database GABLOG data table GLSTRAT was (re-)interpreted by Dr B.R. Senior & Associates Pty Ltd under contract to AGSO during the late 1980s-early 1990s as part of the Great Artesian Basin Wire-line Log Project.

The relationship between the lithostratigraphic (geological) units and the hydrogeological units in the Great Artesian Basin and its constituent sedimentary basins, the Eromanga, Surat and Carpentaria Basins and parts of the Bowen and Galilee Basins is shown in Figure 18 (after Habermehl, 1980a, Habermehl & Lau, 1997).

The lithostratigraphic units (Formations) are included in Appendix 3. The Formation or lithostratigraphic unit names are followed by the abbreviation used on the geological and hydrogeological map sheets at scale 1 : 250 000, 1 : 1 000 000 and 1 : 2 500 000 which cover the Great Artesian Basin (Habermehl, 1980a, Habermehl & Lau, 1997, Habermehl, 2001c).

Hydrochemistry Data - GLCHEM

The hydrochemistry data of samples collected from the groundwater in the waterbores is recorded as the laboratory analytical results in the GABLOG database data table GLCHEM. No field measurements are included as they were not recorded. The name of the analytical laboratory, the date of sampling, the date of analysis, pH, electrical conductivity, estimated total dissolved solids, alkalinity and total hardness are recorded, and the values of (all or part of) the following ions, expressed in part per million (ppm) or milligrams per litre (mg/L):

Most common ion results	Less common ion results

- Na	- sodium	- NO_3	- nitrate
- K	- potassium	- Al	- aluminium
- Ca	- calcium	- Fe	- iron
- Mg	- magnesium	- SiO_2	- silica
- F	- fluoride	- B	- boron
- Cl	- chloride	- PO_4	- phosphate
- SO_4	- sulphate		
- CO_3	- carbonate		
- HCO_3	- bicarbonate		

Watersamples from the logged waterbores were generally forwarded by the logging operators to the State Government Laboratories following the collection at the time of the logging operation. Watersamples from logged waterbores in Queensland were analysed by the Queensland Government Chemical Laboratory, in New South Wales by the New South Wales Department of Mines Chemical Laboratory and in the Northern Territory by the Northern Territory Administration Water Resources Branch Laboratory.

ORACLE Views

Two sets of Oracle Views have been developed for the data in the GABLOG database to enhance the utility of the data package. One set of Oracle Views allows data conversion into end user databases and the other Views is set up for conversion into end user spreadsheets.
Reasons for the use of the Oracle Views are:

- Some digitised wire-line logs are not distributable by AGSO, as the logging was carried out for a private company.
- The end users of the distributable data may not have access to an Oracle RDBMS, and they may be limited to specific database or spreadsheet applications. Because of this, on the distribution media for the GABLOG database and digitised wire-line logs, the database has been stored as flat files, with the definitions originally held in authority tables transferred into the data tables. The database is also stored on the distribution media as an Oracle 7 export file (Tucker & Ivkovic, 1997).

Two sets of Views on the database have been defined. The first set of Views is designed to aid transfer of the GABLOG data into other databases, and the second is for data conversion into spreadsheets. Neither of the two sets of Views include data that is not distributable by AGSO. Both Views integrate look up (or authority) table data with the data tables. The Views created for spreadsheets also integrate waterbore location data with each record in the hydrochemistry, flow, stratigraphy and geophysical log description tables, and so reduce the need to cross-reference spreadsheets when selecting data for spatial analyses.
The main differences between the Views of the data and the base data tables are - only data distributed on the CD-ROM is presented in the Views, look up table data is merged with the data tables, waterbore locations in latitude and longitude data are included in all records of the spreadsheet Views (Tucker & Ivkovic, 1997).

Distribution of GABLOG data on CD-ROM

Tucker & Ivkovic (1997) described the structure of the Great Artesian Basin Wire-line Log Database GABLOG, which contains data on the waterbores logged, the lithostratigraphy and hydrochemistry of the waterbores, data on the type of logs obtained, and the format of the digital log data on the CD-ROM.
All distributable data of the Great Artesian Basin Wire-line Log Database GABLOG and the digital data of the logs is distributed on an ISO 9970 format CD-ROM.
All data stored in ASCII files are also stored in MS-DOS text format, with each line terminated by a carriage return character and a line feed character.

The directory structure of the data of the Great Artesian Basin Wire-line Log Database and the digital data of the logs on CD-ROM is shown in Appendix 4.

Database tables from the GABLOG database are stored as ASCII formatted CSV files (comma separated values), with strings enclosed in double quotes. The first line of each CSV file lists the name of each database field (or spreadsheet column). The database tables are also stored in Oracle 7 export format - this format is useful for those end users wishing to import the data into an Oracle 7 database. The files holding the data for conversion to database systems (as described in previous sections of this document) are held in:

Table Name	CSV ASCII File
glvchem	/database/database/glvchem.csv
glvflow	/database/database/glvflow.csv
glvgen	/database/database/glvgen.csv
glvlog	/database/database/glvlog.csv
lvstrat	/database/database/glvstrat.csv

The files holding the data for conversion to spreadsheets (as described in previous sections, and in Tucker & Ivkovic (1997) are held in:

Table Name	CSV ASCII File
glschem	/database/spread/glvchem.csv
glsflow	/database/spread/glvflow.csv
glsgen	/database/spread/glvgen.csv
glslog	/database/spread/glvlog.csv
glsstrat	database/spread/glvstrat.csv

Sample of a CSV database file (glvstrat.csv):

```
=================================================================
"STATE","BOREID","FORM","FORM_NAME","DEPTH_TOP","DEPTH_BOT"
```

```
"n","10322","Cz?","Cainozoic?",0,60
"n","10322","Klc","Coreena Member",60,630
"n","10322","Kld","Doncaster Member",630,1028
"n","10322","Kco","Cadna-Owie Formation",1028,1112
"n","10322","Klws","Wyandra Sandstone Member",1028.1,1055
"n","10322","U","Unnamed Member",1055,1112
"n","10322","JKh","Hooray Sandstone",1112,1246
"n","10337","Cz","Cainozoic",0,88
"n","10337","KTam","Morney Profile",88,326
"n","10337","Kr","Rolling Downs Group",326,950
"n","10337","Kco","Cadna-Owie Formation",950,1173
"n","10337","JKh","Hooray Sandstone",1173,1390
"n","10415","Cz","Cainozoic",0,127
"n","10415","KTam","Morney Profile",127,189
"n","10415","Kr","Rolling Downs Group",189,1069
"n","10415","Kco","Cadna-Owie Formation",1069,1070
"n","10616","Cz","Cainozoic",0,36
"n","10616","KTam","Morney Profile",36,180
"n","10616","Klu","Wallumbilla Formation",180,834
"n","10745","Cz","Cainozoic",0,8
"n","10745","wz","Weathered zone",8,49
"n","10745","Kly","Bungil Formation",49,175
"n","10745","Klmo","Mooga Sandstone",175,225
"n","10745","Juo","Orallo Formation",225,445
"n","10957","Cz","Cainozoic",0,4
"n","10957","wz","Weathered zone",4,68
"n","10957","Kly","Bungil Formation",68,195
"n","10957","Klmo","Mooga Sandstone",195,252
"n","10957","Juo","Orallo Formation",252,667
"n","10957","Jp/Jug","Pilliga Sandstone/Gubberamunda Sandstone",667,797
"n","11718","Cz","Cainozoic",0,81
==================================================================
```

The digitised wire-line logs are stored as ASCII files, with each line of data terminated with a carriage return and linefeed. The first line in the file consists of a descriptor string: this string starts with the characters “BMR GAB” (for Bureau of Mineral Resources, Great Artesian Basin Project), followed by the State in which the waterbore is located, the Registered Number or name of the waterbore, and the type of the log. The second line of the log gives the units for the depth (feet in all cases) and units for the measured parameter (for example, inches for caliper logs). The third line is always blank. On the fourth and subsequent lines, two numeric values appear, the first value is the depth of measurement from the top of the waterbore or kelly bushing of the drilling rig, the second value is the value of the measured parameter.

Digitised wire-line logs are stored in directories holding all geophysical wire-line logs of a specific type. The name of each digitised wire-line log file is composed of a letter specific to the State, then the Registered Number (or name) of the waterbore, one letter indicating if the log is a duplicate, then a file name extension representing the wire-line log type. The digitised logs are held on the CD-ROM in the directories below the /logs directory.

The location of a wire-line log on the CD-ROM is determined by the State in which the waterbore is located, the Registered Number of the waterbore, the type of the wire-line log, and duplicate letter of the log (if more than one wire-line log is present) from the wire-line log database.
For example, if the Registration Number of the waterbore is “1946”, and the waterbore is located in Queensland (state code “q”), and the desired log type is caliper (type code “cal”), then the digitised wire-line log will be located on the CD-ROM in “/logs/cal/q1946.cal”.

Sample of a digitised geophysical wire-line log (/logs/cal/n32500.cal):

```
================================================================
BMR GAB NSW RN 32500 CAL          <- line 1
  Feet    Inches                  <- line 2
                                  <- line 3
   0.50    5.62                   <- line 3
   1.00    5.62                   <- line 4
   1.50    5.82                   <- line 5
   2.00    5.82                   <- line 6
   2.50    5.82                   <- line 7
   3.00    5.78                   <- line 8
   3.50    5.78                   <- line 9
   4.00    5.77                   <- line 10
   4.50    5.77                   <- line 11
   5.00    5.77                   <- line 12
   5.50    5.77                   <- line 13
   6.00    5.77                   <- line 14
   6.50    5.77                   <- line 15
   7.00    5.77                   <- line 16
================================================================
```

A listing of the contents of the database is held as a text file and a postscript 2 file. The textfile (/database/report/loglist.txt) must be reformatted with a wordprocessor prior to printing. The postscript 2 version of the same file (/database/report/loglist.ps) may be printed on a compatible printer on A4 paper (Tucker & Ivkovic, 1997).

Several waterbores were logged more than once, and an example of this is the waterbore RN 1338 (Queensland), which is shown in Figure 22, with logs obtained in 1967 and 1975.
The data on the logs in the GABLOG Database data table GLLOG include the type of log and the year of logging, and several other parameters for each waterbore logged. Multiple copies of logs for a waterbore are shown in this table as duplicates, and identified by the year of logging.

Maps - Wire-line logged waterbores in the Great Artesian Basin

Maps of wire-line logged waterbores

A set of 3 maps:

> **Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000 (Habermehl & others, 1997),**

is included in the back of this report.

The maps show the locations of the waterbores from which wire-line logs were acquired by BMR (now AGSO) in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975, the (State Water Authority) Registered Number, and the type of logs obtained from each of the 1235 waterbores, as well as the availability of lithostratigraphic and hydrochemistry data for each of the waterbores. The set of 3 maps were produced with ESRI's ARC/INFO GIS software.

The maps contain the following information:

Map 1 Waterbores with:

- natural gamma ray logs
- neutron-gamma ray logs
- lithostratigraphy data
- hydrochemistry data

Map 2 Waterbores with:

- temperature logs
- differential temperature logs
- caliper logs
- flowmeter (down) logs
- flowmeter (up) logs

Map 3 Waterbores with:

- spontaneous potential logs
- single point resistance logs
- short normal resistivity logs
- long normal resistivity logs
- lateral resistivity logs

Map 1

The map

Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Map 1 (1 of 3) - map at scale 1 : 2 500 000 (Habermehl & others, 1997),

shows the location and (State Water Authority) Registered Numbers of the logged waterbores preceded by the State abbreviation, and the outlines of 1 : 250 000 map sheets and their names and numbers, the boundary of the base of the Rolling Downs Group and equivalents, which represents the top of the main Lower Cretaceous - Jurassic aquifer sequence (Figure 18), and the outer limit of the Great Artesian Basin.

A small pie diagram at the waterbore location shows the availability of -

- natural gamma ray logs	- 1212 waterbores
- neutron-gamma ray logs	- 345 waterbores
- lithostratigraphy data	- 1170 waterbores
- hydrochemistry data	- 412 waterbores

Map 2

The map

Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Map 2 (2 of 3) - map at scale 1 : 2 500 000 (Habermehl & others, 1997),

shows the location and (State Water Authority) Registered Numbers of the logged waterbores preceded by the State abbreviation, and the outlines of 1 : 250 000 map sheets and their names and numbers, the boundary of the base of the Rolling Downs Group and equivalents, which represents the top of the main Lower Cretaceous - Jurassic aquifer sequence (Figure 18), and the outer limit of the Great Artesian Basin.

A small pie diagram at the waterbore location shows the availability of -

- temperature logs	- 763 waterbores
- differential temperature logs	- 742 waterbores
- caliper logs	- 208 waterbores
- flowmeter (down) logs	- 180 waterbores
- flowmeter (up) logs	- 160 waterbores

Map 3

The map

Wire-logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Map 3 (3 of 3) - map at scale 1 : 2 500 000 (Habermehl & others, 1997),

shows the location and (State Water Authority) Registered Numbers of the logged waterbores preceded by the State abbreviation, and the outlines of 1 : 250 000 map sheets and their names and numbers, the boundary of the base of the Rolling Downs Group and equivalents, which represents the top of the main Lower Cretaceous - Jurassic aquifer sequence (Figure 18), and the outer limit of the Great Artesian Basin.

A small pie diagram at the waterbore location shows the availability of -

- spontaneous potential logs	- 41 waterbores
- single point resistance logs	- 3 waterbores
- short normal resistivity logs	- 24 waterbores
- long normal resistivity logs	- 26 waterbores
- lateral resistivity logs	- 12 waterbores

The combination of the data presented on the maps and on the CD-ROM provides a data set on the waterbores and the logs which facilitates enhanced access and retrieval of the information on logs and waterbores, permits ready access to the digital log data for data processing, analysis and interpretation, and allows for improved distribution and storage options.
This information will be useful to water managers and planners in Commonwealth and State Authorities and other government agencies, and to explorers, developers and users in the petroleum, mining and pastoral industries, as well as other managers and users of groundwater supplies for towns and homesteads and other usage. Used in combination with hydrogeological data from the AGSO Great Artesian Basin Hydrogeological Map (Habermehl & Lau, 1997), and the AGSO Great Artesian Basin Hydrogeological Database and/or the State Water and Geological Authorities Hydrogeological Databases, extensive information on the waterbores and the Great Artesian Basin is available, which can be complemented with information from geological and hydrogeological publications (references in Habermehl, 1980a, 1986, 1996, 2001a, b, c).

In addition, wire-line logs from petroleum exploration and production wells drilled in the Great Artesian Basin area since the early 1960s greatly increase the number of geophysical logs available (Figure 4). A large number of the well completion reports of petroleum exploration wells drilled during the 1960s and early 1970s are included in the Petroleum Search Subsidy Acts Publication Series published by BMR. Information on these and other petroleum exploration and production wells, including those drilled during the late 1970s and 1980s and 1990s are available in Commonwealth Databases (eg. PEDIN - AGSO and the Bureau of Resource Sciences) and State Petroleum Databases within the State Geological Surveys and/or State Mines Departments in Queensland, New South Wales, South Australia and the Northern Territory. The detailed geological descriptions of the petroleum drill-holes and the information from the wire-line logs of these holes, as well as the results of tests and measurements carried out in the petroleum drill-holes, and the associated seismic data from seismic lines across the drill-site regions, are particularly useful for geological and hydrogeological interpretations, as nearly all petroleum drill-holes fully penetrate the Great Artesian Basin sedimentary sequence. This is in contrast to the waterbores, which, even in the case of the deep waterbores, usually only penetrate a small part of the Lower Cretaceous - Jurassic sedimentary sequence (Figures 7 and 18). Most of the flowing artesian waterbores were completed in the upper parts of the main artesian aquifers (Cadna-owie Formation and Hooray Sandstone and equivalents). Non-flowing artesian waterbores usually were completed in the Winton and Mackunda Formations (and their equivalents).

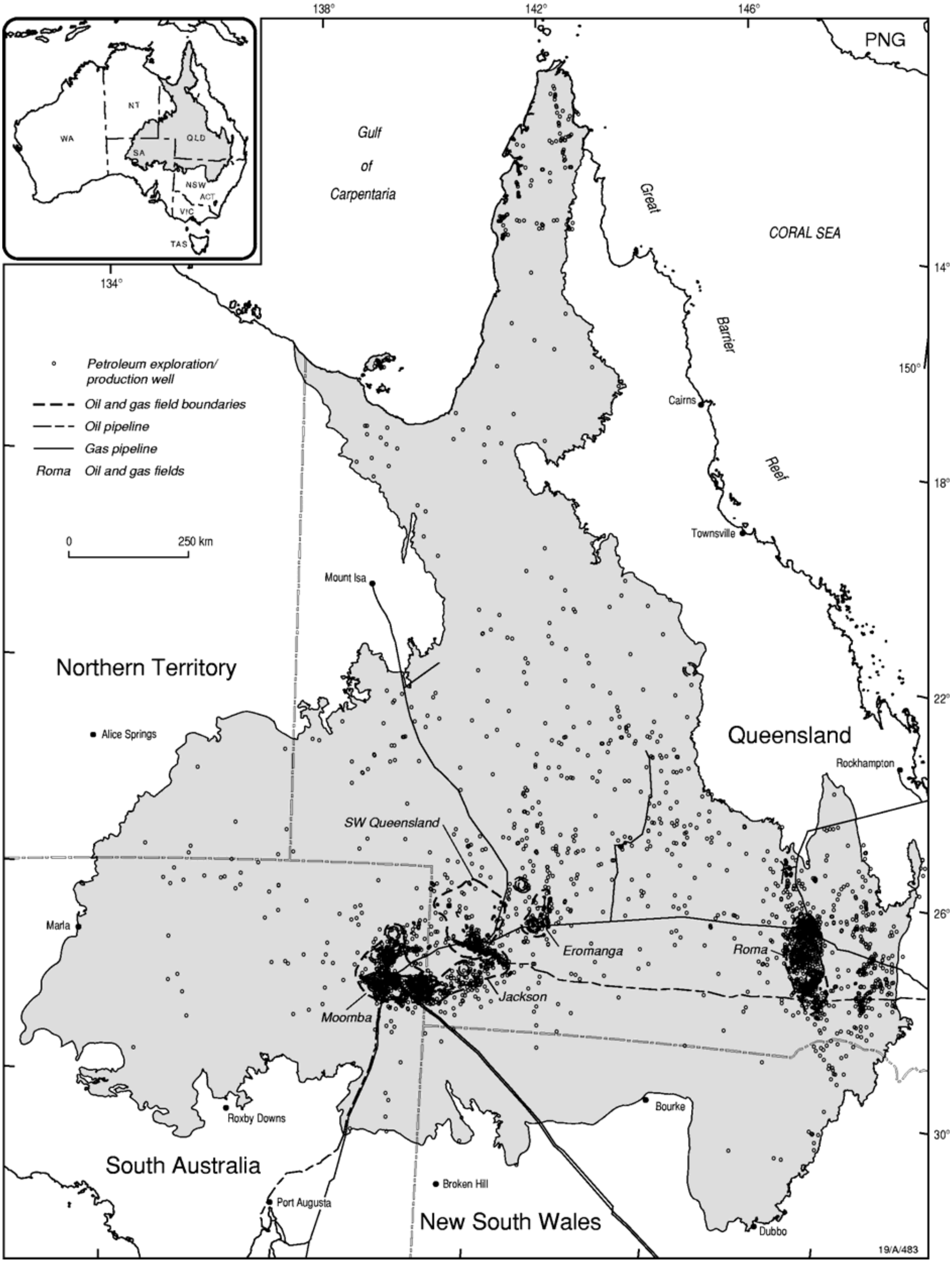

Figure 4 - Location of petroleum exploration and production wells in the Great Artesian Basin (after Habermehl & Lau, 1997)

Application of the wire-line logs in the Great Artesian Basin

Geophysical logging in hydrogeology

Wire-line logging or borehole geophysics or geophysical well logging is "the science of recording and analysing continuous or point measurements of physical properties made in wells or testholes" (Keys, 1989). Most subsurface geophysical methods were developed since the late 1920s, and most were aimed at meeting the needs of the petroleum industry. The geophysical well logging and evaluation has developed into a significant and highly specialised technique, which is closely associated with petroleum exploration drilling, production, well maintenance and petroleum engineering. Geophysical well logs from petroleum exploration and production wells provide essential data for the description and interpretation of the subsurface geology of petroleum accumulations. The measurements, recording, transmission and interpretation of wire-line logs is now highly sophisticated following the introduction of computers and satellite communications, and diverse log interpretation methods have advanced to provide reliable integrated geological formation analysis.

Several of the geophysical logging methods are applicable to groundwater investigations, and though the geophysical logging in waterbores is rather simplistic compared to the applications in the petroleum industry, the use of borehole geophysics provides significant information on the subsurface geology and hydrogeology.

Geophysical logs do not produce unique patterns, and the lithology interpreted from the logs needs to be confirmed and correlated with information from other sources, preferably from the same drill-hole or nearby drill-holes, which have been sampled or cored and described and geologically logged in detail by geologists or hydrogeologists. Correlation of the lithological units between boreholes is based on the similarity of the log response for specific units in different waterbores, and can in many areas enable long distance or even Basin-wide correlation of geological units. However, most lithological units will show changes in thickness, grainsize, texture, mineralogy, composition, matrix, degree of cementation, sedimentary structures, or general gradual change or facies change within the lithological unit, all of which could result in a different log response. In addition, different fluids or groundwaters with different salinities or physical and chemical properties could result in different log responses.

The principles of geophysical logging and their applications to hydrogeology and groundwater investigations is dealt with by Chapellier (1992), Keys (1989), Repsold (1989), Keys & MacCary (1971), and briefly by Fetter (1994), Freeze & Cherry (1979), Bouwer (1978), Brown & others (1977), Emerson & Haines (1974), Campbell & Lehr (1973), Davis & DeWiest (1966), Todd (1959) and others.
Paillet & Crowder (1996) consider the quantitative analysis of geophysical logs in groundwater studies.
Basic and general books on well logs and well log analysis include Rider (1986), Serra (1984a, b), Asquith & Gibson (1983), Pirson (1963, 1978), Schlumberger (1972) and many others.

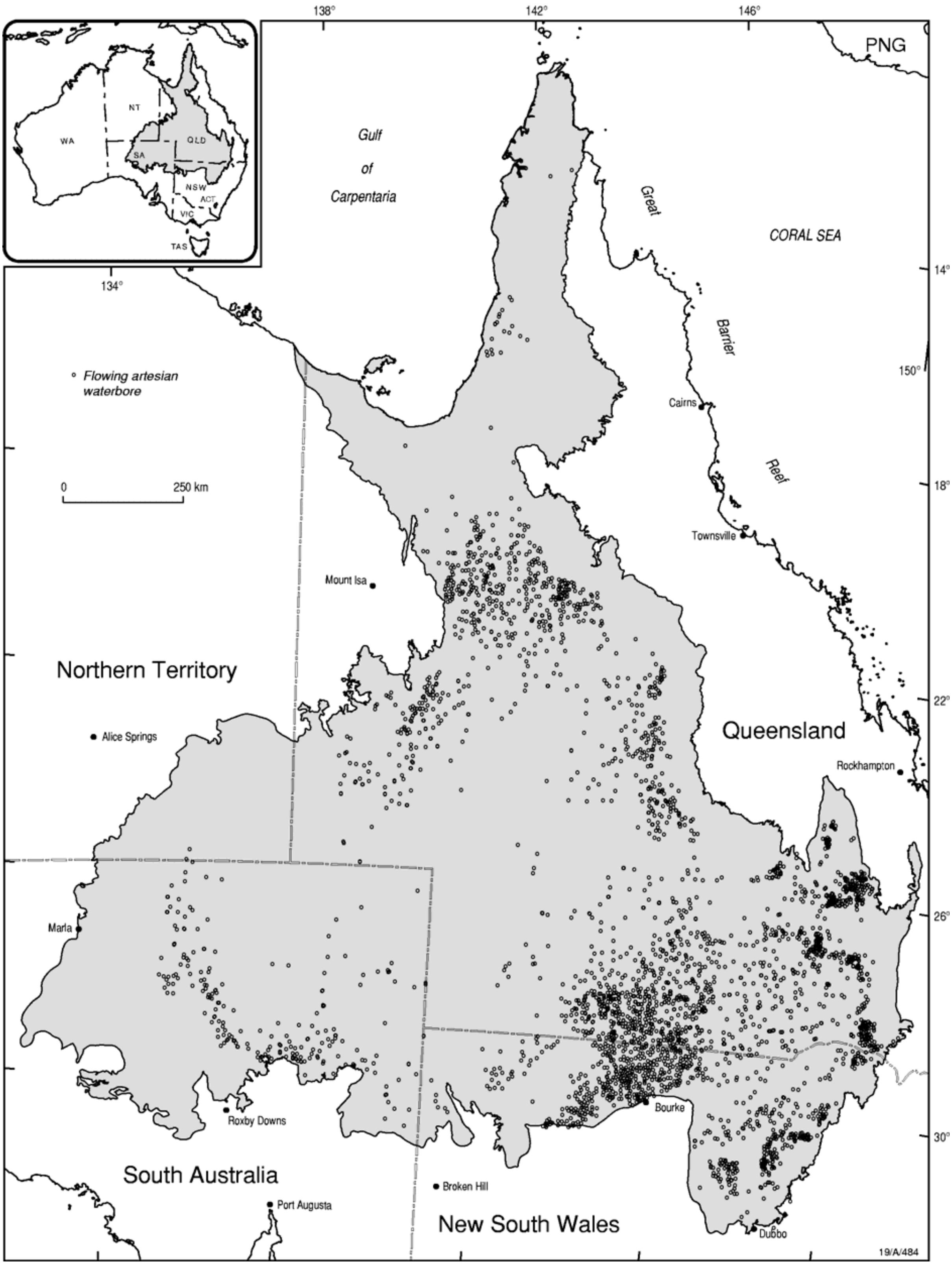

Figure 5 - Location of flowing artesian waterbores in the Great Artesian Basin (after Habermehl, 1980a and Habermehl & Lau, 1997)

Detailed descriptions and explanations of the logs, their characteristics and their interpretation are shown in Rider (1986), Serra (1984a, b), Asquith & Gibson (1982), Chapellier (1992), Keys (1989), Repsold (1989), Keys & MacCary (1971), Pirson (1963, 1978) and Schlumberger (1972) and many others.
Most of the authors describe the logging principles and the different logs and their interpretations, but also the log characteristics and the complexities of the different tools and logging environments.

The wire-line logs from waterbores can be interpreted individually or in combination to determine the lithology, geometry and porosity of lithological units, identify and correlate litho-stratigraphic units and mineral bearing or water bearing beds, to define the source, temperature, salinity, volume and movement of groundwater discharged by aquifers, and to determine construction and corrosion details of the waterbore casings.

The application of geophysical logging in existing and cased waterbores is restricted to a limited number of log types, as most wire-line logs must be run in open holes without casing. Some geophysical logs, ie. the radioactive logs such as natural gamma-ray and neutron-gamma, can be applied in cased boreholes, including steel casing. Borehole casing precludes the use of electric logs in the cased waterbores.

Geophysical logging in the Great Artesian Basin

In the Great Artesian Basin almost all flowing artesian waterbores (Figure 5) and non-flowing artesian waterbores (Figure 6) have been lined with steel casing, with a very small number having polyvinylchloride (PVC) or fibre-glass or fibre reinforced plastic (FRP) casing. Therefore the wire-line logs applied in those waterbores have been the nuclear logs: natural gamma-ray and neutron-gamma logs to determine the properties and characteristics of the surrounding rocks. In addition, temperature, differential temperature, flowmeter, caliper and casing collar locator logs have also been run in these cased waterbores, and give information on the rocks, the groundwater and the borehole casings.
Electric logs such as spontaneous potential and resistivity logs have only been run in waterbores which were uncased at the time of logging (usually newly drilled holes), or in waterbores which had a significant length of uncased hole at the bottom, generally at least 100 m (300 ft).
As a result, the wire-line logs obtained by BMR (now AGSO) from approximately 1250 flowing and non-flowing artesian waterbores in the Great Artesian Basin comprise natural gamma-ray, neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs.

Natural gamma-ray logs were obtained from nearly all of the waterbores logged during 1960 to 1975. Neutron-gamma ray logs were obtained from a small number of waterbores in the early 1970s. Temperature, differential temperature and casing collar locator logs were acquired from most waterbores logged, and flow meter logs were obtained from a limited number of flowing artesian waterbores. Spontaneous potential, resistivity and caliper logs were run in a small number of waterbores.

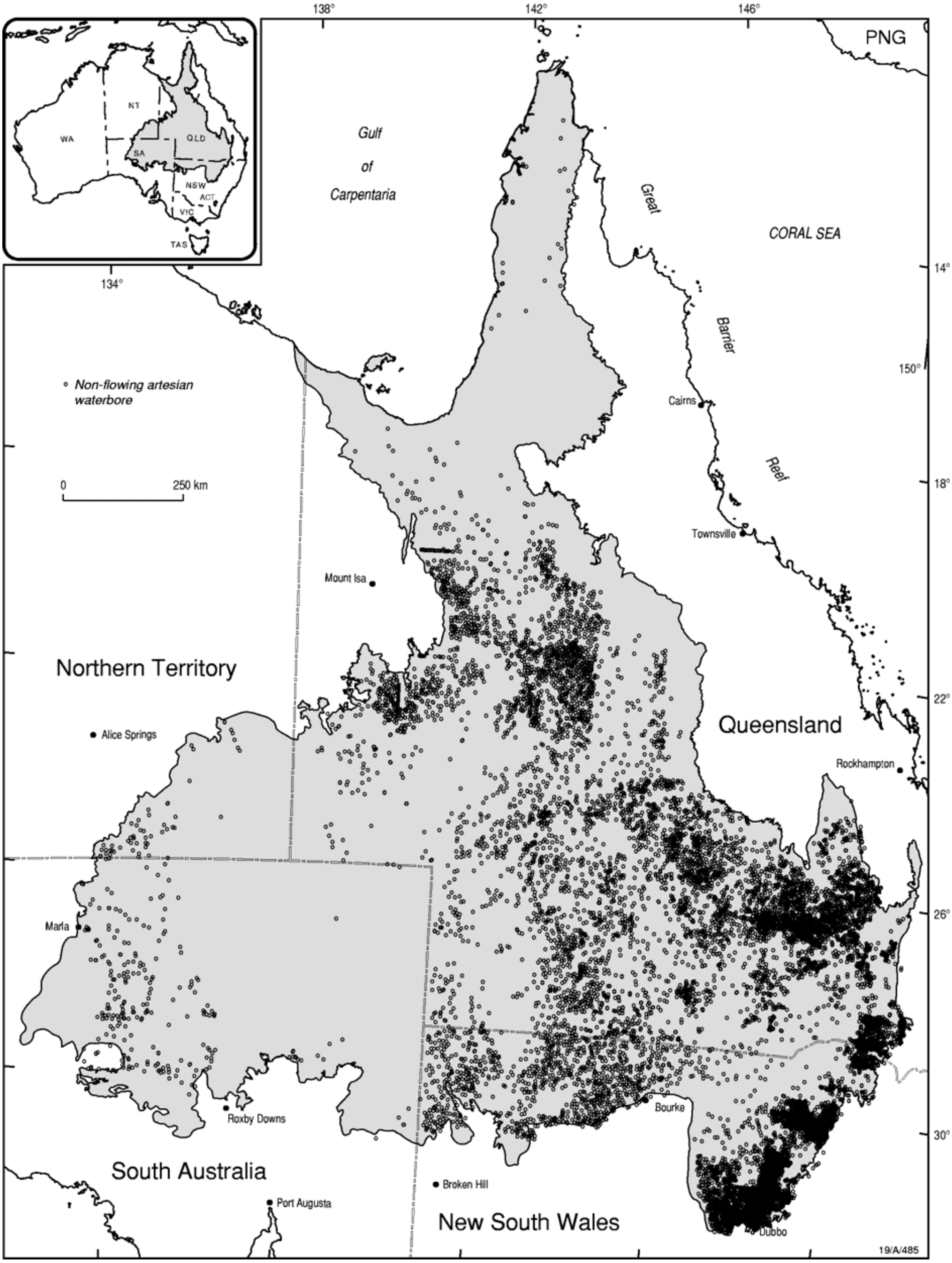

Figure 6 - Location of non-flowing artesian waterbores in the Great Artesian Basin (after Habermehl & Lau, 1997)

Extensive use has been made of the wire-line logs, in particular the natural gamma-ray logs, to define lithostratigraphic units in the Great Artesian Basin (including by the author), and to delineate aquifers as part of the geological mapping during the 1960s and 1970s and the hydrogeological studies during the 1970s, 1980s and 1990s.
Almost all of the waterbores logged have been completed in the upper parts of the Lower Cretaceous - Jurassic sedimentary sequence, including the aquifer sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone (Figures 7 and 18). As a result, most of the logs obtained from the flowing and non-flowing artesian waterbores in the Great Artesian Basin show part or all of the Cretaceous Rolling Downs Group sedimentary sequence and part of the underlying Lower Cretaceous - Jurassic sedimentary sequence (Figure 8).
Most waterbores obtain their artesian groundwater supplies from the above aquifers. In some areas, in particular near the eastern and northeastern margin of the Basin, aquifers in lower lithostratigraphic units in the Jurassic and in the Triassic are encountered at shallower depths in the waterbores, and logs obtained from those waterbores show a larger part of the sedimentary sequence.
During the planning and operational stages of the logging program care was taken to select as many deep waterbores as possible (including by the author), and to include waterbores penetrating the maximum number of lithostratigraphic units.

Data from the natural gamma-ray, neutron-gamma-ray, spontaneous potential and resistivity logs acquired by BMR (now AGSO) during the logging program in the Great Artesian Basin in the 1960s and 1970s are time independent, and geological and hydrogeological information of the rocks surrounding the boreholes can be interpreted from these wire-line logs.
The different conditions or characteristics of the waterbore or the artesian groundwater during the lifetime of a waterbore causes the temperature, differential temperature, flowmeter, caliper and casing collar locator logs to be time dependent. The casing collar locator logs for instance can be interpreted to show the amount of corrosion of the casing at the time of logging.

The wire-line logs were all recorded in analog form, as ink traces on transparent paper (film) at scales 1 inch to 100 feet (1 : 1200) and at a scale of 1 inch to 20 feet (1 : 240), and the originals and the duplicate paper print copies have been held in BMR (now AGSO) for storage, retrieval and access purposes, and for duplication and work purposes.
Access, retrieval, copying and storage of the large number of paper (film) based logs, and the preparation and processing of log data, has been difficult. The conversion of the logs into digital data using PC based digitising systems since the late 1980s, has greatly improved the access and the opportunities for data analysis and interpretation, and also enhanced the storage and distribution of the datasets.

The analog wire-logs at scale 1 inch : 100 feet (1 : 1200) were digitised from early 1991 onwards, using PC-based semi-automatic (oil) well log digitising software. The natural gamma-ray logs, which are present for all the waterbores logged by BMR (now AGSO) from 1235 waterbores in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975, were completed in early 1992, and all neutron-gamma-ray logs, and any available temperature, flowmeter, caliper, spontaneous potential and resistivity logs for the waterbores were digitised and a total of 3875 logs were completed by 1993/1994. The casing collar locator logs could not be digitised for technical reasons, and is not

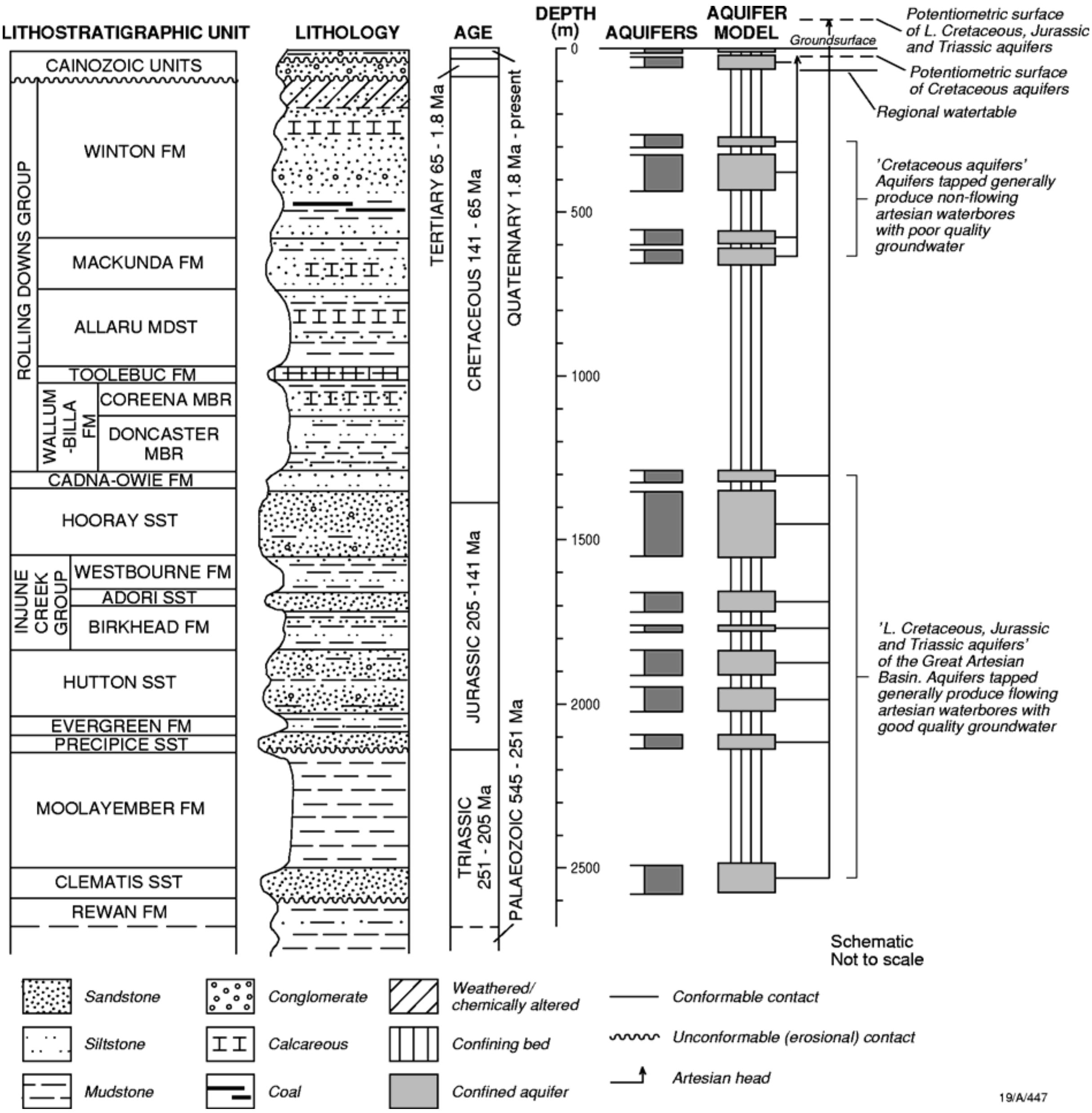

Figure 7 - Schematic lithostratigraphic column of the Great Artesian Basin based on the Central Eromanga Basin part (see Figure 18), simplified aquifer groups and hydraulic characteristics (after Habermehl, 1980a and Habermehl & Lau, 1997)

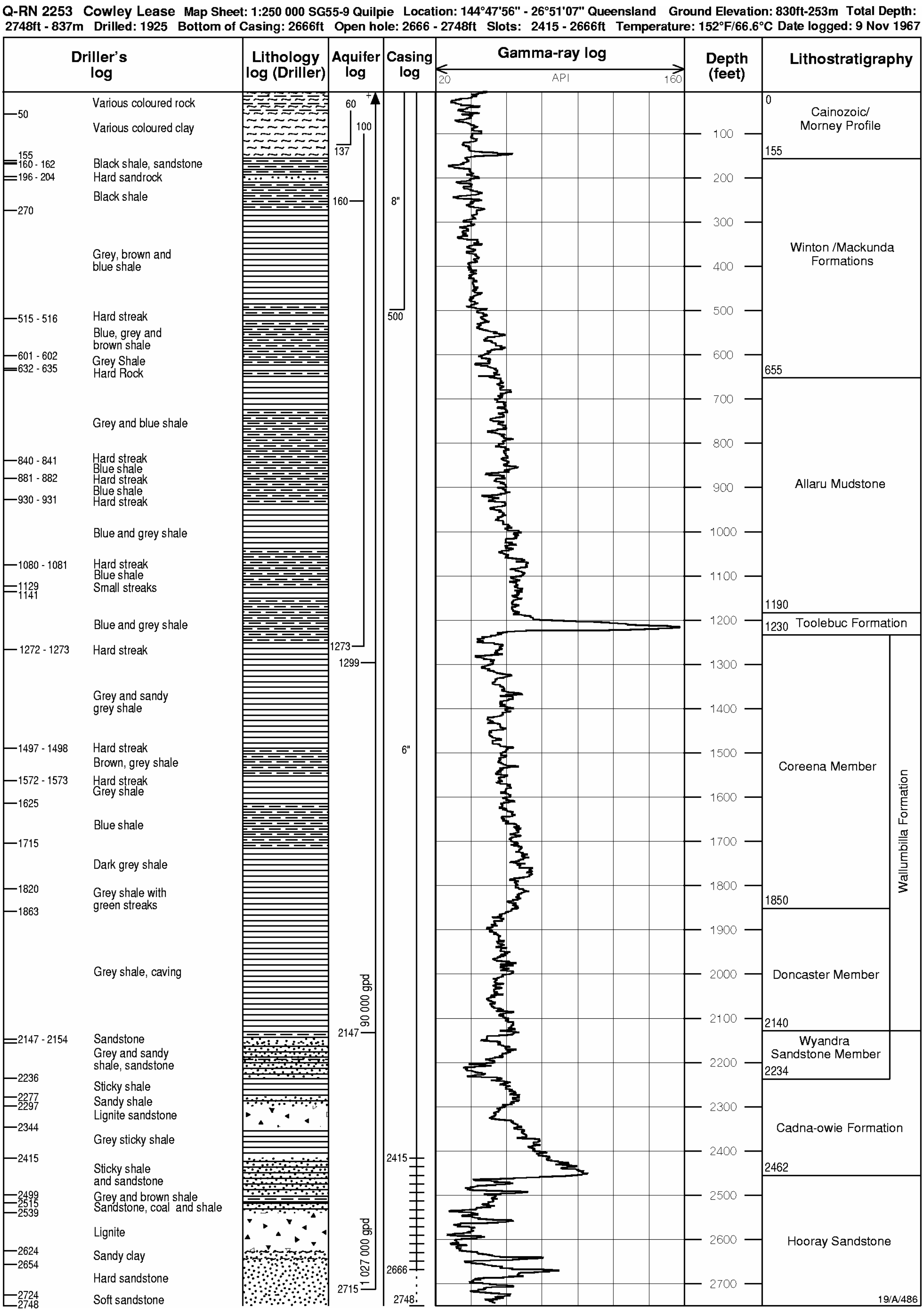

Figure 8 - Natural gamma-ray log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 2253 (Queensland)

included in the digital dataset of the logs.

The digital log data, and data on the waterbores logged, including the identification, location, elevation, depth and year of completion of the waterbores, the lithostratigraphic units encountered in the waterbores and their depths, and the hydrochemical laboratory analyses results obtained from watersamples taken at the time of logging, showing pH, electrical conductivity, total dissolved solids, alkalinity and the detailed analyses results of 8 or 9 major ions are included in a database on CD-ROM in the back of this report.

The locations of the waterbores from which wire-line logs were acquired by BMR (now AGSO) in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975 are shown in Figures 2 and 3. The waterbore locations, and the type of logs obtained from each of the 1235 waterbores, as well as the availability of lithostratigraphic and hydrochemistry data for each of the waterbores is shown on a set of 3 maps –

Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Maps 1, 2 and 3, at scale 1 : 2 500 000 (Habermehl & others, 1997),

which is included in the back of this report.

Type of logging equipment - logging tools or probes

The type of logging equipment or logging tools or probes used during the Great Artesian Basin Wire-line Logging Program varied depending on the organisation, which carried out the logging, and the time the logging was undertaken, but all recording was carried out with analog equipment.

Details about the logging tools and the logging parameters are given in the individual log headings, an example of which is shown in Figure 9.

The log headings also contain data on the waterbore, its Registered Number and name, location (latitude and longitude), elevation and location on 1 : 250 000 map sheet. The datum (usually groundlevel) and the measurement of the log in relation to the datum are recorded. The date of logging, the run number, depth of the waterbore as recorded by the driller and by the logger are shown, and the bottom and top depths (interval) of the log. The type of log, type of fluid in the borehole, salinity and density of the fluid, waterlevel or flowing artesian condition, maximum recorded temperature, operating time and operating personnel were recorded.

Borehole and casing data were listed, in particular the casing diameter and depth intervals of the casings.

The equipment data provides the details about the logging probes, including the run number, tool model number, diameter, detector model number, type, length, distance to the source (for natural gamma-ray combined with neutron probes), truck and instrument number or identification and tool serial number.

The logging data shows the run number, depths logged from and logged to, logging speed (feet/minute), time constant, sensitivity settings, zero division left or right and API gamma-ray units per log division.

The natural gamma-ray logs and natural gamma-ray and neutron logs contain calibration data and curves at the bottom of the logs. The probes were calibrated at each logging run, and instrument zero, background and test source and statistical variations were determined, and the API units standardised on the chart scales.

GAMMA RAY - NEUTRON LOG

G16-95A

BUREAU OF MINERAL RESOURCES

R.N. 4963

NAME Raceview

LOCATION

SHEET NAME Charleville SG55-10

GRID REF

LAT 26-20-50 N. LONG 146-23-22 E.

OTHER SERVICES T/dT

ELEVATION

METHOD

PERMANENT DATUM. GL ELEV 325.8m

LOG MEASURED FROM 0 FT. ABOVE PERM. DATUM

DRILLING MEASURED FROM

KB

DF

GL 325.8m

DATE	10-11-1975		
RUN NO.	1		
DEPTH DRILLER	1302 ft		
DEPTH LOGER	1258 ft		
BTM. LOG INTER.	1258 ft		
TOP LOG INTER.	0		
TYPE LOG	Gamma neutron		
TYPE FLUID IN HOLE	Water		
SALINITY PPM CL			
DENSITY			
LEVEL	19		
MAX. REC. TEMP. °C	41°C		
OPERATING RIG TIME			
RECORDED BY	GSJ		
WITNESSED BY	MJR		

BORE-HOLE RECORD				CASING RECORD			
NO.	BIT	FROM	TO	SIZE	WGT	FROM	TO
				10"		0	203 ft
				8"		0	401 ft
				6"		0	1302 ft
				perforations		1201	1241 ft

EQUIPMENT DATA

NEUTRON	
RUN NO.	1
LOG TYPE	neutron
TOOL MODEL NO.	GCN27U5A
DIAMETER	43mm
DETECTOR MODEL NO.	
TYPE	prop.
LENGTH	15cm
SOURCE MODEL NO.	NB370
SERIAL NO.	
SPACING	43cm
TYPE	ambe
STRENGTH	3cu

GAMMA RAY	
RUN NO.	1
TOOL MODEL NO.	GCN27U5A
DIAMETER	43mm
DETECTOR MODEL NO.	
TYPE	GM
LENGTH	462mm
DISTANCE TO N SOURCE	2m

GENERAL	
HOIST TRUCK NO.	
INSTRUMENT TRUCK NO.	394
TOOL SERIAL NO.	23

LOGGING DATA

GENERAL				GAMM RAY				NEUTRON			
RUN NO.	DEPTHS FROM	DEPTHS TO	SPEED FT. MIN	TC SEC	SENS SETTINGS	ZERO DIV. L OR R	API GR. UNITS PER LOG DIV	TC SEC	SENS SETTINGS	ZERO DIV. L OR R	API N. UNITS PER LOG DIV
1	1258	0	30	2	800	0	10	3	800	0	100

REFERENCE LITERATURE

REMARKS

19/A/487

Figure 9 - Log heading of the natural gamma-ray and neutron logs from waterbore RN 4963 (Queensland)

The following logging tools were used, though this listing is not complete:

- natural gamma-ray
- neutron-gamma
- casing collar locator
- temperature
- differential temperature
- caliper
- flowmeter
- resistivity - long normal
- resistivity - lateral
- resistivity - short normal
- spontaneous potential
- single point resistance

The logging of the waterbores involved the lowering of the logging probes or combinations of

the logging probes, inside the borehole to the maximum depth possible. In some instances a dummy tool might have been lowered prior to the logging tools to determine the presence or absence of any obstructions.
Usually the temperature and differential temperature tools would have been run first with the probes going downhole, and recording the temperature and temperature variations in the undisturbed watercolumn. The temperature and differential temperature probes were usually combined with the natural gamma-ray and casing collar locator probes, and on the (return) uphole run, the natural gamma-ray and casing collar locator logs would be recorded.
The neutron-gamma probe was usually combined with the natural gamma-ray and casing collar locator probes, and would be used on the uphole run together with these probes.

The flowmeter and caliper probes were commonly used in another, separate combination, with the flowmeter results being recorded on the downhole run, and the caliper results on the uphole run. Some flowmeter logs were run uphole, and the direction of logging has been indicated on the logs and in the data sets.

Another, separate run was carried out for the recording of the spontaneous potential and resistivity logs, which were run in the uphole direction.

Types of logs acquired from waterbores in the Great Artesian Basin

The types of logs which are available in the AGSO Great Artesian Basin Wire-line Log collection include:

- natural gamma-ray
- neutron-gamma
- casing collar locator
- temperature
- differential temperature
- caliper
- flowmeter (logged down)
- flowmeter (logged up)
- resistivity - long normal
- resistivity - lateral
- resistivity - short normal
- spontaneous potential
- single point resistance

The different types of logs obtained from the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program are described below, and their main characteristics given (see also the references to textbooks in the chapter Geophysical logging in hydrogeology).

Natural gamma-ray logs

The natural gamma-ray tool measures natural radioactivity in geological formations.

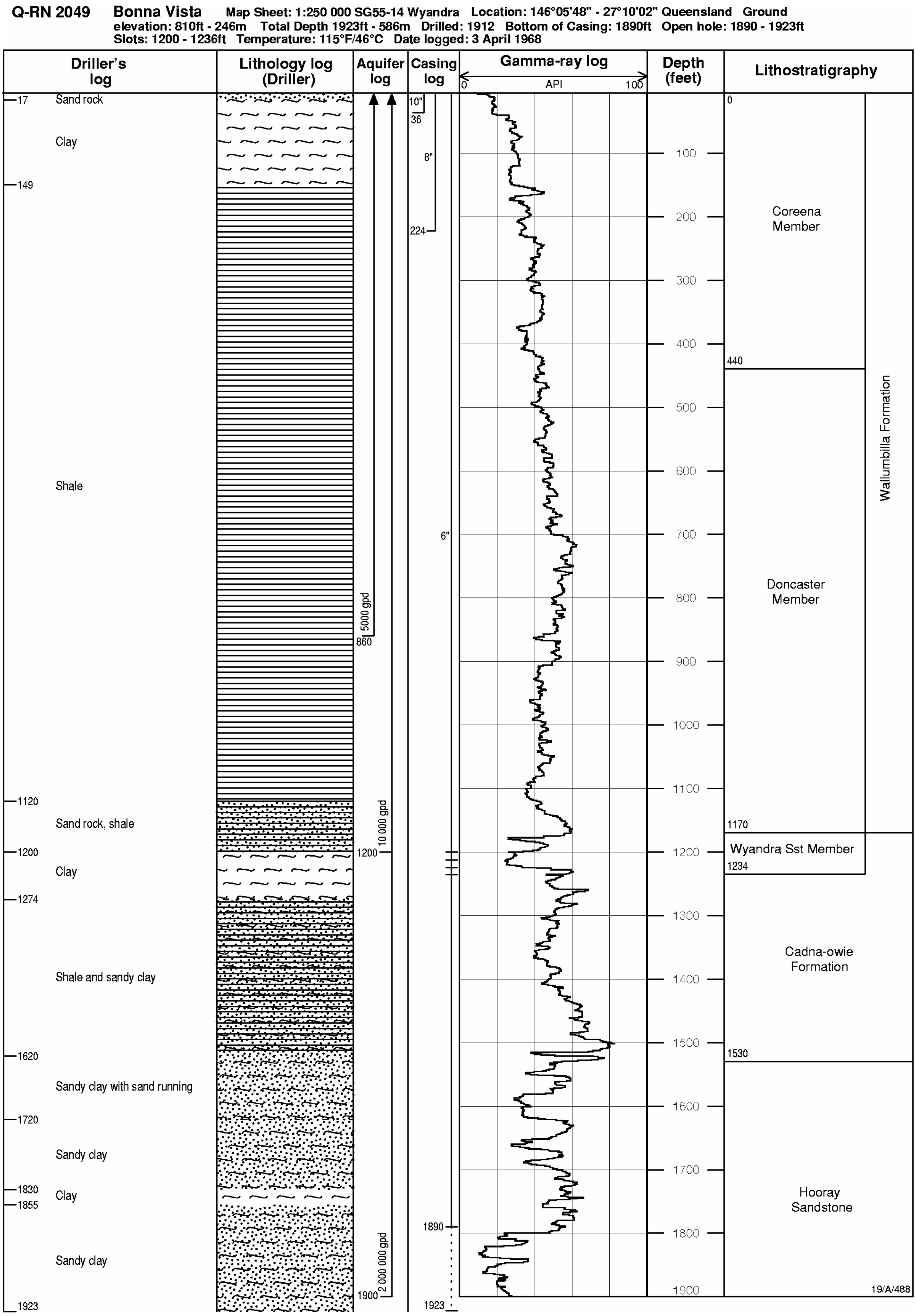

Figure 10 - Natural gamma-ray log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 2049 (Queensland)

The resultant natural gamma-ray log is used to identify and differentiate lithologies and correlate units between different drill-holes. The logs can be used to identify sandstone, mudstone, carbonate and other lithologies in the waterbore, and check the formation depths and thicknesses. The natural gamma-ray log clearly reveals the clay or mudstone layers, which are of interest to the hydrogeologist as they are generally the low permeable layers, and the log also shows the sandstones, which generally are the porous and permeable, waterbearing layers or aquifers.
Quartzose sandstones and quartz sandstones, which are free of clay, shale or mud have low concentrations of radioactive material and give low gamma-ray responses. The main radioactive isotopes which play a role in the radioactivity of minerals and rocks are uranium - ^{238}U, thorium - ^{232}Th, and potassium - ^{40}K. Potassium is present in many clay minerals, and causes radioactivity. With increasing clay, shale or mud content, and therefore increasing concentration of radioactive material, the gamma-ray log response increases. Low clay, shale or mud sandstones may produce a high gamma-ray response if the sandstone contains potassium feldspars, micas, glauconite or uranium rich groundwater. Logging can be carried out in cased and uncased, and dry or fluid filled holes.

Natural gamma-ray logs are available for all the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program. The natural gamma-ray logs have been used extensively to identify and correlate lithological units, and to delineate the subsurface lithostratigraphy of the Great Artesian Basin in combination with the geological mapping of the Basin during the 1960s and 1970s, and to correlate and to define the geometry of the subsurface aquifers of the Basin as part of the hydrogeological studies during the 1970s, 1980s and 1990s. In all studies, the natural gamma-ray logs were only used in a qualitative sense. The availability of the log data in digital format provides possibilities for the quantitative analysis of the log data, in particular the determination of sand-shale ratios and the interpretation of hydrogeological parameters.

Examples of the natural gamma-ray logs and their application in the Great Artesian Basin are shown in Figures 8, 10, 11 and 22 (the locations of the waterbores are shown in Figure 23).
These logs show lower gamma-ray values for sandstone units and higher values for the clay or mudstone units. Precise depth and thickness of the lithological units can be derived from the natural gamma-ray log, and the lithostratigraphic units interpreted and correlated.

Neutron-gamma logs

The neutron-gamma probe measures induced radioactivity or gamma-rays emitted, following irradiation of the formations by a neutron source.
The neutron-gamma logs are mainly used to determine porosity and moisture content of the geological formations. In subsurface rocks, hydrogen is mainly found in water and petroleum, the liquids filling the porosity and under certain conditions the hydrogen contents can be used to estimate the porosity and saturation. Generally the neutron-gamma log, which measures gamma rays emitted after capture of the source neutrons by nuclei of some elements, is widely used in the petroleum industry. The neutron-neutron log, which measures the neutrons slowed down by collisions of the source neutrons with hydrogen nuclei in the formation, is usually applied for hydrogeological purposes.
The neutron-gamma log reveals different lithologies and formations, and allows correlations to

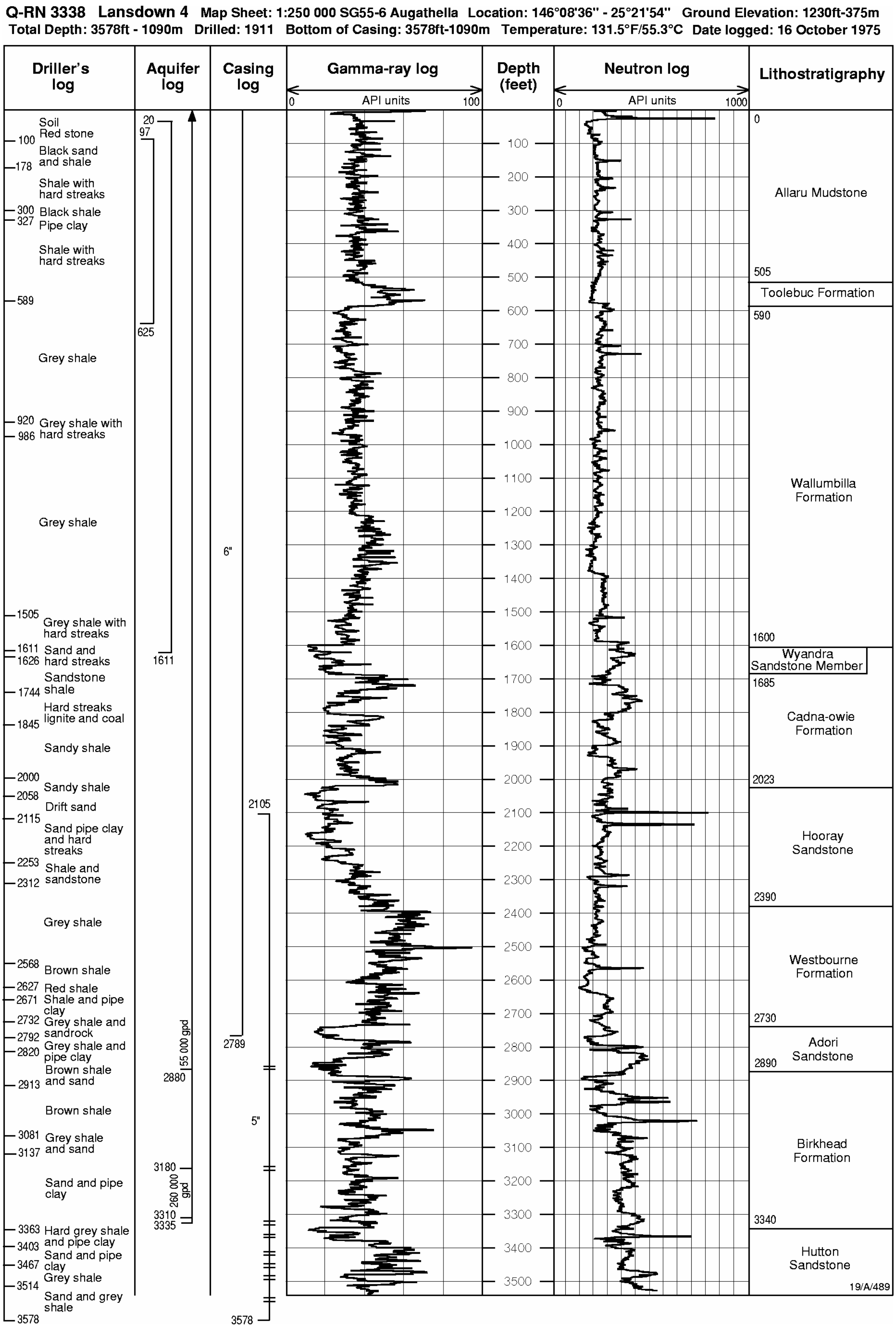

Figure 11 - Neutron-gamma-ray and natural gamma-ray log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 3338 (Queensland)

be made between boreholes. It provides a qualitative determination of clays, mudstones or shales, porous and low porosity formations, and the porosity and water contents of formations can be determined. The watertable in porous formations, especially sands and sandstones can be identified. Logging can be carried out in cased and uncased, and dry or fluid filled holes. The sphere of influence, or the depth of investigation is dependent on the spacing between the source and the detector in the logging probe and the abundance of hydrogen in the formation.
Neutron-gamma logs are available for a limited number of waterbores logged as part of the Great Artesian Basin Wire-line Logging Program. The neutron-gamma logging was only applied during the early 1970s.

An example of the neutron-gamma log is shown in Figure 11.
The neutron-gamma log shows intervals of higher radiation values corresponding to the intervals of lower values in the natural gamma-ray log, which indicates higher porosity and water in the sandstone units.

Casing collar locator logs

The casing collar locator tool measures the location of the casing collars or casing joints.
The casing collar locator log is based on a magnetic device and is used to determine the location of the casing collars of the fixed length casing tubes and so provide accurate depth control for other types of logs.
The casing collar locator log can also be used to provide accurate information on the construction of the casing in the borehole, including the locations of the perforations or slots in the casing, casing joints and intervals of corroded casing. The casing collar locator log has generally been run together with the natural gamma-ray logs in the Great Artesian Basin Wire-line Logging Program.
Casing collar locator logs are present on most original copies of the natural gamma-ray logs obtained as part of the Great Artesian Basin Wire-line Logging Program, but are not available in the digitised versions. A technical problem prevented the digitising (vectorising) of the horizontal marks of the casing collar locator log, as the log digitising software could not distinguish these marks from the horizontal components of the log grid, and these marks were filtered out.

Examples of the casing collar locator logs are shown in Figure 22.

Temperature logs

The temperature tool measures the temperature variations of the groundwater in the borehole, and provides a record of the temperature versus depth.
The temperature logs are continuous recordings of the temperature of the groundwater and give information about the subsurface temperature, record temperature data to determine the geothermal gradient in the geological formations surrounding the borehole, identify anomalies caused by inflow or outflow of groundwater into or out of the borehole and give information to correct electrical logs.

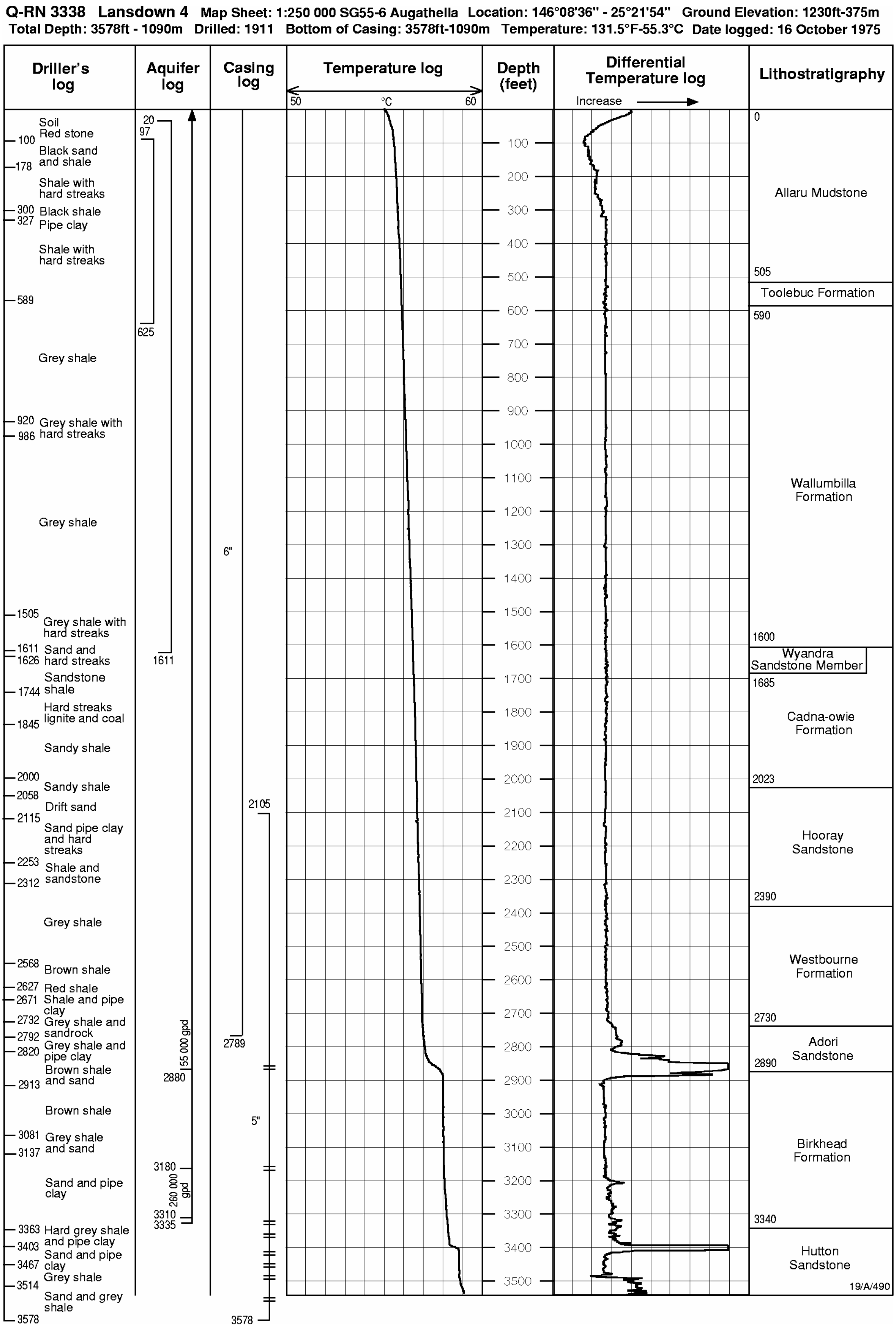

Figure 12 - Temperature and differential temperature log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 3338 (Queensland)

The temperature log needs to be run as the first log down the borehole, before the watercolumn is disturbed in non-flowing (artesian) waterbores, preferably after a considerable period of non-disturbance, when a temperature equilibrium has been reached. The temperature logs can provide information on the depths and thicknesses of aquifers, locate joints and fissures and solution openings in open holes, and leaks or holes and perforated sections in cased holes. The temperature logs are useful to locate the depths of lost circulation and inflow from and outflow to aquifers in the borehole.

Temperature logs are available for more than 60 percent of the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program. The temperature logs have been extensively used in the delineation of the aquifers of the Great Artesian Basin and in the determination of aquifer inflows and outflows and in integrity checks of the bore casing.

An example of the temperature log is shown in Figure 12.
Figures 11, 12 and 13 show examples of the natural gamma-ray, neutron-gamma, temperature, differential temperature, caliper and flowmeter logs obtained from the waterbore RN 3338 in the Queensland part of the Great Artesian Basin (Figure 23). Groundwater inflow from the aquifers into the borehole through the slots (openings in the casing) can be interpreted from the temperature, differential temperature, caliper and flowmeter logs. Inflows originate from the Hutton and Adori Sandstone Aquifers.
The inflow from the Adori Sandstone Aquifer through the slots at 3400 and 2880 - 2883 feet can be distinguished on all logs. Artesian groundwater flow at 2880 feet was noted during the drilling of the waterbore (see Aquifer log in Figures 11, 12 and 13). Compare these results with the Caliper and Flowmeter logs (Figure 13).

Differential temperature logs

The differential temperature probe measures the temperature gradient between two sensors in the borehole, and presents a record of the rate of change versus depth.
The differential temperature logs are continuous recordings of the temperature differential of the groundwater between the two sensors in the borehole. The use of the differential temperature logs shows the rate of changes of the temperature versus depth and this log is more sensitive to changes in temperature gradient.
Differential temperature logs are available for more than 60 percent of the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program. The differential temperature logs have been extensively used in the delineation of the aquifers of the Great Artesian Basin and in the determination of aquifer inflows and outflows and in integrity checks of the bore casing.

An example of the temperature log is shown in Figure 12.
Figures 11, 12 and 13 show examples of the natural gamma-ray, neutron-gamma, temperature, differential temperature, caliper and flowmeter logs obtained from the waterbore RN 3338 in the Queensland part of the Great Artesian Basin (Figure 23). Groundwater inflow from the aquifers into the borehole through the slots (openings in the casing) can be interpreted from the temperature, differential temperature, caliper and flowmeter logs. Inflows originate from the Hutton and Adori Sandstone Aquifers.

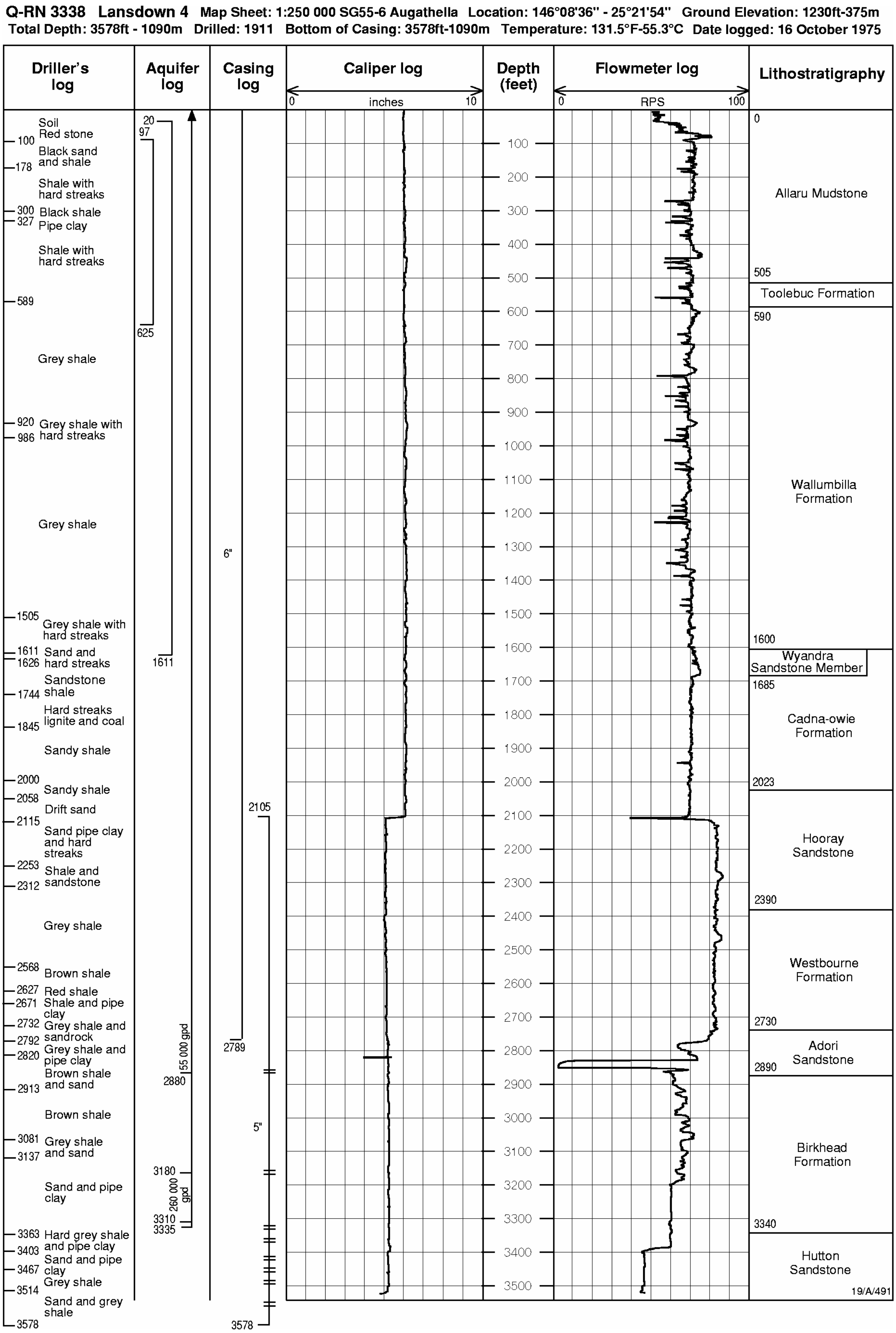

Figure 13 - Caliper and flowmeter log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 3338 (Queensland)

The inflow from the Adori Sandstone Aquifer through the slots at 3400 and 2880 - 2883 feet can be distinguished on all logs. Artesian groundwater flow at 2880 feet was noted during the drilling of the waterbore (see Aquifer log in Figures 11, 12 and 13). The effects of the inflow of groundwater into the borehole are quite pronounced on the differential temperature log. Compare these results with the Caliper and Flowmeter logs (Figure 13).

Caliper logs

The caliper tool measures the drillhole size or casing diameter.
The caliper logs are used to determine the drillhole diameter and to estimate the lithologic character of the formations. The logs can be also be used to locate joints, fractures and solution openings and other cavities in the formations drilled, and the logs have many applications to determine information required for the construction and completion of drillholes and estimating diameters and volumes of material to be used.
The caliper logs are useful in cased holes to determine the diameter and the changes in diameter of the casing present in the borehole, and to detect any breaks and fractures in the casing or perforated or slotted intervals in the casing.

Caliper logs are available for more than 17 percent of the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program. The caliper logs have been extensively used in the integrity checking of the bore casing of waterbores in the Great Artesian Basin and in the determination of aquifer inflows and outflows in combination with the temperature logs.

An example of the caliper log is shown in Figure 13.
The Caliper log of waterbore RN 3338 in the Queensland part of the Great Artesian Basin shows different casing diameters related to the 5 inch and 6 inch casings in the borehole. The slots do not show on the Caliper log, though the slots are generally narrow vertical cuts, and the spring-loaded arms of the Caliper tool might not have encountered any of the slots. The blip on the Caliper log at 2810 feet appears unrelated to the slots at the 2880 - 2883 feet interval. The position of the slots at the latter depths is confirmed by the Casing log, Temperature and Differential Temperature logs and Flowmeter log.
The anomaly in the Caliper log at 2810 feet could be related to an obstruction in the 5 inch casing.

Flowmeter logs (logged down or up)

The flowmeter probe measures the flow of groundwater in the borehole.
The flowmeter log shows the measurement results of the direction and quantity of groundwater flow up or down the borehole, and can be used to determine the inflow of groundwater into the borehole from aquifers through casing openings. The flowmeter log can be used to determine the relative quantities of groundwater flow through the borehole and can be used to interpret and locate openings and leaks in the casing.

The flowmeter log derived from a flowmeter probe running down the borehole will be different from the flowmeter log derived from a flowmeter probe running up the borehole, if the

groundwater flow is upwards in the borehole. If the groundwater flow velocity is equal to the logging speed, then the spinner (impeller or screw propellor) ceases to rotate. The combination of the flowmeter log with the caliper log provides data to interpret the quantity of the groundwater flow and the location of casing openings.
Flowmeter logs (flowmeter logs up and down combined) are available for 27 percent of the waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the flowmeter log is shown in Figure 13.
The Flowmeter log of the waterbore RN 3338 in the Queensland part of the Great Artesian Basin shows the variations in the rotation speed of the spinner (impeller or screw propellor) of the flowmeter probe and reflect the changes in the artesian groundwater flow up the casing in the borehole. The inflow from the Adori Sandstone Aquifer at 2830 feet probably causes the artesian groundwater in the borehole below this inflow level to stagnate, as shown by the drop in the spinner revolutions.
The increase in size of the casing tubes from 5 inch to 6 inch diameter at 2105 feet also results in a reduction of the spinner revolutions, as the groundwater flow in the casing slows down in the larger casing opening.
A comparison with the other logs from this waterbore, including the Temperature and Differential Temperature logs shows that all logs provide different information, and the maximum amount of information and interpretation results is only possible by combining all available logs.

Resistivity - long normal logs

The resistivity - long normal probe measures the electrical resistivity of the lithological units.
The resistivity - long normal log is used in uncased drillholes to identify the resistivity in thick beds of the formation where mud invasion is not too deep. The logs can be used to determine the formation resistivity, the resistivity of the formation water, invaded zone (by drilling mud) resistivity and porosity.
Resistivity - long normal logs are available for 26 waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the resistivity - long normal log is shown in Figure 14.

Resistivity - short normal logs

The resistivity - short normal tool measures the electrical resistivity of the lithological units.
The resistivity - short normal log is used in uncased drillholes to identify the resistivity in beds of the formation where mud invasion is deep. The logs can be used to determine the formation resistivity, the resistivity of the formation water, invaded zone (by drilling mud) resistivity and porosity.
Resistivity - short normal logs are available for 24 waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the resistivity - short normal log is shown in Figure 14.

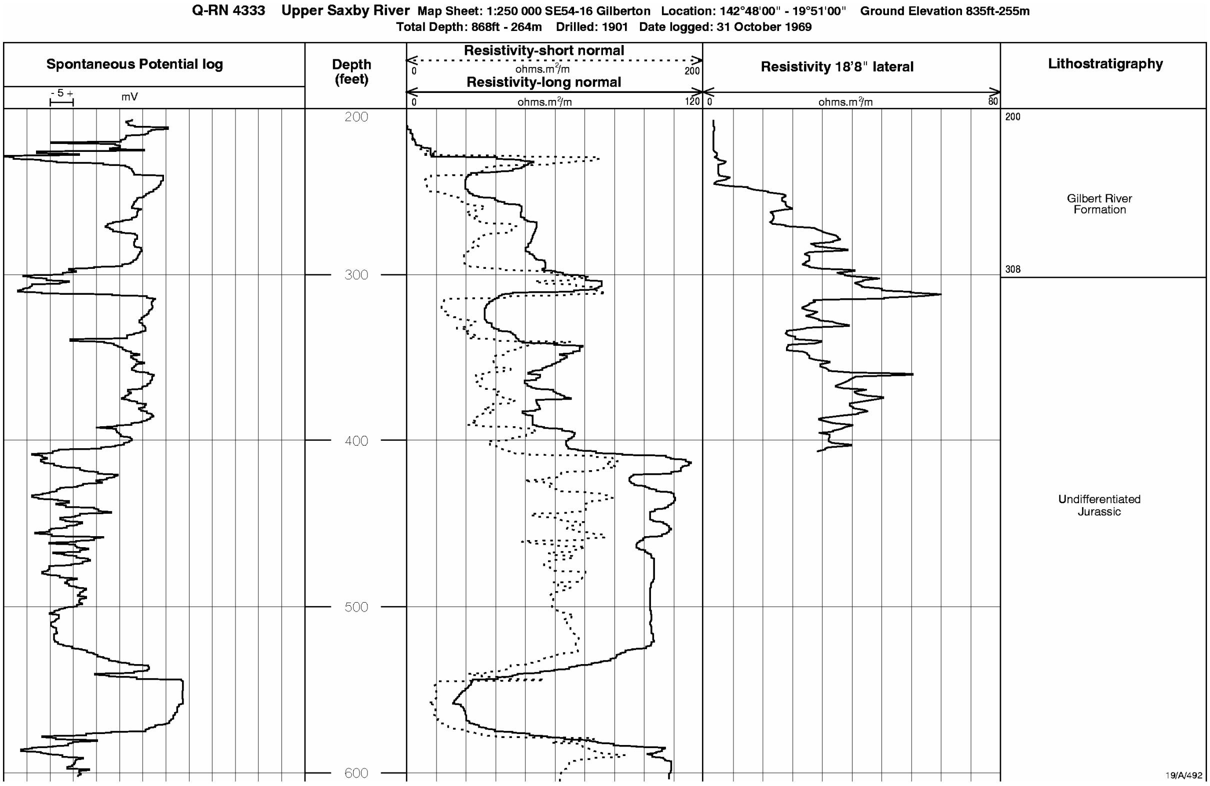

Figure 14 - Spontaneous potential and resistivity logs (short normal resistivity + long normal resistivity + lateral resistivity) + lithostratigraphy + depths from waterbore RN 4333 (Queensland)

Resistivity - lateral logs

The resistivity - lateral tool measures the electrical resistivity of the lithological units.
The resistivity - lateral log is used in uncased drillholes to identify the resistivity in thin beds of the formation where mud invasion is not too deep. The logs can be used to determine the formation resistivity, the resistivity of the formation water, invaded zone (by drilling mud) resistivity and porosity.
Resistivity - lateral logs are available for 12 waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the resistivity - lateral log is shown in Figure 14.

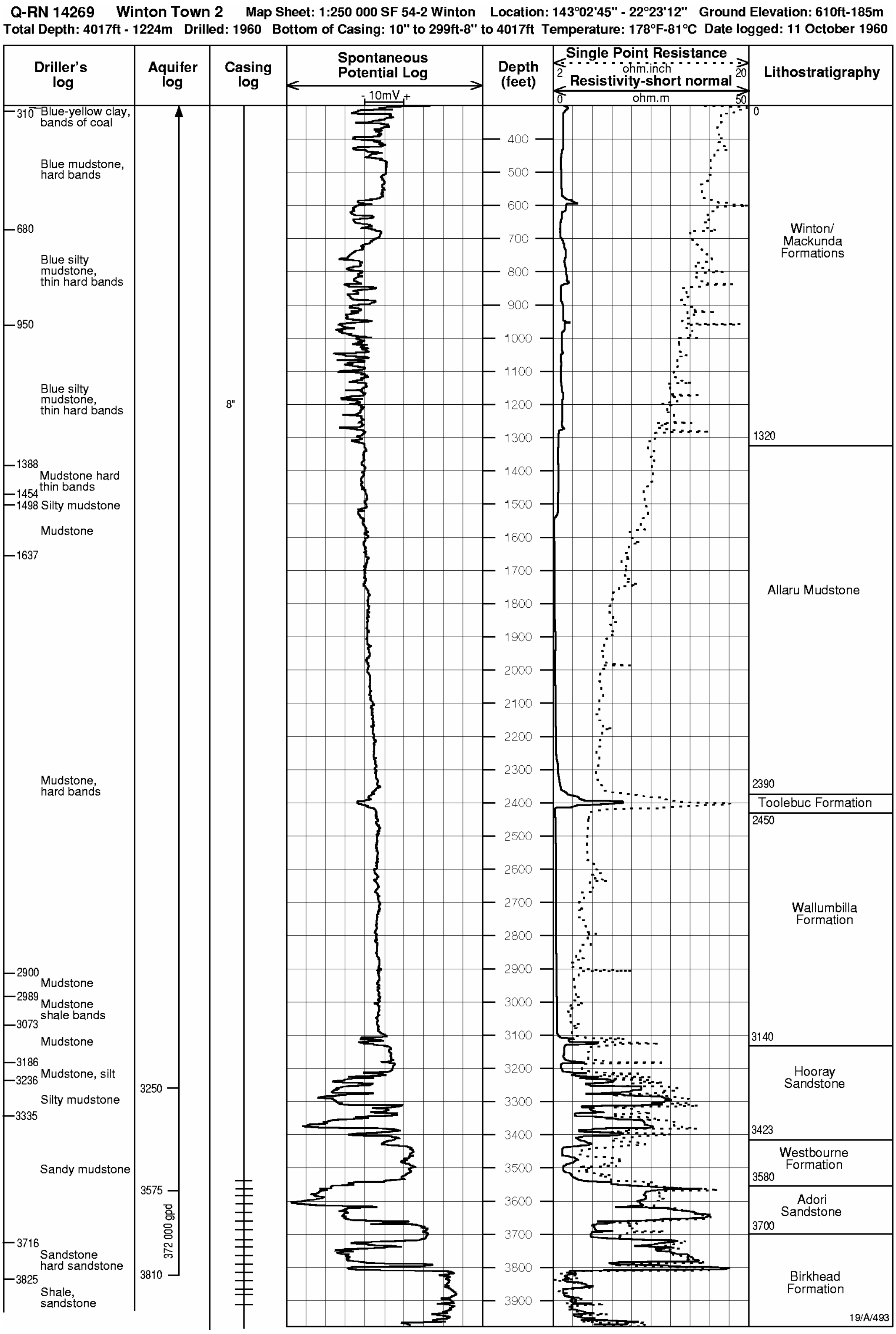

Figure 15 - Single point resistance log and spontaneous potential log and resistivity short normal log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 14269 (Queensland)

Spontaneous potential logs

The spontaneous potential probe measures the differences in natural electrical potential between the surface electrode and an electrode in the drillhole, and so measures the differences in natural electrical potential between the drillhole fluid and the surrounding rock material.
The spontaneous potential log is used to determine bed thicknesses, the nature of the formations, identify porous and permeable beds and indicate the salinity of the groundwater in the formation.
Spontaneous potential logs are available for 41 waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the spontaneous potential log is shown in Figure 14.

Single point resistance logs

The single point resistance tool measures the resistance between two points, the surface electrode and the electrode in the fluid or mud filled drillhole.
The single point resistance log is used to determine the resistivity of different lithological units in the borehole, and can be used to interpret the depth and thickness of beds and to identify rocks and correlate formations.
Single point resistance logs are available for only 3 waterbores logged as part of the Great Artesian Basin Wire-line Logging Program.

An example of the single point resistance log is shown in Figure 15.
Note the drift of the reference of the point resistance log in Figure 15. The most likely cause of this is probably the poor (electrical) contact of the reference electrode in the dry upper soil layer, the latter being a poor conductor (Chappellier, 1992, Figure 17).

Log Data in GABLOG Database

The data on the logs in the GABLOG Database data table GLLOG include the type of log, name of the log, the top and bottom depths of the log, log unit, year of logging, the direction of the logging (up or down), the temperature at the top and bottom, availability of transparent and/or paper copy of the log, scale of the available log copy (1 inch to 100 feet or 1 inch to 20 feet), the scale of the hardcopy from which the wire-line log was digitised, the owner of the log, the file name of the digitised log data, any problems encountered during the geophysical logging of the waterbore and any problems encountered during the digitising of the wire-line log.

The contribution of wire-line logs to the geology

and hydrogeology of the Great Artesian Basin

The Great Artesian Basin

The Great Artesian Basin is one of the world's largest artesian groundwater basins comprising confined aquifers in quartzose sandstones of continental origin and Triassic, Jurassic and Cretaceous ages. The main confining unit is a thick argillaceous sequence of sediments of marine origin and Early Cretaceous age, which is underlain by the Lower Cretaceous-Jurassic aquifers, and overlain by the confined aquifers of Early to Late Cretaceous age. The Lower Cretaceous-Jurassic and Triassic aquifers alternate with confining beds of siltstone and mudstone, which are of continental and marine origin and Triassic and Jurassic in age (Habermehl, 1980a, 1996, Habermehl & Lau, 1997, Habermehl, 2001a, b).

The Great Artesian Basin occupies an area about one-fifth of the Australian continent, and underlies most of Queensland, parts of New South Wales, South Australia and the Northern Territory (Figure 1).
Basin sediments are up to 3000 m thick, and form a large synclinal structure, uplifted and exposed along its eastern margin, and tilted southwest. Recharge occurs mainly in the eastern marginal zone, an area of relatively high rainfall, and large-scale regional groundwater movement is generally towards the southwestern, southern, western and northern margins. Recharge also occurs in the western margin of the Basin, and groundwater flow directions are towards the southwestern and southern discharge margins. Natural discharge occurs from flowing artesian springs in areas along the southern, southwestern and northwestern margins of the Basin. Most springs have built up mound-shaped deposits of sediments or carbonates. Discharge from the artesian aquifers near the discharge margins also occurs by diffuse discharge where the overlying confining beds are thin. Many springs are associated with structural impediments, generally also by abutment of aquifers against bedrock or thin confining beds near the discharge margins.

Abundant artesian groundwater supplies of good quality are obtained from flowing artesian waterbores, and from pumped artesian waterbores in the Basin. Groundwater in the most exploited aquifers in the Lower Cretaceous-Jurassic sequence generally contains about 500 - 1500 mg/L total dissolved solids, and is therefore of good quality, making it suitable for domestic and town water supply, stock use in the pastoral industry and water supplies for the mining and petroleum industries.

The Great Artesian Basin underlies arid and semi-arid regions, where surface water is sparse and unreliable. The discovery of the Basin's artesian groundwater resources around 1880, made settlement possible, and led to the establishment of an important pastoral industry. Pastoral activity and town water supplies are to a very large extent dependent on artesian groundwater in the Basin area. In recent years artesian groundwater has been used increasingly in the mining (since the 1980s and 1990s) and petroleum (since the 1960s and 1970s) industries located both inside and outside of the Basin area. Most of these industries are largely or totally dependent on the Basin's artesian groundwater resources, eg. Olympic Dam and the town of Roxby Downs in South Australia, several mines (Osborne, Cannington, Eloise and Ernest Henry) in the northwest margin of the Basin in Queensland, oil and gas production in the northeast of South Australia, the southwest of Queensland and the east of Queensland. Use in some areas for irrigation is also on the increase, though generally most of the artesian groundwater is unsuitable for irrigation because in much of the Basin area it is chemically incompatible with the dominantly montmorillonitic clay soils, and because sodium absorption ratios are too high.

Hydrocarbon source and reservoir rocks are abundant in the sedimentary sequence of the Basin, and commercial and sub-commercial oil and gas discoveries have been made in several Jurassic and Cretaceous sandstones, contradicting earlier beliefs that the Basin-wide groundwater flow had flushed hydrocarbons out of the system. Dissolved hydrocarbons in the artesian groundwater are generally dry gases and are useful petroleum exploration indicators.

Geology

The hydrogeological Great Artesian Basin comprises the geological Eromanga, Surat and Carpentaria Basins and parts of the Bowen and Galilee Basins (Habermehl, 1980a, 1996, Habermehl & Lau, 1997, Habermehl, 2001a, b and Figure 16). The geology of the Basins has been reviewed in Habermehl (1980a, 1986, 1996, 2001a, b). These constituent sedimentary basins are continuous across shallow ridges and platforms of older sedimentary, metamorphic and igneous rocks. The Basin consists of several broad synclinal structures trending north and northeast, overlying sedimentary, metamorphic and igneous rocks of pre-Jurassic or pre-Triassic ages.
The Mesozoic sedimentary sequence in the central part of the Basin reaches a maximum total thickness of about 3000 m. Parts of the marginal areas of the Basin have been eroded, in particular along the eastern border, which was uplifted during Cainozoic times. Sheet-like, conformable beds extend relatively unchanged for hundreds of kilometres and are almost horizontal.

The Great Artesian Basin is an asymmetrical basin elongated northeast-southwest, and tilted towards the southwest. Four centres of basin subsidence are present, two coinciding with the Surat and Carpentaria Basins, and two within the Eromanga Basin, separated by the Birdsville Track Ridge, and overlying the Cooper Basin and the Pedirka Basin (Habermehl, 1980a, Habermehl & Lau, 1997, Habermehl, 2001a, b and Figure 17).
Cainozoic and earlier uplift along the eastern margin, and subsidence in several parts of the Basin, particularly in the central and southwestern parts, produced the Basin's asymmetry.
Many of the near surface folds, particularly monoclinal features, grade downwards into faults and are the product of draping and differential compaction of the sediments over fault bounded basement blocks. Several major fault and fold systems occur in the Basin, in places forming en echelon structures. Throws of up to 300 m are evident across some major faults, though the displacement of Jurassic-Cretaceous sediments along normal faults is usually much less.

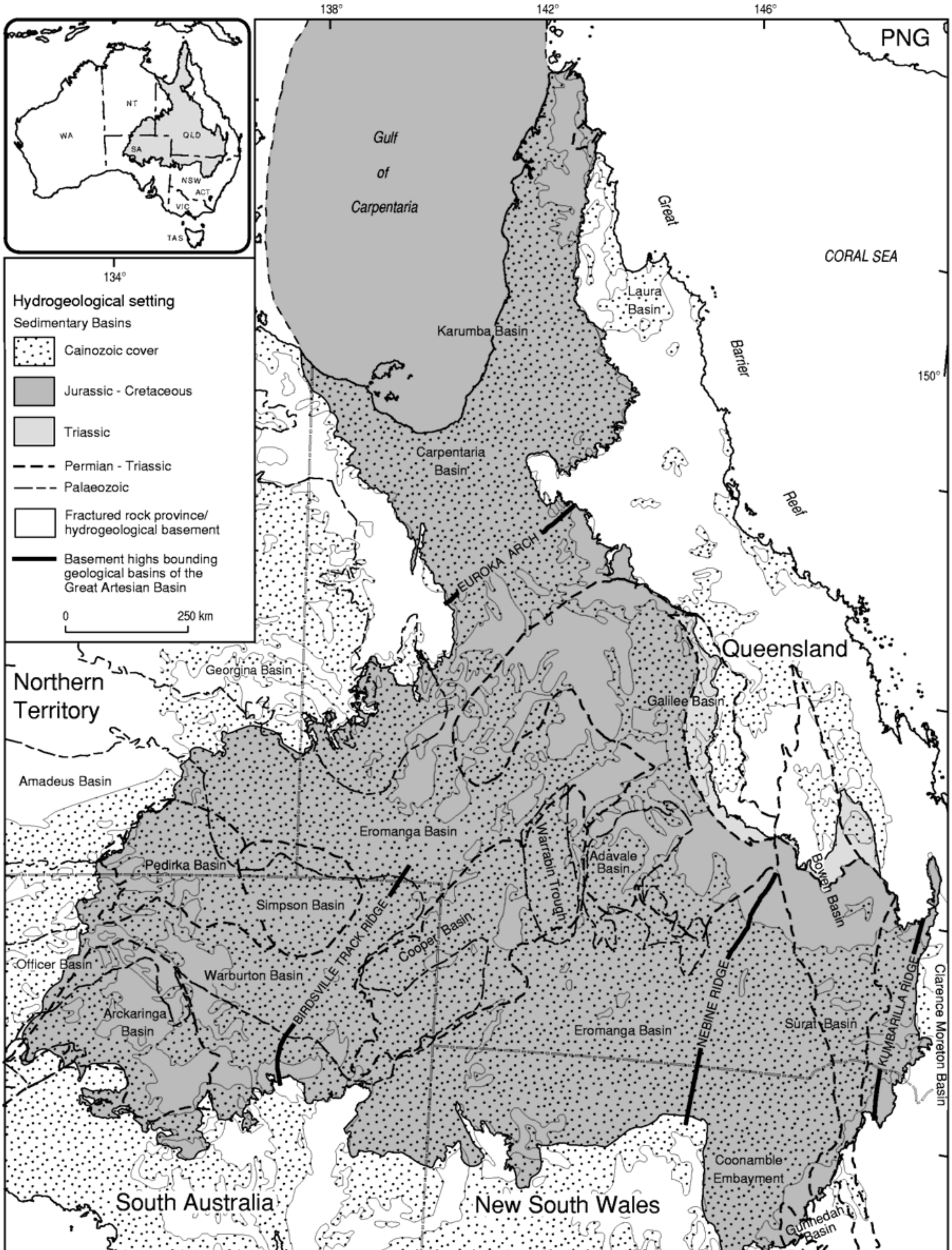

Figure 16 - Constituent sedimentary basins, intermediate ridges, underlying older basins and overlying Cainozoic sediments in the Great Artesian Basin area (after Habermehl, 1980a and Habermehl & Lau, 1997)

The stratigraphic succession in the Great Artesian Basin is given in Habermehl (1980a, 1986, Habermehl & Lau, 1997, Habermehl, 2001a, b) and Figure 18, and shows the distribution and correlation of the rock units of Middle Triassic to Late Cretaceous ages and the hydrogeological units in the constituent sedimentary basins (see also Figure 7). The Jurassic sequence comprises continental deposited quartzose sandstones, with siltstone and mudstone interbeds. Siltstone, mudstone and lithic sandstone were deposited in shallow marine environments during Early Cretaceous times. During the Late Cretaceous more sandy sediments were laid down in lacustrine and fluviatile environments.

The Eromanga Basin is deepest where it overlies Palaeozoic and older Mesozoic sedimentary basins. Thinner sequences are present across the shallow ridges and platforms connecting the Eromanga Basin with the Surat and Carpentaria Basins (Figures 16 and 17).
The southeastern parts of the Great Artesian Basin includes the sedimentary Surat Basin, and the Coonamble Embayment, and consist of an alternation of Jurassic continental sandstone, siltstone, mudstone and some coal. The Cretaceous sediments are partly continental, but mainly shallow marine lithic sandstone and mudstone.
The Carpentaria Basin contains continental rocks of Jurassic age, and marine sedimentary rocks of Cretaceous age.
The deeply weathered erosional surface of the Cretaceous sediments in these basins are overlain by Tertiary sediments, which are also partly weathered and silicified, and by mostly unconsolidated Quaternary sediments. The latter overlie parts of the Great Artesian Basin, and are usually up to several tens of metres in thickness, but form shallow basins as much as 150 m deep in some regions. Tertiary basalts cover some areas of Mesozoic rocks in the northeastern, eastern and southeastern parts of the Basin.

Hydrogeology

The confined aquifers of the Great Artesian Basin are bounded by the Rewan Group at the bottom, and the Winton Formation at the top, but the complete rock sequence is not present across the entire Great Artesian Basin (Figures 7, 17 and 18, Habermehl, 1980a, Habermehl & Lau, 1997).
Aquifers are present in the Clematis, Precipice, Boxvale, Hutton, Adori and Hooray Sandstones, and the Cadna-owie Formation and their equivalents, and in the Mackunda and Winton Formations. The geometry of the aquifers has been determined from the drillers and wire-line logs of a large part of the 4700 flowing artesian waterbores and the 20 000 non-flowing artesian waterbores, from the 3500 petroleum exploration and production wells, and from extensive seismic lines in the Basin. Most of the individual aquifers are relatively spatially uniform in their hydrogeological characteristics, and they are continuous and hydraulically connected across the constituent geological basins.
The major confining beds consist of the Rewan Group, Moolayember, Evergreen, Birkhead, Westbourne, Wallumbilla and Toolebuc Formations, and their equivalents, and the Allaru Mudstone, and parts of the Mackunda and Winton Formations.
The hydrogeological basement comprises impervious Mesozoic, Palaeozoic and Proterozoic sedimentary, metamorphic or igneous rocks, and this basement forms in part an aquiclude or aquifuge.

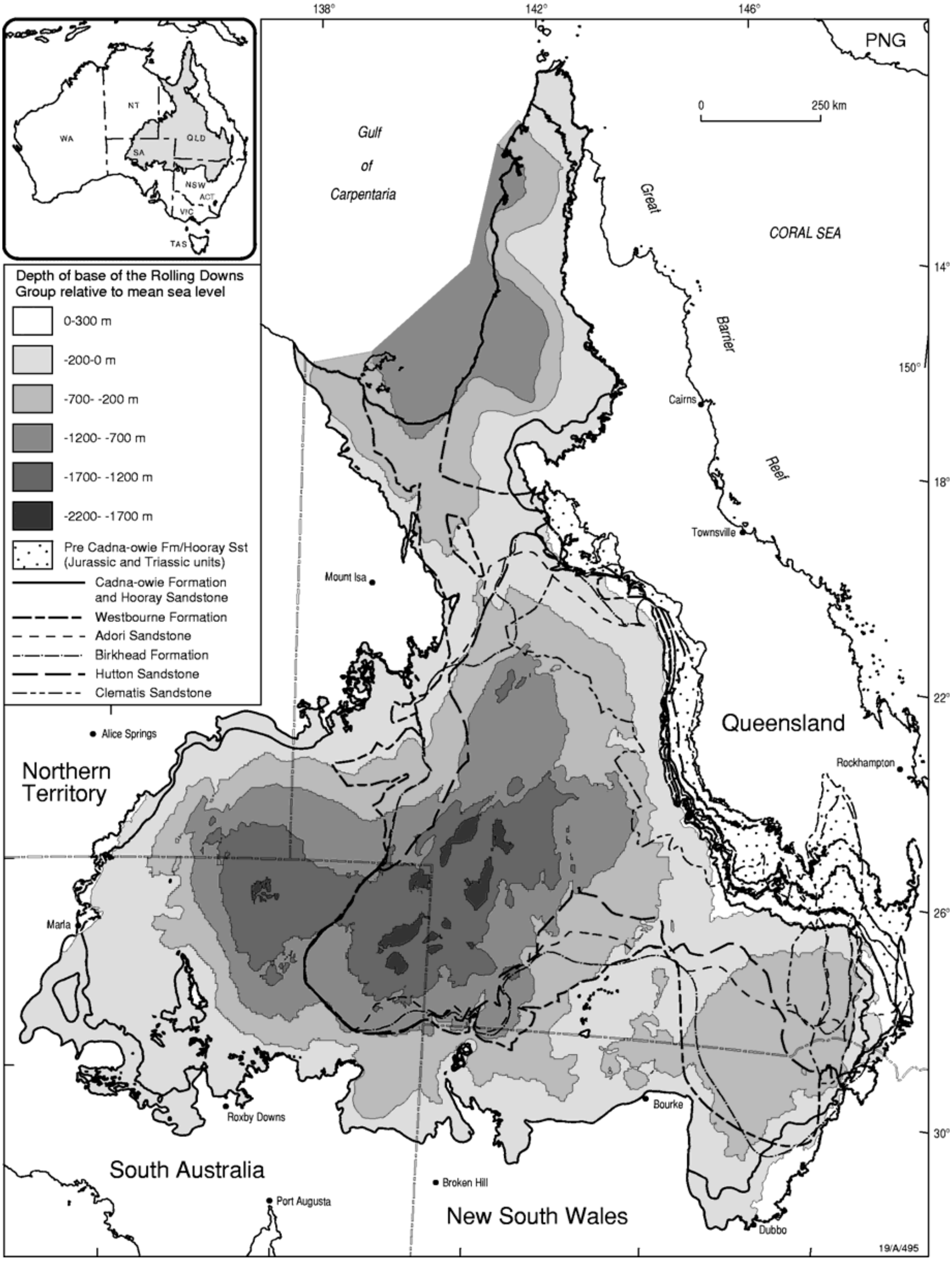

Figure 17 - Structure contour map (elevation map of the top) of the Cadna-owie Formation (the top of the main artesian aquifer sequence), and boundaries of the main aquifers and confining beds in the Great Artesian Basin (after Habermehl, 1980a, Habermehl & Lau, 1997)

Wire-line log use in geology and hydrogeology

The wire-line logs obtained from waterbores in the Great Artesian Basin as part of the Great Artesian Basin Wire-line Logging Program have been extensively used, in particular the natural gamma-ray logs, to define and correlate lithostratigraphic units in the Great Artesian Basin, and to delineate and correlate aquifers as part of the geological mapping during the 1960s and 1970s and the hydrogeological studies during the 1970s, 1980s and 1990s (Figure 19A and B).
Figure 19A shows a cross-section through several waterbores (their location is shown in Figure 23), and the correlation of lithostratigraphic units in those bores based on the natural gamma-ray logs. Figure 19B shows the same waterbores and cross-section, with the main sandstone beds (aquifers) and their correlation, based on the interpretation of natural gamma-ray logs. The waterbore RN 2049 shown in Figure 19 - natural gamma-ray log comprises the type section of the Wyandra Sandstone Member of Cadna-owie Formation in the Eromanga Basin - Great Artesian Basin.

Exon (1976), Exon & Senior (1976), Senior & others (1975), Senior & others (1978), Smart & others (1980), Burger & Senior (1979) and Burger (1989), and the author extensively used the BMR (AGSO) wire-line logs of the waterbores to delineate and correlate the lithostratigraphic units in the Surat, Eromanga and Carpentaria Basins. These authors show BMR (AGSO) wire-line logs and log interpretations, including tops and bottoms of geological formations and cross-sections based on the correlations and interpretations of wire-line logs from waterbores in the Great Artesian Basin. Andrews & Leys (1984) used geophysical logs obtained from non-flowing artesian waterbores by BMR (AGSO) and from flowing artesian waterbores by the New South Wales Geological Survey to identify and correlate lithostratigraphic units in the New South Wales part of the Great Artesian Basin. Natural gamma-ray logs and cross-sections based on these logs are shown by these authors. Muller (1989a, b) and Quarantotto (1986, 1989) also used the BMR (AGSO) wire-line logs to determine the lithostratigraphy in the boreholes, and to identify the aquifers being tapped by the waterbores in the Eromanga Basin and Surat Basin parts of the Great Artesian Basin in Queensland.
Green & others (1989a, b) show correlations and interpretations of wire-line logs from petroleum exploration wells in the central Eromanga Basin in southwestern Queensland, including tops and bottoms of geological formations and cross-sections.
Alexander & Hibburt (1996) show logs from petroleum exploration wells in the Eromanga Basin in South Australia. The detailed geological and geophysical logs from the petroleum exploration wells can be correlated with the wire-line logs from waterbores in the Great Artesian Basin, and produce a dense network of boreholes with good controlled lithostratigraphic and hydrogeological units.

The logs obtained from the flowing and non-flowing artesian waterbores in the Great Artesian Basin show part or all of the Cretaceous Rolling Downs Group sedimentary sequence and part of the underlying Lower Cretaceous - Jurassic sedimentary sequence (Figures 18 and 19).
The majority of the waterbores logged have been completed in the upper parts of the Lower Cretaceous - Jurassic sedimentary sequence, including the aquifer sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone. The large number of wire-line logs from waterbores which contain the significant boundary between the Lower Cretaceous mudstones of the Rolling Downs Group - Wallumbilla Formation - Doncaster Member and the equivalent Bulldog Shale, with the underlying Lower Cretaceous

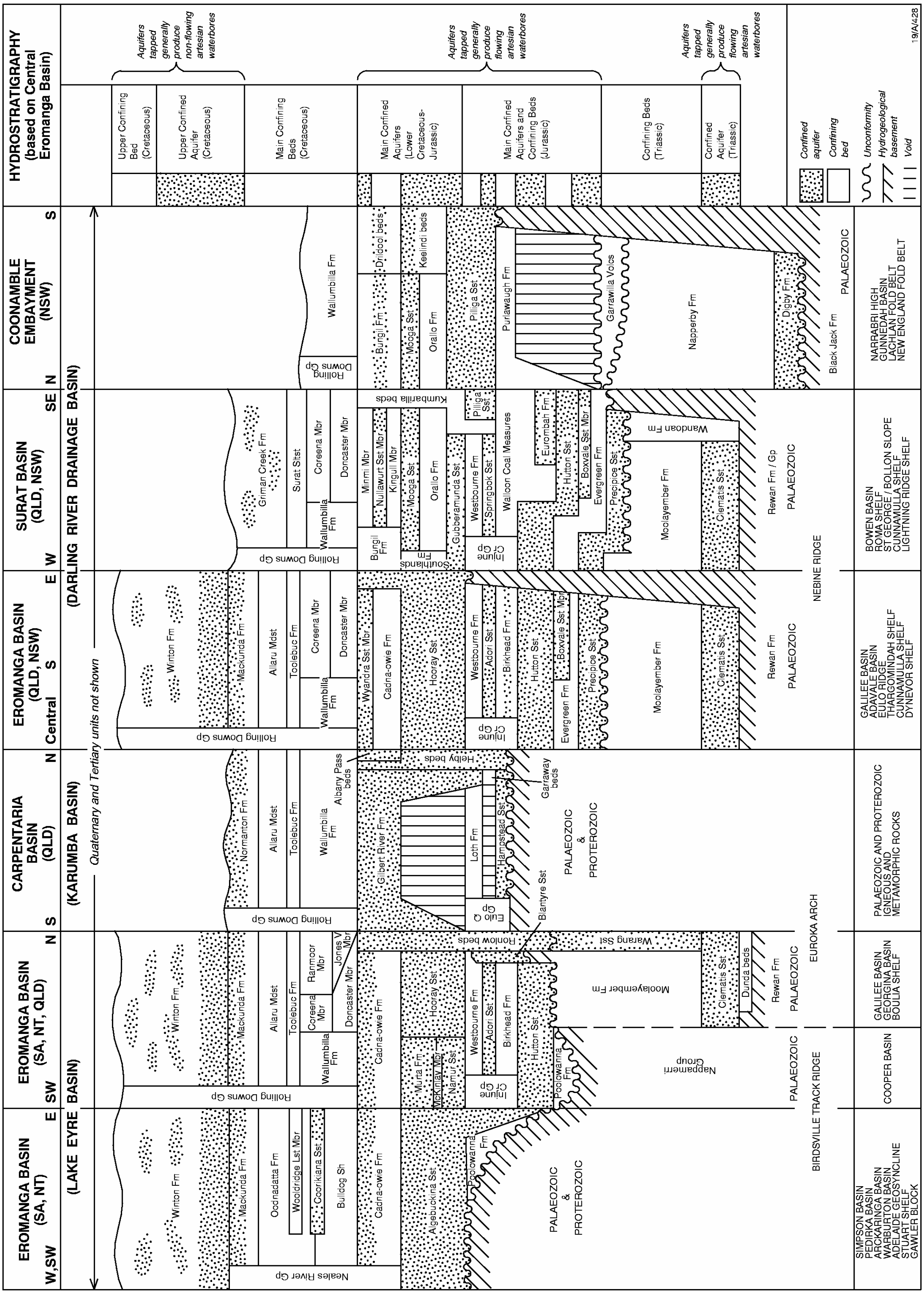

Figure 18 - Relationship between the geological and hydrogeological units in the constituent sedimentary basins of the Great Artesian Basin (after Habermehl, 1980a and Habermehl & Lau, 1997)

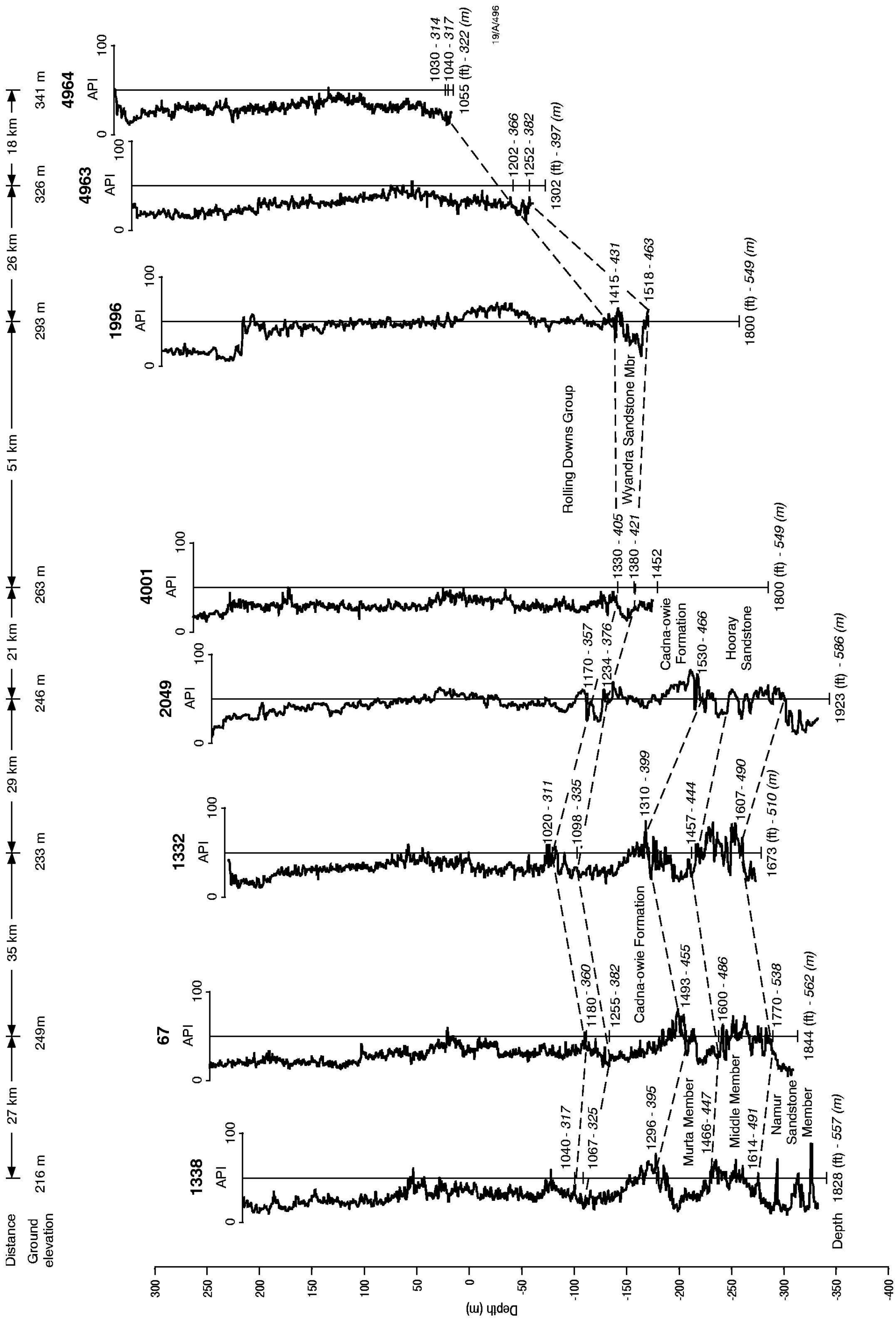

Figure 19 A - Correlation of natural gamma-ray logs from waterbores (Queensland) RN 1338 - 67 - 1332 - 2049 - 4001 - 1996 - 4963 - 4964 and the lithostratigraphic units in those waterbores in the Great Artesian Basin (locations of the waterbores in Figure 23)

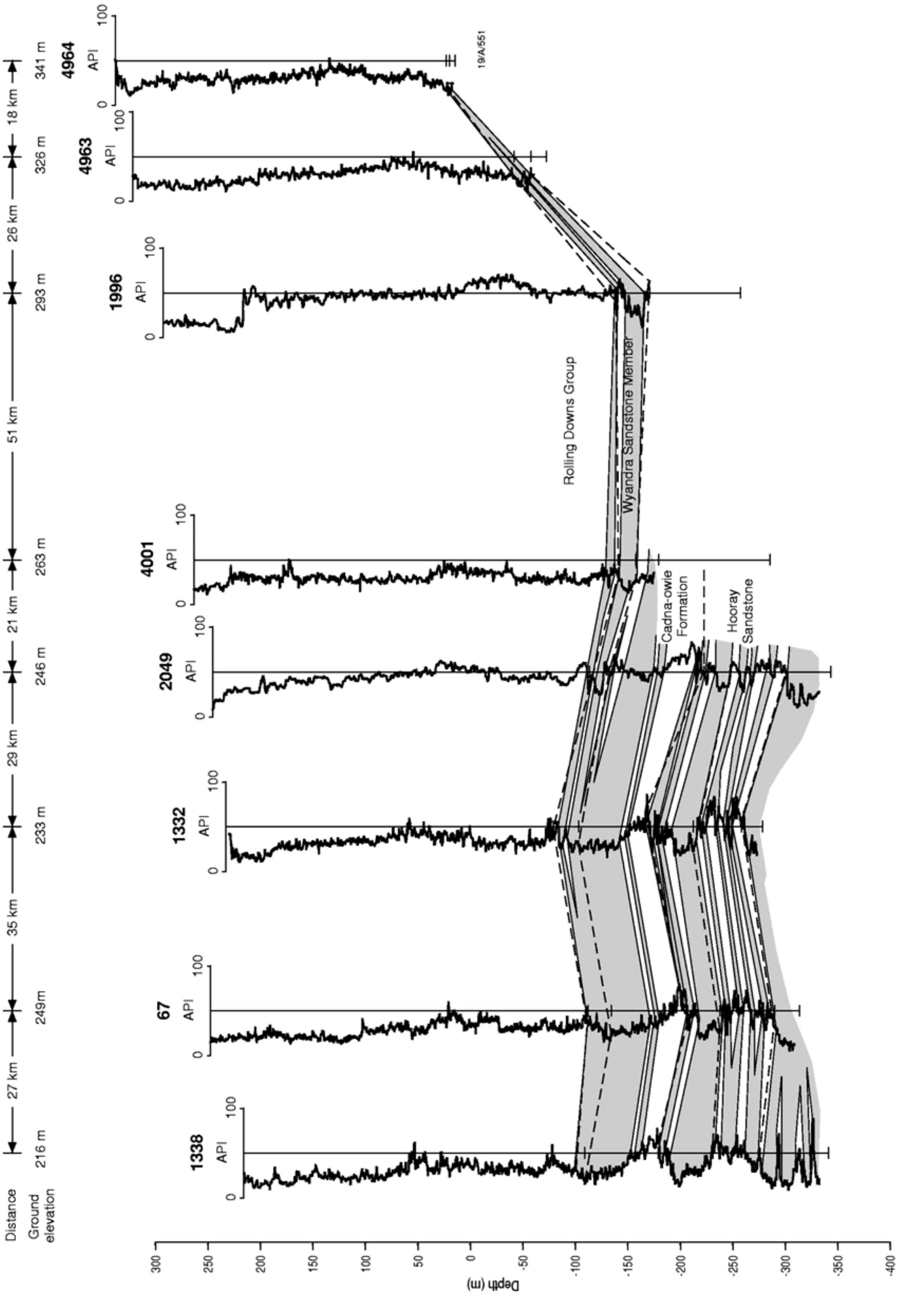

Figure 19 B - Correlation of natural gamma-ray logs from waterbores (Queensland) RN 1338 - 67 - 1332 - 2049 - 4001 - 1996 - 4963 - 4964 and the main sandstone beds (aquifers) in those waterbores in the Great Artesian Basin

- Jurassic sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone, enabled a good interpretation of this important horizon, and the preparation of a high quality structure contour map of the base of the Rolling Downs horizon (Figure 17, Habermehl, 1980a, Habermehl & Lau, 1997, Habermehl, 2001a, b).
This structure contour map of the base of the Rolling Downs Group or the top of the underlying Lower Cretaceous - Jurassic sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone is an important map, as it shows the depths to the top of the main artesian aquifer sequence in the Great Artesian Basin (Figure 17). Waterbores tapping aquifers below this boundary generally result in flowing artesian waterbores in the Great Artesian Basin.
The aquifers in the Lower Cretaceous - Jurassic sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone provide most flowing artesian waterbores in the Great Artesian Basin with their artesian groundwater supplies. Deeper aquifers in older, lower lithostratigraphic units in the Jurassic and in the Triassic are encountered in waterbores in some areas near the eastern and northeastern margin of the Basin, and logs from a larger part of the sedimentary sequence were obtained from waterbores in those areas.
Deep waterbores, penetrating the maximum number of lithostratigraphic units were selected for geophysical logging during the planning and operational stages of the BMR wire-line logging program during the period 1960 to 1975.

The number of geophysical logs greatly increased with the availability of wire-line logs from petroleum exploration and production wells drilled in the Great Artesian Basin area since the early 1960s. Nearly all petroleum drill-holes fully penetrate the Great Artesian Basin sedimentary sequence. The detailed geological descriptions of the petroleum drill-holes and the information from the geophysical logs of these holes, as well as the results of tests and measurements carried out in the petroleum drill-holes, and the associated seismic data from seismic lines across the drill-site regions, are particularly useful for geological and hydrogeological interpretations. Most of the flowing artesian waterbores were completed in the upper parts of the main artesian aquifers (Cadna-owie Formation and Hooray Sandstone and equivalents), and therefore, even in the case of the deep waterbores, usually only penetrate a small part of the Lower Cretaceous - Jurassic sedimentary sequence. Non-flowing artesian waterbores usually were completed in the Winton and Mackunda Formations (and their equivalents).
Wire-line logs and geological logs from petroleum exploration wells are included in the well completion reports of petroleum exploration wells, and many of the wells drilled during the 1960s and early 1970s are included in the Petroleum Search Subsidy Acts Publication Series published by BMR. Information on these and other petroleum exploration and production wells, including those drilled during the late 1970s, 1980s and 1990s are available in Commonwealth Databases eg. PEDIN (AGSO and the Bureau of Resource Sciences) and State Petroleum Databases within the State Geological Surveys and/or State Mines Departments of Queensland, New South Wales, South Australia and the Northern Territory.

Structure contour and isopach maps of the lithostratigraphic units between the upper surface of the Winton Formation and the base of the Rolling Downs Group (or top of the Lower Cretaceous - Jurassic sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone) have been prepared from data interpreted from wire-line logs of waterbores and information from petroleum wells. The large number of datapoints in some areas

ensure that these maps are quite reliable. The number of waterbores with wire-line logs which intersect parts of the sedimentary sequence below the Lower Cretaceous - Jurassic sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone is limited, and provide only a limited number of datapoints. In most areas of the Great Artesian Basin reliable information on the (lower) Jurassic and Triassic parts of the sedimentary sequence has to be obtained from petroleum wells and seismic data. As a result, the geometry of the lithostratigraphic units in the Jurassic sequence is less well known, and maps showing the regional relationships of these units are only interpretative in some areas.
The interpretation of drillers logs is difficult in some areas and some of these logs are unreliable. If the drillers logs are the only sources of information used for the identification and correlation of lithostratigraphic units in some parts of the Great Artesian Basin, then the reliability of the results are usually less than the results obtained from the interpretation of geophysical logs.

Structure contour maps of the whole of the Great Artesian Basin at scale 1 : 1 000 000 have been prepared by Dr B.R. Senior & Associates Pty Ltd during the 1990s under contract to AGSO as part of the AGSO Hydrogeological Study of the Great Artesian Basin. The maps comprise data from waterbores, petroleum wells, seismic data and other information in the Basin and were used to prepare a detailed geometry model for the GABMOD computer based groundwater simulation model, for the following formation tops (Habermehl, 1995):

- Top of the Winton & Griman Creek Formations and equivalents
- Top of the Allaru Mudstone and equivalents
- Base of the Rolling Downs Group
- Top of the Injune Creek Group, Westbourne Formation and equivalents
- Top of the Adori Sandstone and equivalents
- Top of the Birkhead Formation and equivalents
- Top of the Hutton Sandstone and equivalents
- Top of the Moolayember, Nappamerri and Wandoan Formations
- Top of the Clematis Group, Warang Sandstone and equivalents
- Base of the hydrogeological Great Artesian Basin

The structure contour maps of the lithostratigraphic units are horizons of geological and hydrogeological entities, and though the rock units are not necessarily time equivalents, and are not always in direct continuity, they represent the most continuous aquifers and aquicludes in the Basin, and they exhibit similar, basin-wide, hydraulic and structural characteristics.

The seventy maps, which cover the 10 stratigraphic levels shown above, were prepared at scale 1 : 1 000 000 to cover the whole of the Great Artesian Basin. These maps show depth contours and fault lines, and were scanned, vectorised, and converted into ARC/INFO GIS coverages and form the basic geometry framework for the hydrogeological studies of the Great Artesian Basin.
Data in the most southwestern part of the Basin is sparse, and the stratigraphy of that area is less well defined.

Groundwater temperatures

Groundwater surface temperatures of waterbores tapping aquifers in the Lower Cretaceous-Jurassic sequence generally range from about 30^0 to 100^0 C, and springs have temperatures from about 20^0 to 45^0 C, with the highest temperatures having been measured in the Dalhousie Springs group in northern South Australia.

The high temperature of the artesian groundwater from flowing artesian waterbores requires cooling of the water before use, a disadvantage for most homesteads and town water supplies, and for pastoral use. The high temperatures of the groundwater in the Great Artesian Basin represents a geothermal resource, which has not yet been exploited, though some isolated geothermal energy projects have been run for short periods of time at Mulka Station along the Birdsville Track in South Australia during the 1980s, and at Birdsville, Queensland.

Figure 20 shows the temperatures of the groundwater from waterbores in the Great Artesian Basin, ie. the temperature of the groundwater at the surface outlet of the waterbore, or the bottom-hole temperature of the temperature log.

In general, a clear correlation exists between the temperature of the groundwater in the aquifers, and the depths of the aquifers. Figure 20 shows that the shallow parts of the Basin near the margins, contain relatively cool water with temperatures up to 40^0C. The regions of intermediate depths have temperatures between 40^0 and 60^0C, and the deeper parts of the Basin show higher temperatures between 60^0 and 100^0C (Figure 17).

Figure 21 shows a geothermal gradient surface, with the geothermal gradients calculated (by T. Ransley) from temperature log data obtained from waterbores in the Great Artesian Basin. The geothermal gradient map shown in Figure 21 indicates low geothermal gradients in the eastern and southeastern basin marginal areas, and in most parts of the Surat Basin, and in the southwestern part of the Eromanga Basin within the Great Artesian Basin. Higher geothermal gradients occur in the south-central, northwestern and northern parts of the Basin. Very high geothermal gradient values are present in several isolated ares in the southwestern, south-central and northern areas of the Basin, and coincide with the location of flowing artesian springs.

Polak & Horsfall (1979) provided an interpretation of the temperature logs and the data derived from those logs, and interpreted geothermal gradients in the Great Artesian Basin. The geothermal gradients calculated by these authors from the BMR Great Artesian Basin temperature wire-line logs have values ranging from 15.4 ^{0}C/km to 102.6 ^{0}C/km, and have a mean of 48 ^{0}C/km. More than 75 percent of these values exceed the world representative average value of 33 ^{0}C/km, which suggests that the Great Artesian Basin is an area of higher than normal geothermal gradients (Polak & Horsfall, 1979).

Cull & Conley (1983) used several different assumptions on the groundwater data, aquifer models and temperature corrections, and determined a mean geothermal gradient of 38.6 (± 0.1) ^{0}C/km, which is closer to the world average of 33 ^{0}C/km than the results of Polak & Horsfall (1979).

Estimates of the heat flow from the Great Artesian Basin are consistent with the configuration of the major aquifer systems, with low values of heat flow observed along the recharge areas in the eastern part, and corresponding high values in the western, discharge areas of the Basin. Anomalies in other areas might be generated by vertical groundwater flow along geological faults and near basement structures (Habermehl, 1980a, Cull & Conley, 1983).

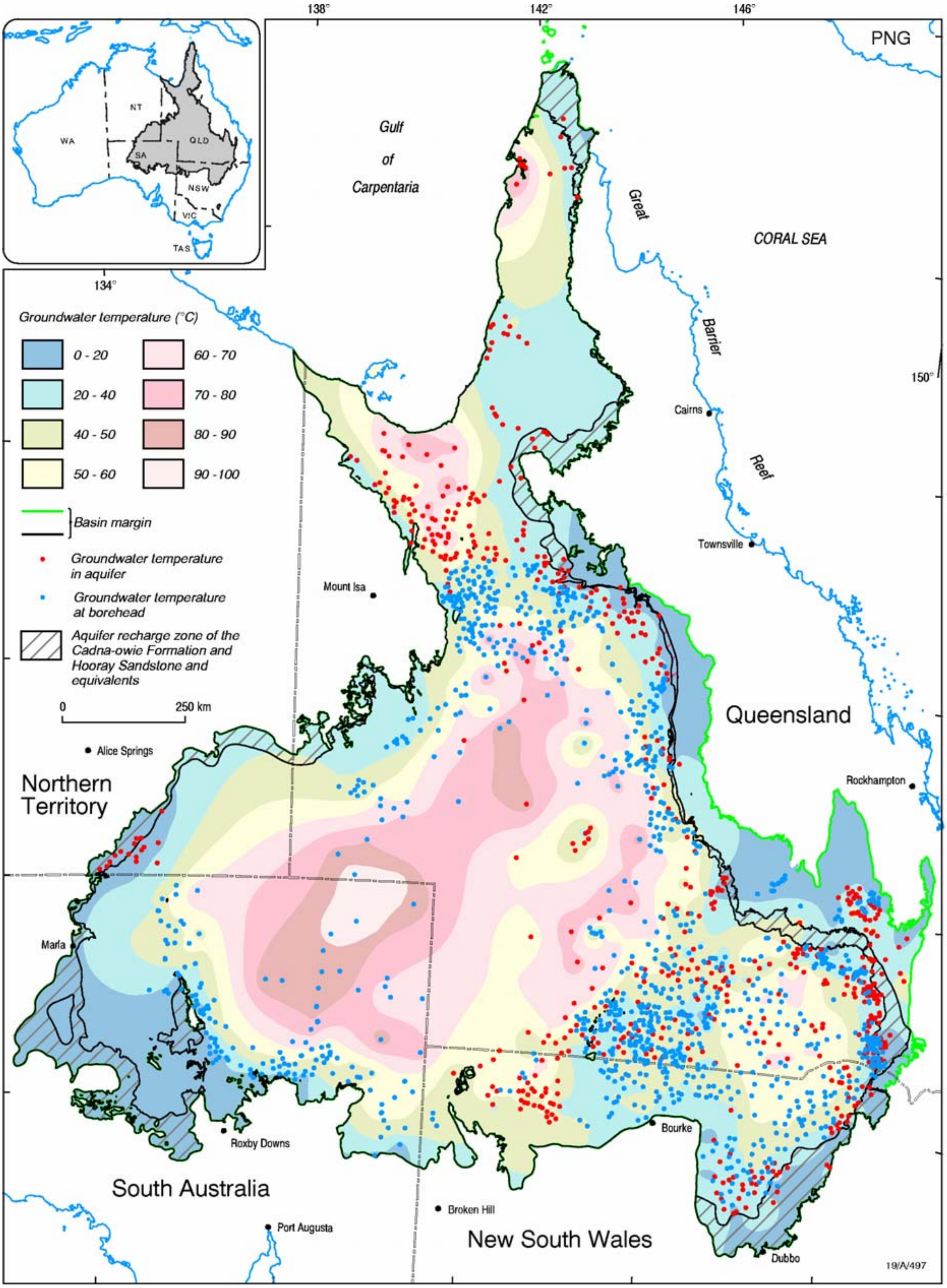

Figure 20 – Groundwater temperatures obtained from waterbores in the Great Artesian Basin

Cull & Conley (1983) made a comparison between the temperature data from waterbores and petroleum exploration wells, and concluded that temperature data from petroleum wells appear to be of similar quality to those obtained from waterbores in the Great Artesian Basin, and that the calculations of error in the average gradient are similar, even though the depth range is greatly extended. Actual gradients appear to be slightly less than those indicated by the waterbore data, but the intercept is slightly greater. Waterbore values for the geothermal gradients, though internally consistent, are too high, based on data from deeper petroleum exploration wells in the central part of the Basin (Cull & Conley, 1983).
Geothermal gradients derived from petroleum exploration wells in the central part of the Great Artesian Basin, in northeastern South Australia and southwestern Queensland, ie. the Cooper-Eromanga Basin region, are given in Pitt (1986).
Torgersen & others (1992) attributed the heat flow in the Basin to heat produced in the earth's crust by uranium and thorium, and by recent volcanic activity.

Great Artesian Basin Bore Rehabilitation Program

The Great Artesian Bore Rehabilitation Program is a joint initiative of the Commonwealth and State Governments, carried out by the State Government Authorities of Queensland, New South Wales and South Australia. The Program commenced in 1989, though in South Australia rehabilitation of uncontrolled waterbores has already been underway since 1977 (Reyenga & others, 1998). The Great Artesian Bore Rehabilitation Program was followed by the Great Artesian Basin Sustainability Initiative, a Commonwealth Government commitment to provide $ 31.8 million over 5 years from 1999 to accelerate bore rehabilitation and drain replacement programs in the Great Artesian Basin in the interests of partial recovery of artesian pressures in strategic areas of the Basin.
The Great Artesian Bore Rehabilitation Program and the subsequent the Great Artesian Basin Sustainability Initiative aim to rehabilitate flowing artesian waterbores in order to eliminate or at least reduce the large number of uncontrolled flowing artesian waterbores and reduce the wastage of artesian groundwater. Better management of the artesian groundwater resources is seen as the final outcome once all waterbores are fully controlled. However, most of the wastage of the artesian groundwater by the pastoral industry could largely be eliminated by a changeover from the open earth drain distribution system to fully controlled waterbores equipped with piped distribution systems, connected to valve controlled tanks and troughs.
The rehabilitation or reconditioning of the artesian waterbores involves the installation of proper headworks, including control valves or the repair and/or the replacement of the corroded headworks. The repair or replacement of broken or corroded borehole casings is also included in the Program. As a result of these activities and measures, which will lead to reduced extraction rates, the pressures in the artesian groundwater system are expected to increase or be partially restored, and the Basin-wide diminution in artesian pressures reduced (Cox & Barron, 1998). The circumstances of the reconditioning of the waterbores vary considerably. In some cases the work is very difficult and expensive. Under these circumstances consideration may be given to closing the waterbore off with cement and drilling a new bore. However, a new bore will not be considered if the old bore cannot be plugged.
The existence of a relatively dense network of wire-line logged waterbores is useful for the Great Artesian Basin Bore Rehabilitation Program and the Great Artesian Basin Sustainability Initiative, in particular for the identification and correlation of the aquifers and the definition of

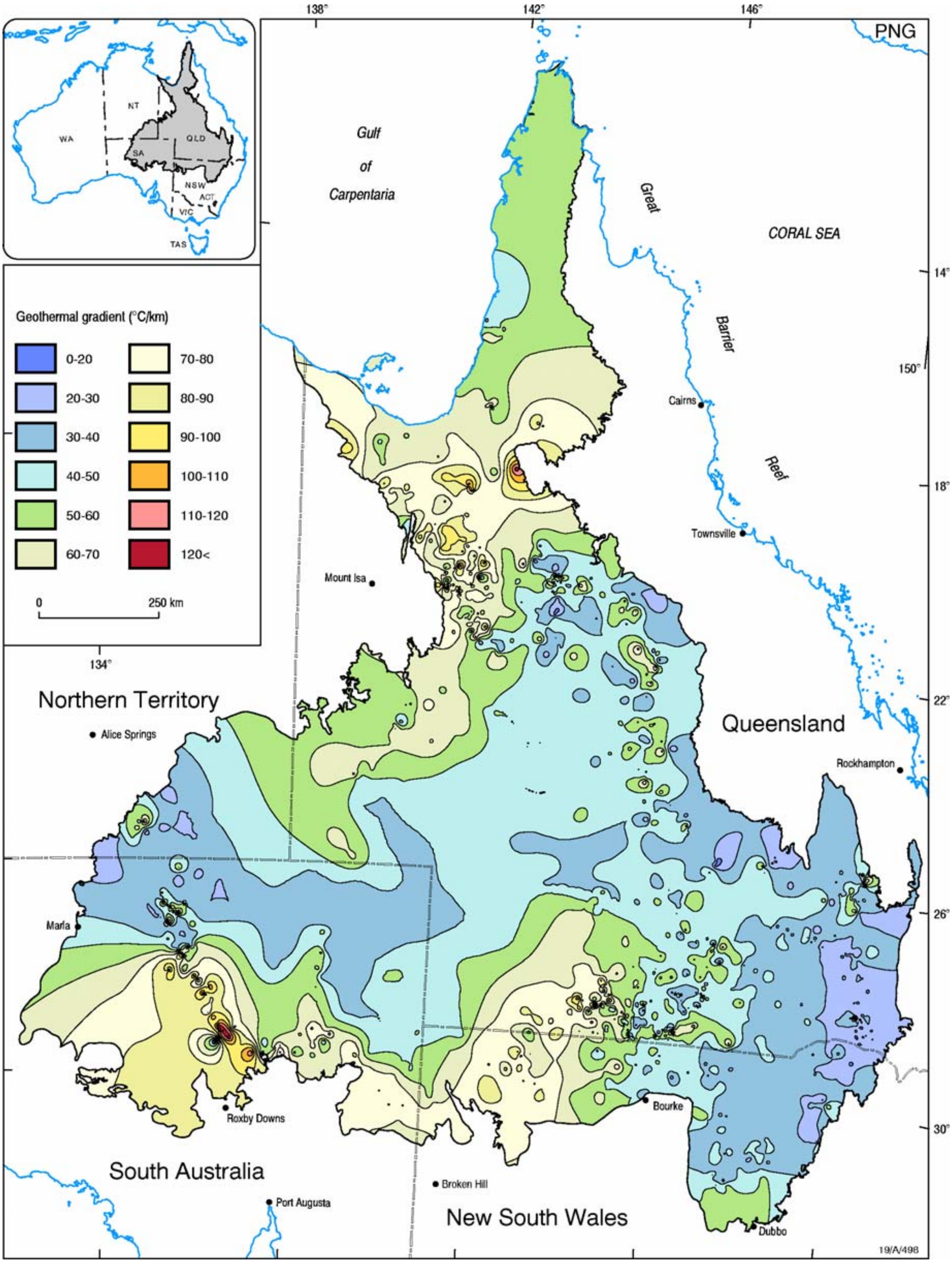

Figure 21 – Geothermal gradients obtained from waterbores in the Great Artesian Basin

the downhole characteristics of the waterbores.

A good understanding of the aquifer geometry, groundwater hydraulics, including groundwater pressures and discharges are essential for the activities of the Great Artesian Basin Bore Rehabilitation Program and the Great Artesian Basin Sustainability Initiative, and the priority selection of areas and specific waterbores to be rehabilitated.

The planning of rehabilitation of waterbores in the Great Artesian Basin is aided by the existence of wire-line logs from waterbores in the areas to be considered.

The existence of wire-line logs for the waterbores to be included in the Great Artesian Basin Bore Rehabilitation Program and the Great Artesian Basin Sustainability Initiative is an advantage, as the logs provide reliable information on the downhole conditions. The gamma-ray log provides detailed information about the lithostratigraphic units in the borehole and the depths and thicknesses of the aquifers. The temperature, differential temperature, caliper and flowmeter logs give information on the inflow of artesian groundwater from the aquifer into the borehole. The casing collar locator logs can be interpreted to show the amount of corrosion of the casing at the time of logging. The identification and correlation of aquifers from the wire-line logs across areas in which borehole are to be rehabilitated assists the planning for rehabilitation and/or the drilling of new waterbores.

As part of the Great Artesian Basin Bore Rehabilitation Program and the Great Artesian Basin Sustainability Initiative, the State Water Authorities run wire-line logs in nearly all of the waterbores to be rehabilitated during the later stages of the planning phases of the Program.

The Great Artesian Basin Strategic Management Plan was published by the Great Artesian Basin Consultative Council in September 2000, and provides a strategic framework for responsible groundwater and related natural resource management in the Great Artesian Basin as a whole. Earlier, the Great Artesian Basin Consultative Council published a Great Artesian Basin Resource Study (Cox & Barron, 1998).

Summary

The wire-line logs acquired by BMR (AGSO) from about 1250 waterbores in the Queensland, New South Wales and Northern Territory parts of Great Artesian Basin during the 1960s and 1970s comprise natural gamma-ray, neutron-gamma, temperature, differential temperature, flowmeter, caliper, spontaneous potential, resistivity and casing collar locator logs.
The wire-line logs have been extensively used, in particular the natural gamma-ray logs, to define and correlate lithostratigraphic units in the Great Artesian Basin, and to delineate and correlate aquifers as part of the geological mapping during the 1960s and 1970s and the hydrogeological studies during the 1970s, 1980s and 1990s. Other applications, including both quantitative and qualitative interpretations of the logs are possible, and make the set of geophysical logs a valuable data set, particularly because of the time independent nature of most of the logs.
Most of the logs obtained from the flowing and non-flowing artesian waterbores in the Great Artesian Basin show part or all of the Cretaceous Rolling Downs Group sedimentary sequence and part of the underlying Lower Cretaceous - Jurassic sedimentary sequence. Almost all of the waterbores logged have been completed in the upper parts of the Lower Cretaceous - Jurassic sedimentary sequence, including the aquifer sandstones of the Cadna-owie Formation, Hooray Sandstone, Pilliga Sandstone and Algebuckina Sandstone.
Most waterbores in the Great Artesian Basin obtain their artesian groundwater supplies from these aquifers. Deeper aquifers in lower lithostratigraphic units in the Jurassic and in the Triassic are encountered in waterbores near the eastern and northeastern margin of the Basin, and logs obtained from those bores show a larger part of the sedimentary sequence.
The planning and operation of the logging program were directed at selecting as many deep waterbores as possible, and inclusion of waterbores penetrating the maximum number of lithostratigraphic units.

Most of the wire-line logs acquired by BMR (now AGSO) during the logging program in the Great Artesian Basin in the 1960s and 1970s show time independent data, including the natural gamma-ray, neutron-gamma-ray, spontaneous potential and resistivity logs, from which geological and hydrogeological information can be interpreted. Other logs, including the temperature, differential temperature, flowmeter, caliper and casing collar locator logs are time dependent, as information obtained from these logs will change with the age and the different conditions of the waterbore during its lifetime. The casing collar locator logs for instance can be interpreted to show the amount of corrosion of the waterbore casing at the time of logging.

The wire-line logs acquired as part of the logging program were all in analog form, as ink traces on transparent paper (film) at scales 1 inch to 100 feet (1 : 1200) and at a scale of 1 inch to 20 feet (1 : 240). A complete set of originals and duplicate paper print copies has been held in BMR (now AGSO) for storage, retrieval and access purposes, and for duplication and work purposes, and a set of paper print copies in BRS since 1998.
Access, retrieval, copying and storage of the large number of paper (film) based logs, and the preparation and processing of log data, has been difficult and therefore restricted. The

availability of the combination of log digitising software and Personal Computers (PCs) since the late 1980s provided the opportunity to convert the logs into digital data, and greatly improve the access and data analysis and interpretation, and also enhance the storage and distribution of the datasets.

Digitising of the analog wire-logs at scale 1 inch : 100 feet (1 : 1200) commenced early in 1991, using PC-based semi-automatic (oil) well log digitising software. The natural gamma-ray logs, which are present for all waterbores logged, were completed in early 1992, and all neutron-gamma-ray logs, and any available temperature, flowmeter, caliper, spontaneous potential and resistivity logs for the waterbores were digitised and a total of 3875 logs were completed by 1993/4. The casing collar locator logs could not be digitised for technical reasons, and are not included in the digital dataset of the logs.
The digital dataset of the logs and data on the types of logs acquired by BMR (now AGSO) from 1235 waterbores in the Great Artesian Basin Queensland, New South Wales and the Northern Territory during the period 1960 to 1975 is included on a CD-ROM in the back of this report.
Figure 22 shows a comparison of the analog natural gamma-ray logs and the digitised version of the natural gamma-ray logs obtained from the same waterbore in the Great Artesian Basin in 1967 and 1975. The two log sets are very comparable, and the same amount of detail is visible in the digitised log as in the original log.

Figure 22A shows the original analog copy of the natural gamma-ray log (a), obtained from the waterbore RN 1338 in Queensland in 1967, and the digitised version of this log (b).
Figure 22B shows the original analog copy of the natural gamma-ray log (c), obtained from the waterbore RN 1338 in Queensland in 1975, and the digitised version of this log (d).
Figure 22C shows a compilation of the original 1967 analog copy of the natural gamma-ray log (a), the digitised version of this log (b), the original 1975 analog copy of the natural gamma-ray log (c), and the digitised version of this log (d) obtained from the waterbore RN 1338 in the Queensland part of the Great Artesian Basin (the waterbore location is shown in Figure 23).

There are some minor differences between the 1967 and 1975 logs, though those are largely the result of different logging speed, time constants and sensitivity settings of the logging equipment and different logging tools.
The 1967 log (a) was run at:

> 30 feet per minute, time constant 5 seconds, sensitivity setting 240, 10 API Gamma Ray units per log division.

The 1975 log (c) was run at:

> 30 feet per minute, time constant 2 seconds, sensitivity setting 800, 10 API Gamma Ray units per log division.

Data on the waterbores logged, including the identification, location, elevation, depth and year of completion of the waterbores, the lithostratigraphic units encountered in the waterbores and their depths, and the hydrochemical laboratory analyses results obtained from watersamples taken at the time of logging, showing pH, electrical conductivity, total dissolved solids, alkalinity and the detailed analyses results of 8 or 9 major ions are included in a database on CD-ROM in the back of this report.

A set of 3 maps –

Wire-line logged waterbores in the Great Artesian Basin (logs acquired by AGSO), Maps 1, 2 and 3 at scale 1 : 2 500 000 (Habermehl & others, 1997),

are included in the back of this report, and show the locations of the waterbores from which wire-line logs were acquired by BMR (now AGSO) in the Great Artesian Basin in Queensland, New South Wales and the Northern Territory during the period 1960 to 1975, and the type of logs obtained from each of the 1235 waterbores, as well as the availability of lithostratigraphic and hydrochemistry data for each of the waterbores.

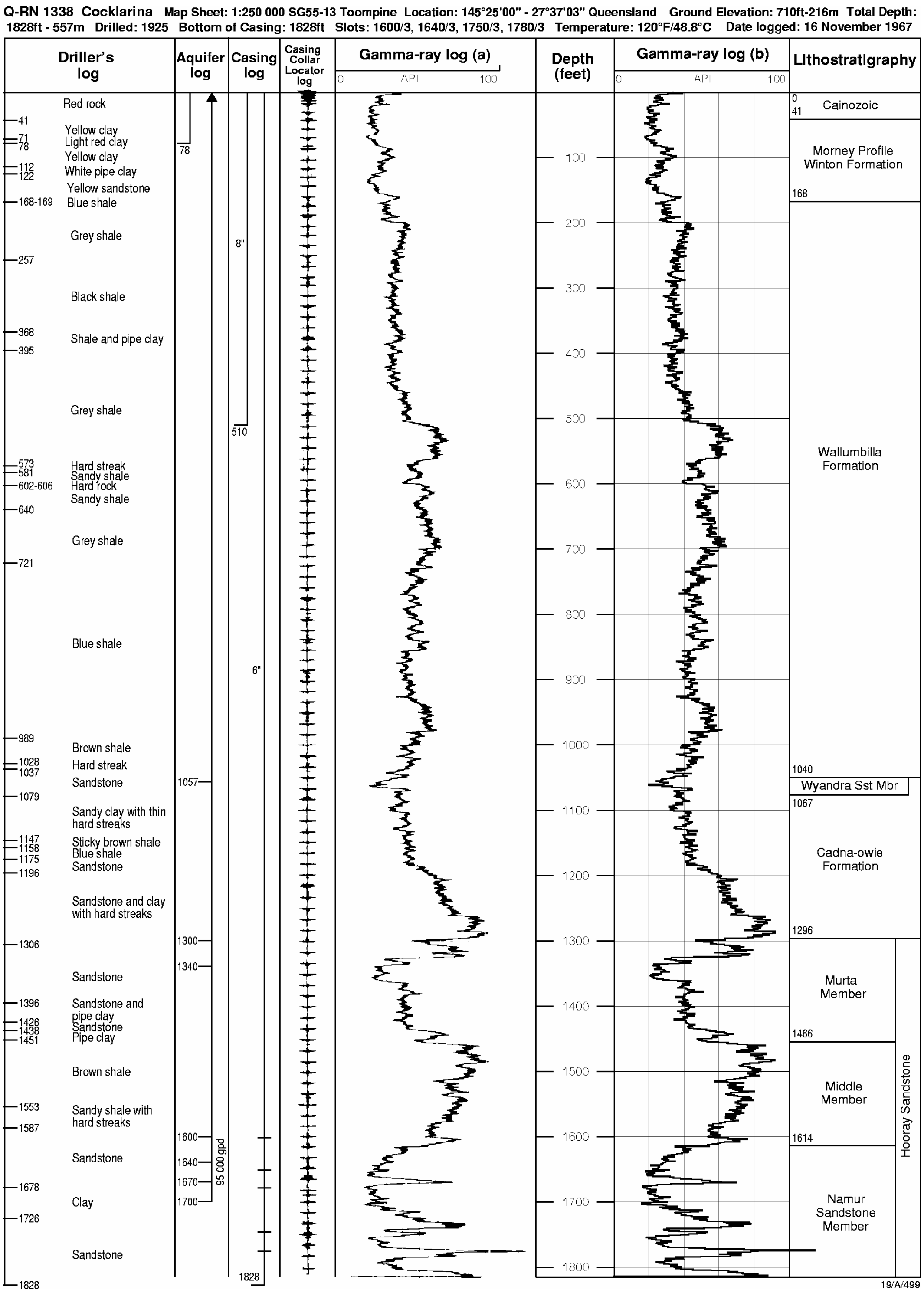

Figure 22 A - Comparison of the analog copy of the natural gamma-ray log and the digital (digitised) copy of the natural gamma-ray log + casing collar locator log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 1338 (Queensland) -

A - natural gamma-ray log of waterbore RN 1338 obtained in 1967, original analog (a), digitised version (b) and casing collar locator log

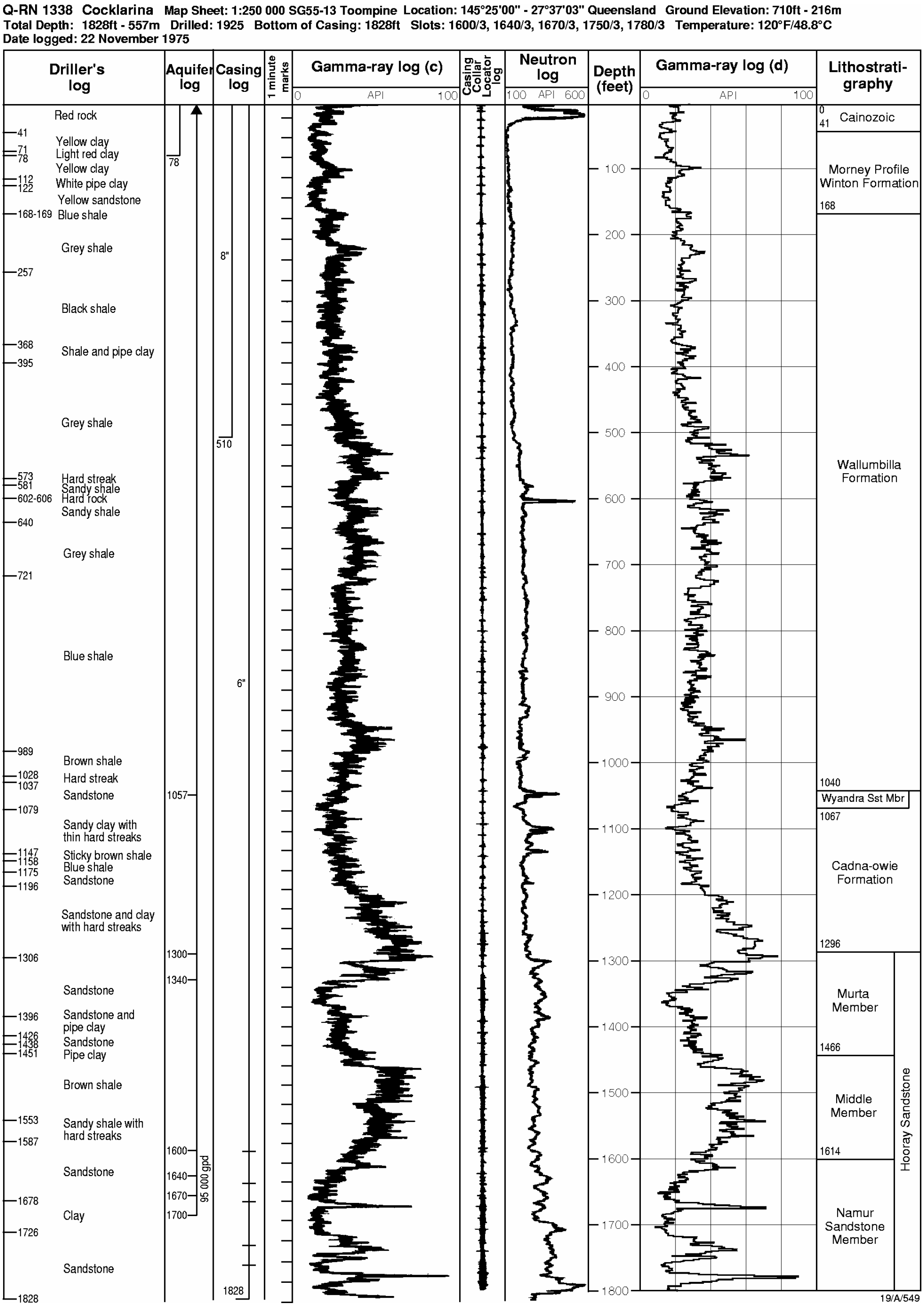

Figure 22 B - Comparison of the analog copy of the natural gamma-ray log and the digital (digitised) copy of the natural gamma-ray log + casing collar locator log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 1338 (Queensland) -

B - natural gamma-ray log of waterbore RN 1338 obtained in 1975, original analog (c) and digitised version (d), neutron log and casing collar locator log

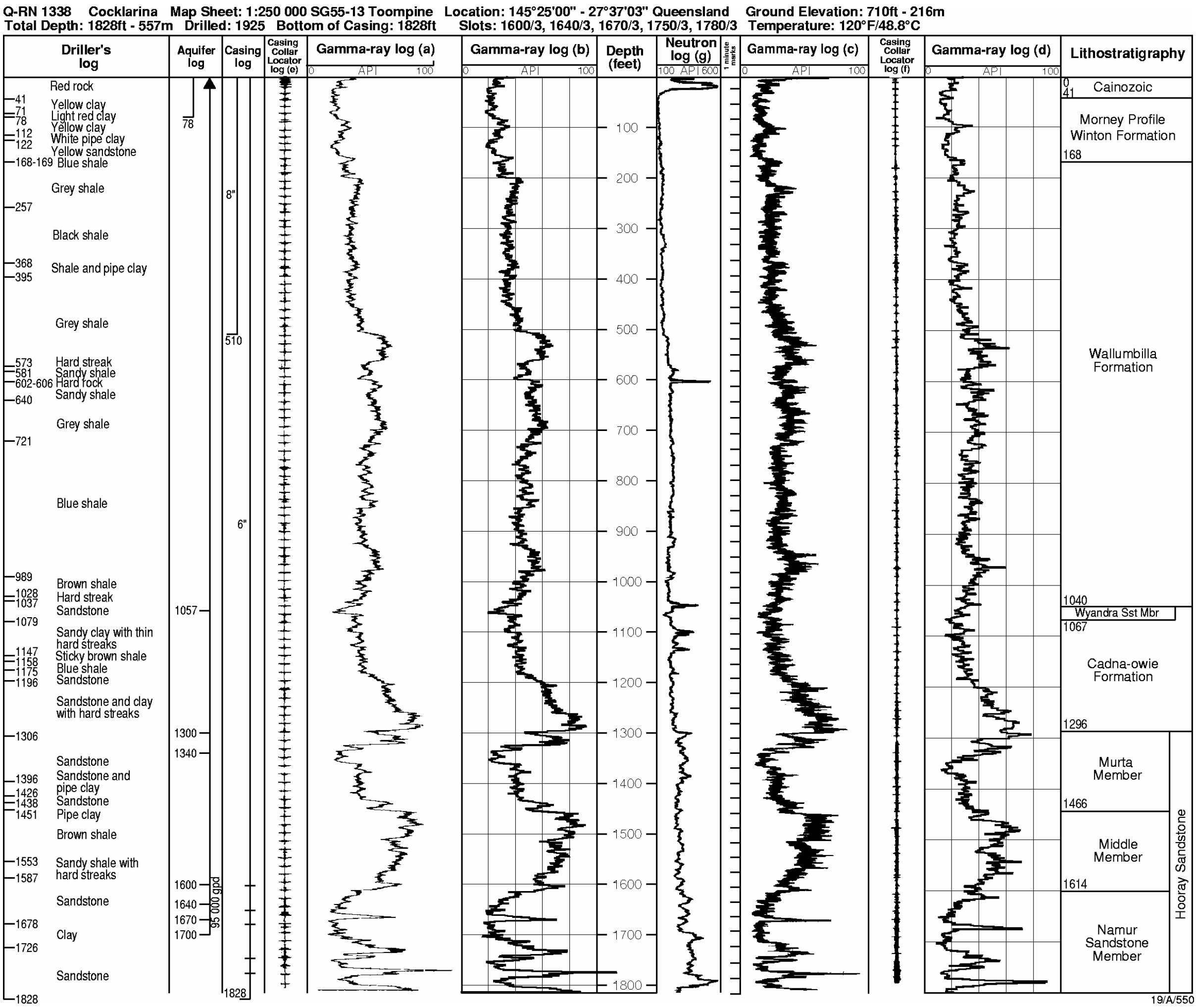

Figure 22 C - Comparison of the analog copy of the natural gamma-ray log and the digital (digitised) copy of the natural gamma-ray log + casing collar locator log + drillers log + aquifer log + casing log + lithostratigraphy + depths from waterbore RN 1338 (Queensland) -

C - natural gamma-ray logs of waterbore RN 1338 obtained in 1967 and 1975, combination of original analog (a + c) and digitised versions (b + d). Casing collar locator log 1967 (e) and 1975 (f) and neutron log 1975 (g)

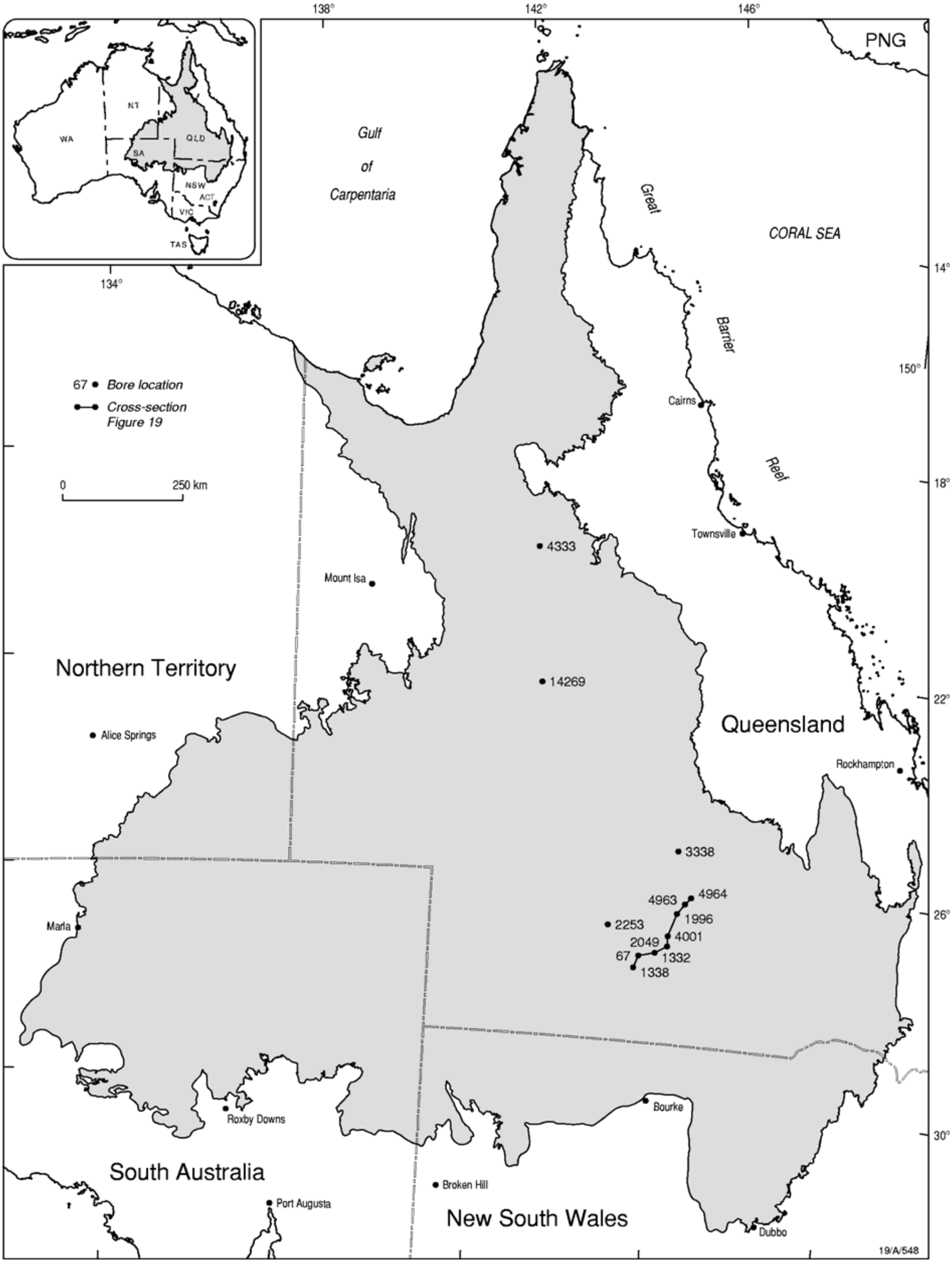

Figure 23 - Location of the waterbores shown in the Figures 8, 9, 10, 11, 12, 13, 14, 15, and 22, and the waterbores shown in the cross-section in Figure 19

Acknowledgments

The Great Artesian Basin Wire-line Log Project component to digitise the wire-line logs from waterbores and to compile the GABLOG database was assisted with funding provided under the Federal Water Resources Assistance Program and the National Component of the National Landcare Program administered by the Commonwealth Department of Primary Industries and Energy (now the Commonwealth Department of Agriculture, Fisheries and Forestry - Australia).

The lithostratigraphy of the waterbores included in the Great Artesian Basin Wire-line Logged Waterbore Database GABLOG was interpreted by Dr B.R. Senior & Associates Pty Ltd under contract to AGSO as part of the Project.
T.R. Ransley compiled the data shown in Figures 20 and 21.

A large number of people have been involved in the Great Artesian Basin Wire-line Log Project since its inception in the late 1950s/early 1960s. They ranged from the BMR staff planning the Project, and planning and administering the field operations and contract operations, maintaining and operating the equipment, to the BMR staff and staff of contract logging companies involved in the logging of the waterbores in the field, the staff from State Water and Geological Authorities in Queensland, New South Wales, South Australia and the Northern Territory, the BMR staff handling and storing the logs and data, the BMR staff interpreting, collating and compiling the logs and data and the BMR and AGSO staff involved in the digitising of the logs and compiling the data and preparing the database, and many others who contributed over several decades. Their efforts and skills are acknowledged.

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APPENDICES

Appendices 1 - 4

Appendix 1 - Time period, operator and area (1 : 250 000 map sheet) of wire-line logging activities in the Great Artesian Basin

PERIOD	OPERATOR	AREA - 1:250 000 MAP SHEET	
3-9-1960 - 3-10-1960 21-10-1960 - 7-11-1960	BMR	SG54-8 SG54-12 SG55-10 SG55-11 SG55-12 SG55-13 SG55-14 SG55-15 SH55-2 SH55-3 SH55-4	Windorah Eromanga Charleville Mitchell Roma Toompine Wyandra Homeboin Cunnamulla Dirranbandi St George
24-8-1961 - 28-11-1961	BMR	SF54-8 SF54-12 SF54-15 SF55-13 SG54-1 SG54-2 SG54-5 SG54-6 SG55-1 SG55-2 SG55-6	Manuka Winton Brighton Downs Longreach Bedourie Machattie Birdsville Betoota Blackall Tambo Augathella
3-10-1962 - 22-11-1962	BMR	SG55-6 SG55-10 SG55-12 SG55-14 SG55-15 SG56-9 SG56-13 SH56-1	Augathella Charleville Roma Wyandra Homeboin Chinchilla Dalby Goondiwindi
3-6-1964 - 1-12-1964	BMR	SF54-3 SF54-4 SF54-7 SF54-8 SF55-5	Julia Creek Richmond McKinlay Manuka Tangorin
11-7-1965 - 23-10-1965	Sclumberger	SF54-4 SF54-8	Richmond Manuka

		SF54-11 SF54-16 SF55-5 SF55-6 SF55-9 SF55-13 SG54-4 SG55-13	Mackunda Maneroo Tangorin Buchanan Muttaburra Longreach Jundah Toompine
July - December 1966	Schlumberger	SF54-7 SF54-8 SF54-10 SF54-14 SF54-15 SF55-13 SG54-1 SG54-2 SG54-3 SG54-6 SG55-1 SG55-5 SG55-9 SG55-10	McKinlay Manuka Boulia Springvale Brighton Downs Longreach Bedourie Machattie Connemara Betoota Blackall Adavale Quilpie Charleville
August - December 1967 March - May 1968	DUWS	SF55-13 SF55-14 SG54-4 SG54-15 SG54-16 SG55-1 SG55-2 SG55-6 SG55-9 SG55-10 SG55-11 SG55-13 SG55-14 SH55-1	Longreach Jericho Jundah Durham Downs Thargomindah Blackall Tambo Augathella Quilpie Charleville Mitchell Toompine Wyandra Eulo
August - December 1968 March - April 1969	DUWS	SG54-12 SG54-15 SG54-16 SG55-9 SG55-10 SG55-13 SG55-15 SH54-4 SH55-1	Eromanga Durham Downs Thargomindah Quilpie Charleville Toompine Homeboin Bulloo Eulo

		SH55-2 SH55-3	Cunnamulla Dirranbandi
July - December 1969 May 1970	DUWS	SF54-6 SE54-7 SE54-10 SE54-11 SE54-14 SE54-15 SE54-16 SF54-2 SG55-15 SH55-4 SH56-1	Burketown Normanton Donors Hill Croydon Dobbyn Millungera Gilberton Cloncurry Homeboin St George Goondiwindi
17-8-1970 - 15-11-1970	BMR	SF54-7 SF54-8 SF54-12 SF54-15	McKinlay Manuka Winton Brighton Downs
14-9-1970 - 14-12-1970 19-4-1971 - 17-7-1971	DUWS	SH55-11 SG55-12 SG55-15 SG55-16 SG56-9 SG56-13 SH55-3 SH55-4 SH56-1	Mitchell Roma Homeboin Surat Chinchilla Dalby Dirranbandi St George Goondiwindi
January - August 1972	Bendix	SE54-16 SF55-1 SF55-4 SF55-5 SG53-3 SG53-6 SG53-7	Gilberton Hughenden Richmond Tangorin Hale River Finke McDills
April - July 1972	BMR	SE54-7 SE54-8 SE54-9 SE54-10 SE54-11 SE54-14 SE54-15 SF55-13 SF55-14 SG54-8 SG55-1	Normanton Red River Lawn Hill Donors Hill Croydon Dobbyn Millungera Longreach Jericho Windorah Blackall

		SG55-5	Adavale
November 1972 - May 1973	DUWS	SG56-13 SH56-1	Dalby Goondiwindi
November 1973 - May 1974	DUWS	SG55-8 SG55-12 SG56-5 SG56-9	Taroom Roma Mundubbera Chinchilla
September - October 1974	BMR	SE54-3 SE54-6 SD54-3 SD54-7 SD54-15 SG54-4 SG55-9 SG55-10 SG55-13	Galbraith Burketown Weipa Aurukun Rutland Plain Jundah Quilpie Charleville Toompine
3-11-1974 - 10-12-1974	DUWS-Agnew	SH55-8 SH55-12 SH55-15 SH55-16 SH56-5	Moree Narrabri Nyngan Gilgandra Inverell
21-4-1975 - 30-6-1975	BMR	SH54-7 SH54-8 SH54-12 SH55-7 SH55-11 SH55-15	Milparinka Urisino White Cliffs Angledool Walgett Nyngan
18-9-1975 - 28-11-1975	BMR	SF55-13 SG55-1 SG55-2 SG55-6 SG55-10 SG55-13 SG55-14 SH55-1 SH55-2	Longreach Blackall Tambo Augathella Charleville Toompine Wyandra Eulo Cunnamulla

BMR - Bureau of Mineral Resources, Geology and Geophysics (now AGSO)
Bendix - Bendix-Austral United Geophysical Pty Ltd
DUWS - Down Under Well Services Pty Ltd
DUWS-Agnew - (Down Under Well Services) Agnew-Go Western Pty Ltd
Schlumberger - Schlumberger Seaco Ltd

Appendix 2 - Map sheets at scale 1 : 250 000 covering the Great Artesian Basin.
Maps marked * are map sheets on which wire-line logged waterbores are present

SC 54 - 11	Torres Strait	
SC 54 - 12	Torres Strait	
SC 54 - 15	Jardine River	
SC 54 - 16	Orford Bay	*
SD 54 - 3	Weipa	*
SD 54 - 4	Cape Weymouth	*
SD 54 - 7	Aurukun	*
SD 54 - 8	Coen	*
SD 54 - 11	Holroyd	*
SD 54 - 12	Ebagoola	
SD 54 - 15	Rutland Plains	*
SD 54 - 16	Hann River	*
SE 53 - 4	Robinson River	
SE 54 - 1	Mornington Island	
SE 54 - 2	Cape Van Diemen	
SE 54 - 3	Galbraith	*
SE 54 - 4	Walsh	
SE 54 - 5	Westmoreland	
SE 54 - 6	Burketown	*
SE 54 - 7	Normanton	*
SE 54 - 8	Red River	*
SE 54 - 9	Lawn Hill	
SE 54 - 10	Donors Hill	*
SE 54 - 11	Croydon	*
SE 54 - 12	Georgetown	
SE 54 - 14	Dobbyn	*
SE 54 - 15	Millungera	*
SE 54 - 16	Gilberton	*
SE 55 - 1	Mosmann	
SE 55 - 5	Atherton	
SE 55 - 13	Clarke River	

SF 53 - 15	Illogwa Creek	
SF 53 - 16	Hay River	
SF 54 - 2	Cloncurry	*
SF 54 - 3	Julia Creek	*
SF 54 - 4	Richmond	*
SF 54 - 5	Urandangi	
SF 54 - 6	Duchess	
SF 54 - 7	McKinlay	*
SF 54 - 8	Manuka	*
SF 54 - 9	Glenormiston	
SF 54 - 10	Boulia	*
SF 54 - 11	Mackunda	*
SF 54 - 12	Winton	*
SF 54 - 13	Mt Whelan	
SF 54 - 14	Springvale	*
SF 54 - 15	Brighton Downs	*
SF 54 - 16	Maneroo	*
SF 55 - 1	Hughenden	*
SF 55 - 2	Charters Towers	
SF 55 - 5	Tangorin	*
SF 55 - 6	Buchanan	*
SF 55 - 9	Muttaburra	*
SF 55 - 10	Galilee	
SF 55 - 13	Longreach	*
SF 55 - 14	Jericho	*
SF 55 - 16	Duaringa	

SG 53 - 2	Rodinga	
SG 53 - 3	Hale River	*
SG 53 - 4	Simpson Desert North	
SG 53 - 5	Kulgera	
SG 53 - 6	Finke	*
SG 53 - 7	McDills	*

SH 53 - 1	Giles
SH 53 - 2	Murloocoppie
SH 53 - 3	Warrina
SH 53 - 4	Lake Eyre
SH 53 - 5	Tallaringa
SH 53 - 6	Coober Pedy

SG 53 - 8	Simpson Desert South		SH 53 - 7	Billa Kalina	
SG 53 - 9	Alberga		SH 53 - 8	Curdimurka	
SG 53 - 10	Abminga		SH 53 - 9	Barton	
SG 53 - 11	Dalhousie		SH 53 - 10	Tarcoola	
SG 53 - 12	Poolowanna		SH 53 - 11	Kingoonya	
SG 53 - 13	Everard		SH 53 - 12	Andamooka	
SG 53 - 14	Wintinna		SH 53 - 15	Gairdner	
SG 53 - 15	Oodnadatta		SH 54 - 1	Kopperamanna	
SG 53 - 16	Noolyeana		SH 54 - 2	Strzelecki	
SG 54 - 1	Bedourie	*	SH 54 - 3	Tickalara	
SG 54 - 2	Machattie	*	SH 54 - 4	Bulloo	*
SG 54 - 3	Connemara	*	SH 54 - 5	Marree	
SG 54 - 4	Jundah	*	SH 54 - 6	Callabonna	
SG 54 - 5	Birdsville	*	SH 54 - 7	Milparinka	*
SG 54 - 6	Betoota	*	SH 54 - 8	Urisino	*
SG 54 - 7	Canterbury		SH 54 - 9	Copley	
SG 54 - 8	Windorah	*	SH 54 - 10	Frome	
SG 54 - 9	Pandie Pandie		SH 54 - 11	Cobham Lake	
SG 54 - 10	Cordillo		SH 54 - 12	White Cliffs	*
SG 54 - 11	Barrolka		SH 54 - 13	Parachilna	
SG 54 - 12	Eromanga	*	SH 54 - 14	Curnamona	
SG 54 - 13	Gason		SH 54 - 15	Broken Hill	
SG 54 - 14	Innamincka		SH 54 - 16	Wilcannia	
SG 54 - 15	Durham Downs	*	SH 55 - 1	Eulo	*
SG 54 - 16	Thargomindah	*	SH 55 - 2	Cunnamulla	*
SG 55 - 1	Blackall	*	SH 55 - 3	Dirranbandi	*
SG 55 - 2	Tambo	*	SH 55 - 4	St George	*
SG 55 - 3	Springsure		SH 55 - 5	Yantabulla	
SG 55 - 4	Baralaba		SH 55 - 6	Enngonia	
SG 55 - 5	Adavale	*	SH 55 - 7	Angledool	*
SG 55 - 6	Augathella	*	SH 55 - 8	Moree	*
SG 55 - 7	Eddystone	*	SH 55 - 9	Louth	
SG 55 - 8	Taroom	*	SH 55 - 10	Bourke	
SG 55 - 9	Quilpie	*	SH 55 - 11	Walgett	*
SG 55 - 10	Charleville	*	SH 55 - 12	Narrabri	*
SG 55 - 11	Mitchell	*	SH 55 - 15	Nyngan	*
SG 55 - 12	Roma	*	SH 55 - 16	Gilgandra	*
SG 55 - 13	Toompine	*	SH 56 - 1	Goondiwindi	*
SG 55 - 14	Wyandra	*	SH 56 - 5	Inverell	*
SG 55 - 15	Homeboin	*	SH 56 - 9	Manilla	

SG 55 - 16	Surat	*	SI 55 - 3	Naromine
SG 56 - 1	Monto		SI 55 - 4	Dubbo
SG 56 - 5	Mundubberra	*		
SG 56 - 9	Chinchilla	*		
SG 56 - 13	Dalby	*		

Appendix 3 - Lithostratigraphic units and the abbreviations used on geological and hydrogeological map sheets, which are included in the Great Artesian Basin Wire-line Logged Borehole Database GABLOG

- Adori Sandstone	- Ja
- Algebuckina Sandstone	- Jua
- Allaru Mudstone	- Kla
- Basement	- Bas
- Birkhead Formation	- Jmb
- Blackwater Group	- Puw
- Blantyre Beds	- Jub
- Boxvale Sandstone Member	- Jlb
- Buckabie Formation	- DCb
- Bulimba Formation	- KTi
- Bungil Formation	- Kly
- Cadna-Owie Formation	- Kco
- Cainozoic	- Cz
- Campaspe Beds	- Tc
- Canaway Profile	- Canp
- Chinchilla Sand	- Tpc
- Claraville Beds	- TQc
- Clematis Sandstone	- TRe
- Colinlea Sandstone	- Plo
- Coreena Member	- Klc
- Crown Point Formation	- Pc
- Doncaster Member	- Kld
- Drildool Beds	- Kd
- Dunda Beds	- TRld
- Etonvale Formation	- Dme
- Eulo Queen Group	- Jue
- Eurombah Formation	- Jme
- Evergreen Formation	- Jle
- Eyre Formation	- Tee
- Floraville Formation	- KTf
- Garraway Beds	- Jw
- Gilbert River Formation	- Klg
- Glendower Formation	- Tg
- Griman Creek Formation	- Klgg
- Gubberamunda Sandstone	- Jug
- Helidon Sandstone	- Jll
- Hooray Sandstone	- JKh
- Hutton Sandstone	- Jlh
- Injune Creek Group	- Ji
- Joe Joe Formation	- CPj

Bas	- Basement
Canp	- Canaway Profile
Ck	- Kuttung Formation
Cpj	- Joe Joe Formation
CPp	- Purni Formation
Cz	- Cainozoic
Czs	- Sturgeon Basalt
Czy	- Wyaaba Beds
DCb	- Buckabie Formation
Dme	- Etonvale Formation
J	- Undifferentiated Jurassic
Ja	- Adori Sandstone
Ji	- Injune Creek Group
JKh	- Hooray Sandstone
JKhm	- Murta Member
JKhn	- Namur Sandstone Mbr
JKk	- Kumbarilla Beds
JKr	- Ronlow Beds
Jlb	- Boxvale Sandstone Mbr
Jle	- Evergreen Formation
Jlh	- Hutton Sandstone
Jll	- Helidon Sandstone
Jlm	- Marburg Sandstone
Jlp	- Precipice Sandstone
Jmb	- Birkhead Formation
Jme	- Eurombah Formation
Jmw	- Walloon Coal Measures
Jp	- Pilliga Sandstone
Js	- Springbok Sandstone
Jua	- Algebuckina Sandstone
Jub	- Blantyre Beds
Jue	- Eulo Queen Group
Jug	- Gubberamunda Sst
Juo	- Orallo Formation
Juw	- Westbourne Formation
Jw	- Garraway Beds
Kco	- Cadna-Owie Formation
Kd	- Drildool Beds
Kla	- Allaru Mudstone
Klc	- Coreena Member

- Kumbarilla Beds	- JKk
- Kuttung Formation	- Ck
- Mackunda Formation	- Klm
- Marburg Sandstone	- Jlm
- Mooga Sandstone	- Klmo
- Moolayember Formation	- TRm
- Morney Profile	- KTam
- Murta Member	- JKhm
- Namur Sandstone Member	- JKhn
- Normanton Formation	- Klr
- Orallo Formation	- Juo
- Permian	- P
- Pilliga Sandstone	- Jp
- Precipice Sandstone	- Jlp
- Purni Formation	- CPp
- Rolling Downs Group	- Kr
- Ronlow Beds	- JKr
- Springbok Sandstone	- Js
- Sturgeon Basalt	- Czs
- Surat Siltstone	- Kls
- Toolebuc Formation	- Klo
- Triassic	- TR
- Undifferentiated Jurassic	- J
- Walloon Coal Measures	- Jmw
- Wallumbilla Formation	- Klu
- Warang Sandstone	- TRlw
- Weathered zone	- wz
- Westbourne Formation	- Juw
- Whitula Formation	- TQw
- Wilgunya Sub Group	- Klw
- Windorah Formation	- XXXX
- Winton Formation	- Kw
- Wondoola Beds	- Qw
- Wyaaba Beds	- CZy
- Wyandra Sandstone Member	- Klws

Kld	- Doncaster Member
Klg	- Gilbert River Formation
Klgg	- Griman Creek Fm
Klm	- Mackunda Formation
Klmo	- Mooga Sandstone
Klo	- Toolebuc Formation
Klr	- Normanton Formation
Kls	- Surat Siltstone
Klu	- Wallumbilla Formation
Klw	- Wilgunya Sub Group
Klws	- Wyandra Sst Mbr
Kly	- Bungil Formation
Kr	- Rolling Downs Group
KTam	- Morney Profile
KTf	- Floraville Formation
KTi	- Bulimba Formation
Kw	- Winton Formation
P	- Permian
Pc	- Crown Point Formation
Plo	- Colinlea Sandstone
Puw	- Blackwater Group
Qw	- Wondoola Beds
Tc	- Campaspe Beds
Tee	- Eyre Formation
Tg	- Glendower Formation
Tpc	- Chinchilla Sand
TQc	- Claraville Beds
TQw	- Whitula Formation
TR	- Triassic
TRe	- Clematis Sandstone
TRld	- Dunda Beds
TRlw	- Warang Sandstone
TRm	- Moolayember Fm
wz	- Weathered zone
XXXX	- Windorah Formation

Appendix 4 - Directory structure of distribution disk

```
/
    readme.txt
    database/
        database/                         (csv files of the distribution database)
            glvchem.csv
            glvflow.csv
            glvgen.csv
            glvlog.csv
            glvstrat.csv
            readme.txt
        oracle7/                          (Oracle 7 dump of distribution database)
            glv.dmp
            readme.txt
        report/                           (text versions of data listings)
            loglist.txt
            loglist.ps
            readme.txt
        spread/                           (text versions of spreadsheet data)
            lschem.csv
            glsflow.csv
            glsgen.csv
            lslog.csv
            glsstrat.csv
            eadme.txt
        readme.txt
    logs/
        cal/
            all caliper logs (*.cal)
        dt/
            all differential temperature logs (*.dt)
        fld/
            all flow logs logged downwards (*.fld)
        flu/
            all flow logs logged upwards (*.flu)
        gr/
            all gamma ray logs (*.gr)
        neu/
            all neutron gamma logs (*.neu)
        rln/
            all long normal resistivity logs (*.rln)
        rlt/
            all lateral resistivity logs (*.rlt)
        rsn/
            all short normal resistivity logs (*.rsn)
        sp/
            all spontaneous potential logs (*.sp)
        spr/
            all single point resistance logs (*.spr)
        t/
            all temperature logs (*.t)
        readme.txt
```

WIRE-LINE LOGGED WATERBORES IN THE GREAT ARTESIAN BASIN

(LOGS ACQUIRED BY AGSO)

MAP 1 of 3

1997

Scale 1: 2 500 000

0 50 100 150 200 250 kilometres

SIMPLE CONIC PROJECTION
STANDARD PARALLELS 18°S AND 36°S, ORIGIN OF LONGITUDE 134°E

Compilation by M.A. Habermehl, A.G. Tucker, A.L. Sedgmen & N.G. Revell
Cartography by B.C. Cotton using ESRI's ARC/INFO GIS software
Produced by Spatial Information and Mapping Services, AGSO
Printed by ULTRA PRESS, Sydney, Australia

This Project was assisted with funding provided under the Federal Water Resources Assistance Program and the National Component of the National Landcare Program administered by the Commonwealth Department of Primary Industries and Energy

Published by the Australian Geological Survey Organisation, Department of Primary Industries and Energy, Canberra, Australia

Issued under the Authority of the Minister for Primary Industries and Energy

Base map compiled by AGSO from maps supplied by the Australian Surveying and Land Information Group, Department of Administrative Services
Topographic base information © AUSLIG 1997

Bore location with Registered Number (Q2348)
Natural gamma-ray log
Neutron-gamma log
Lithostratigraphy data
Hydrochemistry data

Outer limit of the Great Artesian Basin

Boundary of the Base of the Rolling Downs Group and equivalents

COEN SD5408 *1:250 000 map sheet*

Copies of this set of maps may be obtained from:
AGSO Sales Centre
GPO Box 378, Canberra ACT 2601
Phone: 06-249 9519
Fax: 06-249 9982
E-mail: sales@agso.gov.au

It is recommended that this set of maps be referred to as:
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Australian Geological Survey Organisation, Bulletin 240

Included in the text publication is a CD-ROM containing a database with the digital data of the logs obtained from the waterbores shown on the maps, and information on the lithostratigraphy and hydrochemistry of the waterbores

The set of 3 maps shows the type of wire-line logs acquired by the Australian Geological Survey Organisation (previously the Bureau of Mineral Resources, Geology and Geophysics) from waterbores in the Great Artesian Basin, and shows the availability of interpreted lithostratigraphic information and hydrochemical data for those waterbores

The set of 3 maps consists of:

Maps 1, 2 and 3 - Wire-line logged Waterbores with Registered Number (Queensland, New South Wales and Northern Territory Registered Numbers)

- Map 1 - Waterbores with:
  - natural gamma-ray log 1212 bores
  - neutron-gamma log 345 bores
  - lithostratigraphy data 1170 bores
  - hydrochemistry data 412 bores

- Map 2 - Waterbores with:
  - temperature log 763 bores
  - differential temperature log 742 bores
  - caliper log 208 bores
  - flowmeter (down) log 180 bores
  - flowmeter (up) log 160 bores

- Map 3 - Waterbores with:
  - spontaneous potential log 41 bores
  - single point resistance log 3 bores
  - short normal resistivity log 24 bores
  - long normal resistivity log 26 bores
  - lateral resistivity log 12 bores

WIRE-LINE LOGGED WATERBORES IN THE GREAT ARTESIAN BASIN

(LOGS ACQUIRED BY AGSO)

MAP 2 of 3

1997

Scale 1: 2 500 000

0 50 100 150 200 250 kilometres

SIMPLE CONIC PROJECTION
STANDARD PARALLELS 18°S AND 36°S, ORIGIN OF LONGITUDE 134°E

Compilation by M.A. Habermehl, A.G. Tucker, A.L. Sedgmen & N.G. Revell
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Topographic base information © AUSLIG 1997

Q2348 *Bore location with Registered Number*
Temperature log
Differential temperature log
Caliper log
Flowmeter (down) log
Flowmeter (up) log

Outer limit of the Great Artesian Basin

Boundary of the Base of the Rolling Downs Group and equivalents

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  - spontaneous potential log 41 bores
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AGSO AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

NATIONAL LANDCARE PROGRAM

WIRE-LINE LOGGED WATERBORES IN THE GREAT ARTESIAN BASIN

(LOGS ACQUIRED BY AGSO)

MAP 3 of 3

1997

Scale 1: 2 500 000

0 50 100 150 200 250 kilometres

SIMPLE CONIC PROJECTION
STANDARD PARALLELS 18°S AND 36°S, ORIGIN OF LONGITUDE 134°E

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Topographic base information © AUSLIG 1997

Q2348 *Bore location with Registered Number*

Spontaneous potential log

Single point resistance log

Short normal resistivity log

Long normal resistivity log

Lateral resistivity log

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