NORTHERN TERRITORY OF AUSTRALIA
DEPARTMENT OF TRANSPORT & WORKS

PROPOSAL FOR GROUNDWATER INVESTIGATION
McMINNS-BENHAM LAGOON REGION
NORTHERN TERRITORY

P666 August 1979


**CONTENTS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 INTRODUCTION</td>
<td>3</td>
</tr>
<tr>
<td>2.0 APPRECIATION</td>
<td>3</td>
</tr>
<tr>
<td>3.0 COMMENTS ON TERMS OF REFERENCE</td>
<td>6</td>
</tr>
<tr>
<td>3.1 Project 1</td>
<td>6</td>
</tr>
<tr>
<td>3.2 Project 2</td>
<td>8</td>
</tr>
<tr>
<td>4.0 PROPOSED INVESTIGATION - METHOD OF APPROACH</td>
<td>9</td>
</tr>
<tr>
<td>4.1 Project 1</td>
<td>9</td>
</tr>
<tr>
<td>4.2 Project 2</td>
<td>13</td>
</tr>
<tr>
<td>4.3 Objectives</td>
<td>14</td>
</tr>
<tr>
<td>5.0 PROJECT PERSONNEL AND TIMING</td>
<td>14</td>
</tr>
<tr>
<td>5.1 Personnel</td>
<td>14</td>
</tr>
<tr>
<td>5.2 Timing</td>
<td>17</td>
</tr>
<tr>
<td>6.0 BASIS OF ENGAGEMENT OF CONSULTANTS AND COST ESTIMATE</td>
<td>18</td>
</tr>
<tr>
<td>6.1 Fee and Cost Estimate - Project 1</td>
<td>18</td>
</tr>
<tr>
<td>6.2 Fee and Cost Estimate - Project 2</td>
<td>21</td>
</tr>
<tr>
<td>7.0 COFFEY &amp; PARTNERS PTY. LTD. EXPERIENCE IN GROUNDWATER INVESTIGATIONS</td>
<td>23</td>
</tr>
</tbody>
</table>

ATTACHMENT A - Letter of Invitation and Terms of Reference
ATTACHMENT B - Curricula Vitae
ATTACHMENT C - Terms of Engagement and Scale of Fees
ATTACHMENT D - Groundwater Brochure
ATTACHMENT E - Job Listing
The Director,
Department of Transport & Works,
Northern Territory of Australia,
P.O. Box 2520,
DARWIN, N.T. 5794

ATTENTION MR. HUGH WAND

Dear Sir,

RE: McMinns-Benham Lagoon Region
Groundwater Investigation

As requested we are pleased to submit a proposal for professional services to prove the feasibility of developing a major borefield in the McMinns-Benham Lagoon region.

The attached proposal covers those aspects included in your letter of invitation and Terms of Reference.

We have assembled a team covering the fields of hydrogeology, drilling technology, geophysics and computer modelling which, it is felt, is eminently suited to this project. Team members have many years of experience in their particular fields. The experience by both our groundwater and geophysical personnel in Karst areas is, we consider, of particular importance.

Coffey & Partners Pty. Ltd. is the major geotechnical and groundwater consulting firm in Australia with a total staff in excess of 130 and offices in the six mainland capitals and in the regional centres of Southport, Newcastle, Albury/ Wodonga and Wagga. An overseas office is maintained in Jakarta, Indonesia in association with P.T. Sucfindo. Our Company turnover during financial year 1978/79 was some $5.00 million and this ranks Coffey & Partners Pty. Ltd. in the top ten consulting engineering groups in Australia.
We thank you for this invitation to prepare and submit a detailed proposal and trust that all the necessary information is incorporated. In the event that clarification or additional information is required we would appreciate the opportunity of discussion with you.

Yours faithfully,
COFFEY & PARTNERS PTY. LTD.

IAN R. BINCH
1.0 INTRODUCTION

This proposal has been prepared in response to a letter of invitation dated 7th August 1979 from the Northern Territory Department of Transport & Works seeking a submission "for professional services to prove the feasibility of developing a major borefield in the McMinns-Benham Lagoon region". A copy of the letter of invitation and terms of reference is included in Attachment A.

It is understood that the proposed work is part of an ongoing study into the augmentation of Darwin City water supply. As you are aware, Coffey & Partners Pty. Ltd. has recently been involved, in conjunction with Snowy Mountains Engineering Corporation, in a preliminary appraisal of potential groundwater sources in the Darwin region and is well acquainted with the McMinns-Benham Lagoon area.

The proposal sets down briefly our appreciation of the hydrogeological conditions in the area, discusses the investigation techniques which we propose utilising and describes what would be our general approach to the investigation. Timing, project personnel, cost estimates and a listing of Coffey & Partners Pty. Ltd. experience in the groundwater field are also presented for your consideration.

2.0 APPRECIATION

The main aquifer in the study area is formed by the Proterozoic Coomalie Dolomite which occurs at depths of approximately 30 m to 50 m below a cover of sandstones, clays, sands and gravels belonging to the Cretaceous Mollman Beds.

Permeability in the Coomalie Dolomite is imparted by fractures and solution cavities. High yields have been obtained from bores penetrating this aquifer. However, the success of a bore is dependent on intersecting these features and substantial differences in yield of bores in quite close proximity are common.
Cavities within the dolomite are often infilled with sediment which can and has caused difficulty in bore construction and development.

Although the Coomalie Dolomite aquifer has an apparently high groundwater potential, considerable care will be required in the exploration and development of this resource to avoid unnecessary drilling and exploration costs.

Historically, the exploitation of groundwater in the area of interest has had mixed results.

Between 1966 and 1972 the McMinns borefield produced a significant proportion of Darwin’s water supply. Pumping commenced in August 1966 at rates between 0.85 and 2.5 ML/day. Over the following years production steadily increased to a peak of 25 ML/day in July 1970 when 12 production bores were in operation.

However, this supply was not obtained without some difficulties which included:

- Problems siting bores to intersect fractures and solution cavities in the Coomalie Dolomite.

- Bore construction problems; these included hard drilling conditions and lost circulation when drilling through cavities.

- Bore development problems; the inability to develop bores to a sand-free condition was common and in many instances sand and silt collapsed into the hole after development was completed.

These problems were exacerbated in the late 1960s by:

- Urgency to develop a borefield. The demand for water was rapidly exceeding the ability of Manton Dam and its associated pipelines and pumping system to supply water.
to the city. Consequently the pressures to establish a production borefield at McMinns were very great. This left virtually no time for systematic and logical groundwater evaluation and borehole development.

Because of this urgency drilling operations were restricted to crown land (road reserves) to avoid the necessity of acquiring land for pipelines. This severely limited the scope for borehole location and general hydrogeological assessment.

Drilling rigs and ancillary equipment available at that time were underpowered and generally unsuited to the type of drilling operations needed in the peculiar ground conditions encountered in the McMinns area. In particular, the need to construct relatively large diameter bores placed great stress on the machines.

For efficient drilling operations it is imperative that such items as bits, spare parts and other operational equipment and material be readily obtainable. The Government stores procurement system which operated in the Northern Territory in the 1960s, whilst probably being satisfactory for routine procurement, was not geared to accommodate the urgent purchasing which is invariably required in drilling operations. This in some ways added to the problems encountered in developing the McMinns borefield.

Lack of professional supervision. Previous work had insufficient input from experienced groundwater engineers and geologists. Field supervision, data collection and reporting were inadequate. There were no progress reports prepared during the main phase of the development between 1964 and 1974.
Despite these problems a successful borefield was established, in a fairly restricted area, which yielded up to 25 Ml/day. This is over 50% of the yield required from the borefield which is the subject of this proposal.

From the above it can be appreciated that re-establishment and extension of the old McMinns borefield will face some difficulties. However, with the improvement in drilling equipment and techniques over the past 10 years, with the time and space constraints removed and with improved investigation techniques, many of the past difficulties should be eliminated.

It is considered that the following are the major requirements for ensuring successful completion of this project:

- Selection of the most cost-effective field exploration techniques
- Full time professional supervision of field programmes
- Constant overview of the investigation by experienced senior personnel

The following sections of this proposal set down Coffey & Partners Pty. Ltd. recommended approach to the investigation based on past experience, both in the Darwin region and elsewhere.

3.0 COMMENTS ON TERMS OF REFERENCE

The Terms of Reference subdivide the investigation into two parts - Project 1 and Project 2 (see Attachment A).

3.1 Project 1

Activities in Project 1 include an examination of existing hydrogeological data, field surveys including geophysics, the development of an aquifer model and the definition of a test drilling programme for Project 2. In our view
the scope will allow a thorough investigation of the area. However, we have the following comments on the geophysical techniques proposed in the Terms of Reference.

Surface geophysical techniques comprise reflection seismic and refraction seismic profiling of areas of interest. It is agreed that the overall area is very large and that geophysical surveys will have to be restricted to areas of interest to be defined in the initial stages of the investigation. However, we consider seismic reflection to be inappropriate as the cover of Mullaman Beds is too shallow to obtain useful results with this technique. Seismic reflection surveys are also approximately twice the cost of refraction surveys and therefore the technique is not recommended for this investigation. Seismic refraction profiling on the other hand is well suited to the conditions in the area as good seismic contrast should exist between the Mullaman Beds and Coomalie Dolomite.

Although not specified in the Terms of Reference, electrical methods are also suitable for these conditions as there is also good electrical contrast between the Coomalie Dolomite and overlying sediments. Electrical methods can be performed more rapidly and at less cost than seismic methods.

Our approach in this investigation will be to utilise electrical methods for reconnaissance followed by a combination of electrical and seismic methods for detailed work.

Resistivity surveys will be used in reconnaissance. The induced polarisation surveys will use gradient arrays with 100 m spaced lines and 25 m potential dipole and 2000 m current dipole separations. This method allows an area of approximately 1.6 square kilometres to be traversed daily. Dipole-dipole surveys will then be used for detailed work on specific targets and to provide depth information within each block. These surveys should locate zones of interest such as depressions in the dolomite, fractures and major solution cavity areas for definition by seismic refraction.
The seismic refraction surveys would use a 12 channel seismograph, 20 m geophone separations and 5 shots per spread. This will be supplemented by close spacing spreads for detailed velocity information.

3.2 Project 2

As noted in the Terms of Reference, the scope of Project 2 will be largely dependent on the outcome of Project 1.

One of the most important aspects of the first stage will be the results obtained from the seismic refraction and electrical surveys proposed. It is considered that these techniques will allow identification of those areas having the best prospects of successful bores. This has been one of the main problems in the past and every effort should be made to increase the chances of siting successful bores by surface investigation techniques, thereby reducing the costs of exploration drilling. Geophysical methods, in association with hydrogeological and terrain evaluation, afford the best prospects of siting successful bores.

For these reasons it is considered that some allowance should be made in the Terms of Reference for Project 2 for extra geophysical work.

Also, to obtain as much information as possible during Project 2, the observation bores should be developed and air-lifted to provide an indication of water yielding potential and to obtain water samples for analysis.

Apart from these comments the scope of Project 2 is assessed as adequate providing it is understood that the ultimate aim of such a programme is to construct production bores and that this would form a logical extension into Project 3.
4.0 PROPOSED INVESTIGATION - METHOD OF APPROACH

4.1 Project 1

A principal groundwater geologist and a hydrogeologist would mobilise to Darwin at the commencement of the study. After discussion with the project leader they would, in collaboration with Water Division staff, commence a review of existing data, carry out monitoring, collect additional relevant data, initiate technical survey of McMinns borefield, examine bore design drilling and construction techniques, carry out down hole logging of selected bores as outlined in the Terms of Reference.

Areas of interest within the project area for investigation by surface geophysics would be defined during these initial studies. The geophysical team would then mobilise for these surveys. The geophysical investigation would be carried out under the supervision of experienced senior personnel. They would be present on site to direct the surveys and analyse the progress results to ensure the most effective application of technique and effort.

Concurrently with the above work a numerical model of the aquifer system would be developed. The form of this model would be compatible with Water Division's computer facilities.

Estimated timing of the various activities to be undertaken, together with the anticipated involvement of personnel are given in Figure 1.

Brief discussion on the approach proposed for each area of activity is given below.

(1) Hydrogeology and Drilling Methodology

Because of recent and past involvement by Coffey & Partners personnel in the assessment and development of groundwater in the McMinns area, the quantity and quality of available data are well known to us. In our appraisal and analysis of the data we would concentrate on:
Water balance studies
2. Borehole hydrograph analysis
3. Potentiometric surface variations in response to recharge, drainage and pumping
4. Terrain analysis to assess whether subsurface conditions can be evaluated from topographic features
5. Literature survey of "covered" Karst terrain
6. Determination of the most appropriate drilling equipment and techniques for the area
7. Development of a hydrogeological model

This phase of the project would be under the direct supervision of Mr. Bryan Harris. Field work, borehole logging, drill cutting examination and routine data collection would be undertaken by Mr. Errol Briese. Mr. Ian Binch would be available to provide input on borefield analysis, drilling operations and bore construction techniques.

(2) Geophysics

Because of our expectation that the use of surface geophysical methods will play a significant role in borehole siting, this aspect of the investigation has been carefully considered.

It is proposed to use electrical methods for reconnaissance and both electrical and seismic methods for detailed work.

The electrical methods (resistivity and I.P.) will be supervised by Mr. Bob Whiteley and the seismic aspects by Prof. Laric Hawkins, both of the School of Applied Geology, University of New South Wales.

Following the selection of broad areas of interest using topographic and hydrogeologic information, resistivity, supplemented by induced polarisation surveys, will be carried out. These should locate areas such as water-filled depressions, fractures and major sink-hole areas in the dolomite for later definition by seismic work.
It is expected that a substantial electrical and seismic velocity contrast should exist between the Mullaman Beds and the underlying dolomite. Depressions in the carbonate rock, infilled with weathering products and probably unprospective, could be expected to be distinguished from prospective regions using the combination of methods. The induced polarisation method should be quite sensitive to collapsed, rubble filled sink-holes in the dolomite.

Likely targets for water would be expected to be areas of low seismic velocity, high resistivity and low chargeability with appropriate Karst surface features.

Since Karst terrain is notoriously variable, considerable care in both the field surveys and interpretation is required.

- **Resistivity and Induced Polarisation Survey**
  It is intended to sub-contract this survey and to provide supervision and interpretation by Mr. Whiteley. This is considered to be the most cost-effective approach. The survey will operate at two levels - firstly, reconnaissance using gradient arrays with 100 m lines and 25 m potential dipole and 2000 m current dipoles. This allows an area of about 1.6 square kilometres to be covered daily. Several dipole/dipole surveys for detailed work on targets and to provide depth information within each block are also required. This would initially use 50 m dipoles to n = 6 giving about 400 m of detailed depth and lateral electrical information per day.

  About 1 day in 3 field days is required for interpretation.

- **Seismic Refraction Survey**
  For follow up work it is intended to use a 12 channel seismograph, 20 m geophone separations and 5 shots per spread. This will be supplemented by close spacing (or
weathering) spreads for detailed velocity information. It is expected that 4 production spreads can be completed daily with weathering spreads on every 5th day. This gives an overall coverage of 3.25 spreads per day or about 700 m per day.

Shots need to be buried in auger holes to a depth of up to 2 m. Seismic lines should also be levelled to 0.1 m accuracy and pegged at say 100 m intervals.

An additional 1 day for every 2 days field work should be allowed for seismic interpretation.

- **Borehole Logging**
  Logging of existing cased boreholes will be undertaken with Coffey & Partners Austral Middi Logger using Gamma and Gamma-Gamma probes. It is considered that these logs will be most effective in identifying potential water-bearing zones in completed bores.

- **Computer Modelling**
  Development of the aquifer model would be carried out on our in-house Data General Eclipse S/130 computer and would proceed in several stages, as detailed below:

  * Collection of appropriate input data from the results of the field test programme and previous work. Requirements include aquifer geometry (locations of boundaries, details of recharge sources and locations and capacity of existing and planned bores) and aquifer properties (estimates of hydraulic conductivity, storativity and thickness).

  * Construction of the computer model. It is proposed to model the aquifer using a suite of finite element based seepage programs which have been developed by Coffey &
Partners. Initially a steady-state model would be used. However, a compatible transient model is available if required. Preparation of the input data files would be carried out with the aid of mesh generation programs based on interactive graphics. These programs allow rapid formulation and modification of finite element meshes.

* Initial operation and calibration of the model. Once the model has been prepared using the best available estimates of aquifer geometry and properties, a series of model runs would be made in order to compare model behaviour with that observed in the field. At this stage, various model parameters may be altered in order to reproduce more exactly the field behaviour. An assessment would also be made of the suitability of the steady-state model. Because of the similarities between the steady-state and transient analysis computer programs a change to a transient model, if required, would be relatively straightforward.

* Use of the model for the evaluation of proposed aquifer management schemes. Once the model has been prepared and calibrated, various aquifer management schemes can be postulated and examined. The results produced for each scheme can then be evaluated against specified operating constraints and an assessment made of their suitability.

4.2 Project 2

Our general approach to Project 2 would be similar to that outlined for Project 1. Emphasis would be placed on full-time detailed supervision of drilling and testing operations and follow-up geophysical work to complement that done in Project 1. An estimated staffing schedule for Project 2 is given in Figure 2.
4.3 Objectives

The objectives of the commission, as set down by the Department of Transport & Works, are:

1. locate a production borefield or borefields, with an initial safe yield of 25 Ml/day of potable water, suitable for economic incorporation into the Darwin water supply system.

2. establish a water balance to ensure that borefield operation will not diminish the present yield available from existing domestic, agricultural, pastoral and production bores.

3. develop a model for use in the preparation of a plan of management to provide policy guidelines for the extension of production borefields and for an increase in the number of private domestic, agricultural and pastoral bores being sunk.

Throughout both Projects 1 and 2 these objectives would be borne in mind and work carried out would be aimed specifically at achieving them.

5.0 PROJECT PERSONNEL AND TIMING

5.1 Personnel

Curricula vitae for personnel are given in Attachment B. Brief details are given below:

Bryan M. Harris - Principal, Coffey & Partners Pty. Ltd.
Mr. Harris would assume the role of Project Co-ordinator and Senior Hydrogeologist. He has had over 15 years experience in the field of groundwater investigation, assessment and development, both in Australia and overseas.
Mr. Harris has an intimate knowledge of the project area, having recently completed a preliminary hydrogeological report for the Snowy Mountains Engineering Corporation. He has also had considerable previous experience in Karst hydrogeology in the south east of South Australia.

Errol H. Briese - Hydrogeologist, Coffey & Partners Pty. Ltd.

Field operations, including bore logging, drilling and testing supervision and field mapping would be carried out by Mr. Briese. He would also be responsible for office data collection and compilation and logging of borehole cuttings. Mr. Briese has had some 9 years of professional experience, the past 6 of which have been in the groundwater field. His areas of special competence include groundwater exploration, assessment of groundwater basins, design and construction of water bores and groundwater pollution studies.

Robert J. Whitley - Lecturer, Applied Geophysics, UNSW

Mr. Whitley will control and interpret the electrical geophysical investigations proposed. He has had over 12 years experience as a geophysicist with Government, private industry and as a university lecturer. Mr. Whitley has published widely, covering most geophysical methods and fields of research. Of particular importance is his experience in Karst areas. While with the BMR Mr. Whitley was a consultant to the British Phosphate Commission for groundwater exploration on Christmas Island using resistivity methods. With Metals Investment Holdings N.L. he supervised and carried out base metal exploration programs for Mississippi Valley-type deposits in the Georgina Basin, N.T. using reconnaissance geophysical methods and he has recently been a consultant to BHP using seismic methods to explore reefal complexes in Western Australia.

Laric V. Hawkins - Associate Professor, School of Applied Geology, UNSW

Professor Hawkins will direct and interpret the results of seismic refraction surveys. He, too, has had wide experience in carbonate rock investigation, having carried out seismic surveys in the following limestone areas:

- Pillara Springs, W.A. 1979
- Canberra, A.C.T. 1956
Calcrete in S.A. at Maralinga and on Flinders Highway
1954-55 and 1974-75
Northern Delta area of New Guinea 1972

Professor Hawkins has had some 28 years experience as a practicing
geophysicist, specialising in seismic surveys.

Brian C. Burman – Managing Director, Coffey & Partners Pty. Ltd.
Dr. Burman would supervise development of the aquifer model proposed in
the Terms of Reference. His fields of special competence cover computer
applications in geotechnical and water resource engineering, mining studies,
including stability of open pit slopes and underground workings. Dr. Burman
obtained his PhD for research into numerical modelling of the mechanics of
discontinuous masses and stability of slopes in jointed rock. He is responsible
for the development of computer applications and digital modelling studies
within the Company and has developed both steady state and transient finite
element seepage models.

M. Jeffrey Fulton – Computing Engineer, Coffey & Partners Pty. Ltd.
Mr. Fulton would be engaged in the development of the proposed numerical
model and would be responsible for model calibration under the general direction
of Dr. Burman. Mr. Fulton has carried out post-graduate studies into computer
applications and over the past year has undertaken many seepage model studies
using the finite element programs previously mentioned.

Raymond E. Volker – Senior Lecturer in Engineering, James Cook
University of North Queensland
Dr. Volker, whose experience in the numerical modelling of groundwater
flow systems is well known, will be available as an adviser and review
consultant with respect to aquifer modelling. He has been involved in this
field for the past 9 years, has published widely on the subject and is an
acknowledged Australian authority on groundwater modelling.
5.2 Timing

The Terms of Reference set down a quite rigid timetable for both Projects 1 and 2.

Project 1 is expected to commence about 1st November 1979 and to have a duration of 5 months, concluding at the end of March 1980.

Project 2 has a project duration of 7 months and if proceeded with should commence around April 1980, concluding in October or November 1980 prior to the 80/81 wet season.

Figures 1 and 2 present bar charts showing the estimated activity durations and personnel involvement. One problem foreseen with this timing is the probability of access problems for the geophysical investigations in Project 1. Ideally, geophysics should be done soon after the wet, when the ground is moist enough to obtain good electrode contact but dry enough for trafficability. We have based our proposal on access being available but point out that this could present difficulties.

As far as Project 2 is concerned the timing seems to have been based on the use of one drilling rig. It is recommended that consideration be given to using two rigs operating concurrently. They could probably be adequately supervised by one experienced person, possibly with assistance from a technical officer if the distance between rigs was significant.

This would cut the duration of the project in half and also effectively halve the supervision costs. We have adopted this approach in our cost estimate for Project 2. Of course, it would also enable the drilling results to be known 3 to 4 months earlier and allow extra drilling in the 1980 dry season if required.
### McNINNS—BENHAM LAGOON REGION
**GROUNDWATER INVESTIGATION**

**ESTIMATED STAFFING SCHEDULE — PROJECT 1**

**FIGURE 1**

<table>
<thead>
<tr>
<th></th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Authorisation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Note: No allowance is for Xmas break but this will have to be taken into account</td>
</tr>
<tr>
<td>2. Office &amp; Field Studies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Review of existing data, monitoring, data collection &amp; analysis, development of aquifer model, review of bore design and construction techniques, review of existing McNinns field etc.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downhole logging of selected bores</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical and seismic refraction surveys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Prepare draft report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Review of draft report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Prepare final report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BM Harris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EH Bruce</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RJ Whiteley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LV Hawkes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BC Burman</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MJ Fulton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE Walker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Estimated total man days 200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Estimated Man Days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>55</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
</tr>
</tbody>
</table>

---

Access may prove difficult for geophysical surveys.

---

*Full time involvement*  
*Part time involvement*  

---

*Estimated total man days*  
*Estimated total man months*
### Activity

<table>
<thead>
<tr>
<th>Activity</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Authorisation (assumed date)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Drilling Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logging</td>
<td>8.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Development &amp; testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water analyses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Electrical and Seismic Refraction Surveys</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(if required)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Prepare Draft Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Review Draft Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Prepare Final Report</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consultant</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.M. Harris</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E.H. Burke</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R.J. Whiteley</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I.V. Hawkins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Estimated Staffing Schedule -- Project 2**

**FIGURE 2**

<table>
<thead>
<tr>
<th>Activity</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Authorisation (assumed date)</td>
<td>2</td>
<td>dr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Drilling Operations</td>
<td>1</td>
<td>dr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Electrical and Seismic Refraction Surveys</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Consultant**

- B.M. Harris
- E.H. Burke
- R.J. Whiteley
- I.V. Hawkins

**Estimated Mon. Days**

- 15
- 80
- 15
- 15

**Estimated total man days**

- 175
- at 5.5 man months
6.0 BASIS OF ENGAGEMENT OF CONSULTANTS AND COST ESTIMATE

It is proposed that the study be carried out in accordance with the Terms of Engagement of the Association of Consulting Engineers, Australia (revised 1977) with charges assessed on a time and expenses basis in accordance with appendices F, J and L of the Terms of Engagement and Coffey & Partners Pty. Ltd. Terms of Engagement and Scale of Fees, July 1979 (Attachment C).

The indicative timing and duration of the activities of the consulting team are shown in Figures 1 and 2. These schedules have been used to establish the estimates of fees set out below.

Actual fees, however, would be based on time spent on the job. Time spent would be charged on the basis of 8 hours per day or part thereof. Any escalation of fees would be as set out in Attachment C.

The Department would be kept fully informed of any amendments or significant adjustments to the programme likely to result in increases in the fee total as set out below.

6.1 Fee and Cost Estimate - Project 1

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Estimated Time (man days)</th>
<th>Hourly Rate $</th>
<th>Daily Rate $</th>
<th>Estimated Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.M. Harris</td>
<td>45</td>
<td>41.00</td>
<td>328</td>
<td>14,760</td>
</tr>
<tr>
<td>E.H. Briese</td>
<td>55</td>
<td>28.00</td>
<td>224</td>
<td>12,320</td>
</tr>
<tr>
<td>R.J. Whiteley</td>
<td>30</td>
<td>40.00</td>
<td>320</td>
<td>9,600</td>
</tr>
<tr>
<td>L.V. Hawkins</td>
<td>30</td>
<td>40.00</td>
<td>320</td>
<td>9,600</td>
</tr>
<tr>
<td>B.C. Burman</td>
<td>10</td>
<td>41.00</td>
<td>328</td>
<td>3,280</td>
</tr>
<tr>
<td>M.J. Fulton</td>
<td>25</td>
<td>25.00</td>
<td>200</td>
<td>5,000</td>
</tr>
<tr>
<td>R.E. Volker</td>
<td>5</td>
<td>41.00</td>
<td>328</td>
<td>1,640</td>
</tr>
<tr>
<td>Total Man Days</td>
<td>200</td>
<td>Estimated Total Fees</td>
<td>$56,200</td>
<td></td>
</tr>
<tr>
<td>or 9 man months</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In addition to the above, other costs would be incurred, estimates of which are given below:

1. Consultants Home Office Staff:
   Drafting, composing, compilation of data etc. - allow
   $3,000.00

2. Air Fares - Sydney-Darwin-Sydney
   allow 10 No. @ $480
   $4,800.00

3. Accommodation - Darwin
   allow 150 man days @ $50
   $7,500.00

4. Vehicle Hire - Darwin
   allow 120 vehicle days @ $35
   $4,200.00

5. Electrical Surveying
   Contractor: 20 days @ $350
   (includes all equipment, operator, field hand)
   $7,000.00
   2 extra field hands - allow
   $3,200.00

6. Seismic Surveying
   Hire of seismograph, explosives, detonators etc.
   20 days @ $300
   $6,000.00
   3 field hands - allow
   $4,800.00

7. Borehole Logging
   Hire of Logger c/w probes
   allow 2 weeks @ $450
   $900.00

8. Miscellaneous
   Includes communications, air freight, taxi fares etc. - allow
   $1,500.00

Estimated Costs - Project 1
$42,900.00
Thus, the total estimate for both fees and costs for Project 1 is $56,200 + $42,900 = $99,100.

**Computer Charges**

Only approximate estimates for computer charges can be given at this stage since the final amount will depend heavily on decisions which need to be made as the project proceeds.

Initial model development is likely to cost approximately $1,500 with subsequent modifications to model geometry costing between $100 and $400 depending on the extent of the changes. As it is unlikely that substantial changes would be required more than once or twice, total model development costs should not exceed $2,500.

Costs of running the model, both in the calibration phase and the policy evaluation phase will depend on whether a steady state or transient model is used. Typical steady state runs cost $150, while transient model runs may cost five to six times this amount. It is important to note, however, that several runs of the steady state model, with different initial conditions, would be required in place of a single run with the transient model.

Costs for the calibration phase will also be influenced by the availability and quality of the field data. However, a figure of $2,000 should cover most eventualities.

Charges for the policy evaluation stage are the most difficult to estimate. As well as the type of model used, these will depend on the extent of changes made to the policies being considered. There is also the question of whether comprehensive policy evaluation is to be carried out as part of this project or at a later stage by the Department using the models developed during the project.
At this point it is suggested that an allocation of $2,500 should be made to this area for initial evaluation and demonstration of the model to the Department and that a decision then be made as to how the evaluation should proceed.

It should be noted in this context that if the Department requires to run the model on its own computer facilities a separate charge would need to be made for the finite element programs used, as distinct from the data prepared for these programs as part of the project.

Department of Transport Input to Project 1

- Surveying services
- Water analyses
- Technical assistant to assist water level measurements, bore logging etc.
- Maps, plans, aerial photos, files etc.
- Office space and facilities in Darwin

6.2 Fee and Cost Estimate - Project 2

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Estimated Time (man days)</th>
<th>Hourly Rate $</th>
<th>Daily Rate $</th>
<th>Estimated Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>B.M. Harris</td>
<td>15</td>
<td>41.00</td>
<td>228</td>
<td>4,920</td>
</tr>
<tr>
<td>E.H. Briese</td>
<td>80</td>
<td>28.00</td>
<td>224</td>
<td>17,920</td>
</tr>
<tr>
<td>Total Man Days</td>
<td>95</td>
<td>Estimated Fees</td>
<td></td>
<td>$22,840</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition to the above the following is an estimate of fees if further geophysical work is done.

<table>
<thead>
<tr>
<th>Consultant</th>
<th>Estimated Time (man days)</th>
<th>Hourly Rate $</th>
<th>Daily Rate $</th>
<th>Estimated Cost $</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.J. Whiteley</td>
<td>15</td>
<td>40.00</td>
<td>220</td>
<td>4,800</td>
</tr>
<tr>
<td>L.V. Hawkins</td>
<td>15</td>
<td>40.00</td>
<td>220</td>
<td>4,800</td>
</tr>
<tr>
<td>Total Man Days</td>
<td>30</td>
<td>Estimated Fees</td>
<td></td>
<td>$9,600</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Estimated Total Fees</td>
<td></td>
<td>$32,440</td>
</tr>
</tbody>
</table>
An estimated staffing schedule for Project 2 is given in Figure 2.

In addition to the above, other costs would be incurred, estimates of which are given below:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Consultants Home Office Staff: Drafting, composing, compilation of data etc. - allow</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>2. Air Fares - Sydney-Darwin-Sydney allow 6 No. @ $480</td>
<td>$2,880.00</td>
</tr>
<tr>
<td>3. Accommodation - Darwin allow 125 days @ $50</td>
<td>$6,250.00</td>
</tr>
<tr>
<td>4. Vehicle Hire - Darwin allow 110 vehicle days @ $35</td>
<td>$3,850.00</td>
</tr>
<tr>
<td>5. Electrical Surveying: Contractor: 10 days @ $350 (includes all equipment, operators, field hand)</td>
<td>$3,500.00</td>
</tr>
<tr>
<td>2 extra field hands - allow</td>
<td>$1,600.00</td>
</tr>
<tr>
<td>6. Seismic Surveying Hire or seismograph, explosives, detonators etc.</td>
<td>$3,000.00</td>
</tr>
<tr>
<td>10 days @ $300</td>
<td></td>
</tr>
<tr>
<td>3 field hands - allow</td>
<td>$2,400.00</td>
</tr>
<tr>
<td>7. Miscellaneous Includes communications, air freight, taxi fares etc. - allow</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Estimated Costs - Project 2</td>
<td>$25,480.00</td>
</tr>
</tbody>
</table>
Thus, the total estimate for both fees and costs for Project 2 is $32,440 + $25,480 = $57,920.

Additional to the above would be the cost of constructing 15 No. test bores as proposed.

The best way of organising the drilling operations will have to be determined at a later date. Options are:

1. Use N.T. Government drilling rig
2. Use private contractor operating under N.T. Government period contract
3. Draw up specifications and call tenders especially for this project

It is assumed that the Water Division would arrange the drilling but we would be prepared to do so if required. On the basis of preliminary quotations obtained from private drilling contractors it is estimated that this part of the work could cost in the order of $100,000.

Department of Transport Input to Project 2

- Surveying services
- Water analyses
- Borehole logging machine
- Office space and facilities in Darwin, if required
- Technical assistant for drilling supervision, if required

7.0 COFFEY & PARTNERS PTY. LTD. EXPERIENCE IN GROUNDWATER INVESTIGATIONS

A brochure describing Coffey & Partners groundwater activities is given as Attachment D and a listing of recent groundwater projects is given in Attachment E.
<table>
<thead>
<tr>
<th>Project</th>
<th>Client</th>
</tr>
</thead>
<tbody>
<tr>
<td>Singida groundwater project, Tanzania, East Africa</td>
<td>Snowy Mountains Engineering Corporation</td>
</tr>
<tr>
<td>Hydrogeology of proposed petrochemical plant site, Point Wilson, Victoria</td>
<td>ICI (Australia) Ltd.</td>
</tr>
<tr>
<td>Investigation of brine deposits, Lake Tyrrell area, Victoria</td>
<td>ICI (Australia) Ltd.</td>
</tr>
<tr>
<td>Dewatering design and monitoring, Eraring Power Station, N.S.W.</td>
<td>Electricity Commission N.S.W.</td>
</tr>
<tr>
<td>Burma village water supplies project - implementation and monitoring evaluation, Burma</td>
<td>Australian Development Assistance Bureau</td>
</tr>
<tr>
<td>Preliminary appraisal of groundwater resources in the Darwin area, N.T.</td>
<td>Snowy Mountains Engineering Corporation</td>
</tr>
<tr>
<td>Groundwater investigation and dewatering design for basalt quarry, Griffith, N.S.W.</td>
<td>Farley &amp; Lewers Ltd.</td>
</tr>
</tbody>
</table>

Current projects in Australia and overseas include:
P666
29th August 1979

Dewatering - design and implementation for trial open cut coal pit, Port Wakefield, S.A.

Electricity Trust of South Australia
ATTACHMENT A

LETTER OF INVITATION

AND TERMS OF REFERENCE
DEPARTMENT OF TRANSPORT AND WORKS

P.O. BOX 2620
DARWIN NT 0801

REFERENCE 4-17-42

7 August 1979

Coffey and Partners Pty Ltd.,
P.O. Box 125,
NORTH RYDE, NSW. 2113

Dear Sirs,

MCMINNS - BENHAM LAGOON REGION - GROUNDWATER INVESTIGATION

You are invited, as one of several consultants, to submit a proposal for professional services to prove the feasibility of developing a major borefield in the McMinns - Benham Lagoon region.

Relevant information is attached.

Your proposal which may be used as a basis for the negotiation of a contract, should include the following information:

- review of terms of reference
- explanation of any deviation from prescribed terms of reference
- method of approach
- organization and programme
- proposed services to be provided by Department
- manpower schedule in bar chart form covering the duration of the commission
- curricula vitae of nominated personnel
- cost proposal giving hourly home offices rates, daily field rates and details of reimbursable items.

Separate cost proposals should be given for Projects 1 and 2. The successful completion of Project 1 may, but will not necessarily, lead to the engagement of the consultant on Project 2.

Please acknowledge receipt of this letter of invitation and indicate if the assignment is of interest to you.
Proposals should be delivered by 31 August, 1979.

Yours faithfully,

[Signature]

Hugh Wand
for A/Director
Water Division

Telephone: 812153
BACKGROUND

An appraisal of the McMinn's - Benham Lagoon region, shown on the attached map, indicates a large groundwater potential and studies are now being undertaken to prove the feasibility of establishing a major borefield to supply potable water to Greater Darwin and Darwin East.

Appended is an investigation programme now being carried out by the Project Leader and staff members of the Water Division; it is intended to commission a consultant for two related projects.

Project 1

A desk study and field investigation described in the Terms of Reference.

- Project period: 5 months
- Professional input: 9 man/months

Project 2

Test Drilling

- Project period: 7 months
- Professional input: 7 man/months

OBJECTIVES

The purpose of the commission is to:

1. locate a production borefield or borefields, with an initial safe yield of 45 ML/day of potable water, suitable for economic incorporation into the Darwin water supply system.

2. establish a water balance to ensure that borefield operation will not diminish the present yield available from existing domestic, agricultural, pastoral and production bores.

3. develop a model for use in the preparation of a plan of management to provide policy guidelines for the extension of production borefields and for an increase in the number of private domestic, agricultural and pastoral bores being sunk.
Project 1

1. Collaborate with Project Leader in reviewing and analysing existing data including examination of borehole logs, borehole cuttings and geophysical surveys, preparation of geological sections and photo interpretation.

2. Collaborate with Project Leader in monitoring a selected network of bores in the McMinns - Benham Laupon area.

3. Carry out down hole logging of selected bores by appropriate methods.

4. Carry out reflection seismic and refraction seismic profiling of areas of interest.

5. Collaborate with Project Leader in the collection and analysis of additional data required to provide a wider understanding of the hydrogeology of the area.

6. Develop an aquifer model in a format compatible with Water Division's computer facilities for use in planning production borefields and formulation of long-term management policies.

7. Recommend appropriate bore design, drilling techniques and standards of construction to be followed.

8. Examine technical feasibility and economic viability of re-starting existing McMinn's borefield.

9. Prepare draft Terms of Reference for Project 2 covering a test drilling programme to prove the groundwater potential of the area.

10. Submit four copies of a draft report within four months of acceptance of proposal.

11. Submit twenty copies of final report within four weeks of return of approved draft.

Project 2

1. Subject to the findings of Project 1 investigations it is envisaged that a test drilling programme will be undertaken comprising about 15 holes to depths between 60m and 100m.
2. At the conclusion of drilling the bores will be geophysically logged and then completed as observation bores.

3. Water samples will be taken for chemical analysis.
McMINNS - BENHAM LAGOON REGION

AREA TO BE INVESTIGATED FOR
MAJOR BOREFIELD

Scale = 1 : 250,000
DRAFT BRIEF

1. Project Title          := Darwin Rural Area Hydrogeology
2. Project No             := 90 Priority : 9
3. Prepared By            := R. Sureshi
4. Project Timetable     := Attached

GEOLOGIC WORK

This includes :

(i) Review of adequacy of bores to provide a monitoring network and the selection of bores to be included in the initial geochemical survey.

(ii) Examination of available bore logs and cores and then selections of bore network to be included in R.L. survey.

(iii) Preparation of 1:10 000 overlays showing R.C. and p.H. and piezometric contour maps.

(iv) Estimate yield and recharge up the study area. Prepare a programme of drilling and pump testing considered to be desirable.

BORE LOCATION AND DATA COLLECTION AND COLLATION

This includes :

(i) Compilation of list of existing bores, springs and gauging stations in the study area.

(ii) Preparation of 1:10 000 working sheets showing boundaries of freehold and crown land blocks, tenants names and reputed position of bores and springs.

(iii) Field work comprising :

(a) Physical check of existence of bore,
(b) Measure T.D., S.W.L.
(c) Accurate plotting of bore on 1:10 000 maps.

(iv) Revision of 1:10 000 bore location maps showing diameter, total depth and depth to S.W.L. at date of survey.

(v) Preparation of 1:10 000 overlays and piezometric contour maps.
DRILLING

This includes :-

(1) Drilling of investigation holes.

TEST-PUMPING AND WATER SAMPLE COLLECTION

This includes :-

(i) Test-pumping and W/S collection from investigation bores.
(ii) Test-pumping and W/S collection from other selected bores.

SURVEY AND LEVELLING OF HOLES

This includes :-

(i) Execution of a R.I. survey including establishment of Water Division Benchmarks for future reference.

DEAFTING

This includes :-

(i) Preparation of a 1:10 000 keyplan showing extent of study area and key to 1:10 000 working sheets.
(ii) Drafting of 1:10 000 overlay showing E.C. and p.H. isopleths and lithology.
(iii) Drafting of piezometric contour maps.

REPORT WRITING

This includes :-

(i) Writing a detailed report on the study area.

PROJECT PERSONNEL

Project Leader :- H. Qureshi
Project Officer :- Hydrogeologist I (to be appointed)
T.O.I. :- G. Wright
T.A.II :- G. McSann
Field Assistant :- G. Moszadri

6.7.77
<table>
<thead>
<tr>
<th>1979</th>
<th>1980</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL</td>
<td>AUG</td>
</tr>
<tr>
<td>SEP</td>
<td>OCT</td>
</tr>
<tr>
<td>NOV</td>
<td>DEC</td>
</tr>
<tr>
<td>JUL</td>
<td>FEB</td>
</tr>
<tr>
<td>MAR</td>
<td>APR</td>
</tr>
<tr>
<td>MAY</td>
<td>JUN</td>
</tr>
<tr>
<td>JUL</td>
<td>AUG</td>
</tr>
<tr>
<td>SEP</td>
<td>OCT</td>
</tr>
<tr>
<td>NOV</td>
<td>DEC</td>
</tr>
</tbody>
</table>

**PROJECT 90**

1. **GEOLICAL WORK**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

2. **Bore Location and Data Collection**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

3. **Drilling**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

4. **Test Pumping with Collect**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

5. **Survey and Leveling of Bores**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

6. **Drafting**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

7. **Report Writing**
   - 1979: Activity Timeline
   - 1980: Activity Timeline

8. **Hydro Geologist**
   - 1979: Activity Timeline
   - 1980: Activity Timeline
   - T. D. I.
   - T. A. I.
   - F. A.
ATTACHMENT B

CURRICULA VITAE
DATE OF BIRTH 5th March, 1940

COUNTRY OF CITIZENSHIP Australia

EDUCATIONAL QUALIFICATIONS
Bachelor of Science, University of Adelaide, 1964
Post Graduate studies in Engineering Hydrology, University of New South Wales, 1969
Master of Science, Flinders University of South Australia, 1972.

FIELDS OF SPECIAL COMPETENCE
Hydrogeology including groundwater exploration, assessment of groundwater basins and design and construction of groundwater wells.

EXPERIENCE AND COUNTRIES WORKED IN
Over 14 years of professional experience in groundwater development in Australia, Thailand, Indonesia and the United States.

1965 - 1972
Assistant Senior Geologist, Department of Mines, South Australia on a broad range of investigation of groundwater basins, groundwater exploration, high water table problems in irrigation areas and development of town water supplies. Major projects include:

- Investigations of areas proposed for the disposal by evaporation of saline water underflow from the Chowilla Dam and evaluation of seepage return to the Murray River.
- Investigations of construction material sources for Chowilla Dam.
- Engineering geological investigations of the Kangaroo Creek dam site.

- Investigations into the development of high water table conditions in the Murray River irrigation areas in South Australia. The studies included the evaluation of seepage to the river and subsoil drainage schemes.

- Investigations of the groundwater resources of the Northern Adelaide Plains basin.
Regional assessment of the groundwater resources in the south east of South Australia, a groundwater province of some 10,000 square km. Detailed investigations of the groundwater resources in the Padthaway Irrigation area. Development of town water supplies.

1972 - 1977

Associate, Dames & Moore. Involved in hydrological investigations for water resource development, environmental and dewatering studies. Major projects included groundwater and dewatering studies at the Mt. Newman Mine, W.A., design of a dewatering scheme for a large dry dock in Western Australia, the development of a scheme to trap and remove oil seepage on groundwater in an industrial area. Overseas experience includes:

- Development of a large groundwater supply for a pineapple plantation in Thailand. This was the first major development of groundwater in the region.
- Hydrological studies for preliminary safety analysis report on a nuclear power plant in Missouri, U.S.A.
- Resident in Indonesia from 1974 until 1977 and carried out investigations for development of groundwater supplies for timber developments, industrial and mining development in Indonesia.

1977 - present

Principal Geologist, Coffey & Partners Pty. Ltd. 
Evaluation of City of Sale town water supply. 
Investigation into the dewatering of a proposed dry dock near Lake Macquarie, New South Wales.

Investigation and design of water supply for the City of Kota Bumi, South Sumatra. This was the first major development of groundwater in this region and involved geological and geophysical surveys, exploration and production bore drilling and the design of production borefields.

Investigation of groundwater supply potential for the twin cities of Tanjung Karang and Teluk Betung, Indonesia.

Village water supply development, South Sumatra involving hydrogeological and geophysical surveys for a pilot investigation.
Review of groundwater potential, Lamongan and Juana-Pati, Java, Indonesia.

Review of effects of sand mining operations on groundwater quality, Fraser Island, Queensland.

Open cut coal mine - feasibility study, Blackwater, Queensland.

Review of groundwater development programme for irrigation tubewells, Bangladesh.

Evaluation of organisational procedure for monitoring technical progress in 3100 village water supply programme, Burma.

Review of groundwater potential for augmentation of Darwin City Water Supply.

Investigation of groundwater regime for environmental purposes in region of proposed major petrochemical plant, Geelong, Victoria.

Investigation of saline groundwater for major proposed saltmaking field, Victoria.
DATE OF BIRTH: 6th June, 1947
COUNTRY OF CITIZENSHIP: Australia
EDUCATIONAL QUALIFICATIONS: Bachelor of Science (University of Adelaide) 1969.

Bachelor of Science Honours (University of Adelaide) 1970.

PROFESSIONAL MEMBERSHIP: Australian Institute of Mining & Metallurgy
FIELDS OF SPECIAL COMPETENCE: Hydrogeology - groundwater exploration, assessment of groundwater basins, design & construction of groundwater wells and groundwater pollution studies.

PROFESSIONAL EXPERIENCE: Some 9 years of professional experience, 3 years in mineral exploration and 6 years in hydrogeology.

1971 - 1973 Project Geologist - Samedan of Australia
1974 Project Geologist - Amdex Mining
1974 - 1979 Hydrogeologist - Geological Survey of Western Australia.
1979 - present Hydrogeologist - Coffey & Partners Pty. Ltd.

MAJOR PROJECTS:

<table>
<thead>
<tr>
<th>Year</th>
<th>Project/Location</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>Orange, N.S.W.</td>
<td>Geologist-in-charge of field investigations for base metal deposits. The exploration programme was designed to locate copper-lead-zinc mineralisation in acid volcanic rocks. It involved regional and detailed geological mapping, a detailed geochemical survey and diamond drilling.</td>
</tr>
</tbody>
</table>

continued...
### MAJOR PROJECTS (cont'd.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Project/Location</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1973</td>
<td>Yilgarn Block, W.A.</td>
<td>To assess nickel and uranium leases and to put forward proposals for exploration programmes.</td>
</tr>
<tr>
<td>1974 - 1976</td>
<td>Canning Basin, W.A.</td>
<td>To investigate and evaluate the groundwater potential of the south-west portion of the Canning Basin as a possible future resource for the developing communities in the iron ore region of the Pilbara of W.A. An area of over 3000 km² was investigated by surveying all existing station bores and wells, geophysical (seismic) surveys, and drilling. Over 60 bores were drilled by the rotary mud technique to depths of up to 360m. Duties involved supervision of drilling, construction design of bores for both artesian and water table conditions, interpretation of geophysical logs (gamma, resistivity, self potential), selection of aquifers to be screened and bore screens, design of pump and flow tests and the evaluation of all data obtained.</td>
</tr>
<tr>
<td>1976 - 1977</td>
<td>Moora, W.A.</td>
<td>To investigate and evaluate the aquifer potential of the on-shore part of the Perth Basin, west of Moora. A line of bores spaced every 5 km were drilled to a maximum depth of 800m. Duties included drill supervision, regional survey of all existing bores, interpretation of geophysical logs, selection of formations and aquifers for testing, construction design of bores and design test programmes. Supervision of pump tests on deep bores in the southern Perth Basin, using pressure transducers and chart recorders to record data.</td>
</tr>
</tbody>
</table>
**MAJOR PROJECTS, cont.:**

<table>
<thead>
<tr>
<th>Year</th>
<th>Project/Location</th>
<th>Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978 - 1979</td>
<td>Dwellingup, W.A.</td>
<td>To study the effects of bauxite mining on the groundwater hydrology of the Darling Range, W.A. This involved supervision of drilling bores in paired catchments &amp; the monitoring of water and salinity levels to gauge the effects of clearing one catchment &amp; mining it. To assess the hydrogeology &amp; recommend bore sites for groundwater supplies for the townships of Nagumbat &amp; Dandaragan, W.A. To supervise drilling and construction of these bores.</td>
</tr>
<tr>
<td>1979</td>
<td>Coffey &amp; Partners Pty. Ltd. - Hydrogeologist.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dora Creek, N.S.W</td>
<td>Investigation for the dewatering of the caisson construction area, intake canal, Eraring Power Station, Dora Creek, N.S.W.</td>
</tr>
<tr>
<td></td>
<td>Port Wakefield, S.A.</td>
<td>Supervision of drilling and bore construction for dewatering of trial pit for open cut coal mining operation. Electricity Trust of South Australia, Port Wakefield, S.A.</td>
</tr>
</tbody>
</table>

**LANGUAGES Spoken:** English, German & French.
EDUCATIONAL QUALIFICATIONS:  
BSc(Hons), Sydney University, 1967  
MSc, Sydney University, 1972  
Member, Australian Society of Exploration Geophysicists  
Member, Society of Exploration Geophysicists  
Member, European Association of Exploration Geophysicists

EXPERIENCE:

1967 - 1970  
Geophysicist, Engineering Group Bureau of Mineral Resources - supervision of geophysical programs for dam, bridge, building foundation sites, groundwater, coal exploration, etc. throughout Australia and New Guinea.

1970 - 1972  
General Manager, Lightning Ridge Mining NL, Senior Geophysicist, Metals Investment Holdings NL - supervision and implementation of mineral exploration programs in Australia.

1973 - present  
Lecturer in Applied Geophysics, University of N.S.W. Consultant to numerous engineering, mineral and petroleum companies

PUBLICATIONS:

* denotes co-author  
** denotes senior author  
no symbol denotes sole author

* 1968  
A Field Test of the Unipole Method of Resistivity Profiling, Aust. Jour. Sci. Vol 31 No. 4

** 1971  
A Combined Deep Resistivity and Magneto-telluric Sounding in the Eromanga Basin, Qld., Search Vol 2 No. 3

1971  

1973  


Effective Application of the Seismic Refraction Method to Highway Engineering Projects, Aust. Road Research Vol 6 No. 5


The Geology and Magnetic Characteristics of Precious Opal Deposits, South West Queensland, B.M.R. Journal of Australian Geology and Geophysics 2, 1977

A Hydrogeological Assessment of the Lucas Heights Land Fill, Waste Disposal and Water Management in Australia, p 10


Velocity Inversion and the Shallow Seismic Refraction Method, Geoexploration 17, 1979

Monography accepted for publication

1979 (editor) Geophysical Case Study of the Woodlawn Ore Body, N.S.W., Accepted by Pergamon Press Oxford, Jan 1979 pp 500
SPECIFIC EXPERIENCE IN LIMESTONE (KARST) TERRAINS:

Whilst with the B.M.R. was a consultant to the British Phosphate Commission for groundwater exploration on Christmas Island using resistivity methods.

With Metals Investment Holdings NL - supervised and carried out base metal exploration programs for Mississippi Valley-type deposits in the Georgina Basin, NT using reconnaissance geophysical methods.

Have recently been a consultant to BHP using seismic methods to explore reefal complexes in Western Australia.

1973 - 1979

Consultant and advisor to the following companies and organisations

Engineering Firms

Dames & Moore - coal exploration, cathodic protection of pipelines in NSW using electrical resistivity

Coffey & Partners Pty. Ltd. - foundation studies for oil storage tanks, Kurnell, NSW using seismic methods

Golder Associates - foundation studies for offshore extensions of sewer outfalls in NSW using marine seismic methods

McDonald Earthmoving Pty. Ltd. - highway studies in SA using seismic methods

Mineral Exploration Companies

BHP - base metal exploration limestone terrains, WA using seismic and gravity methods

Peter H. Stitt & Associates - industrial mineral exploration in NSW using seismic and electrical methods

Pancontinental Mining Ltd. - uranium exploration, NT using aeromagnetic methods

Getty Mining Co. - base metal exploration, Qld using aeromagnetic methods
<table>
<thead>
<tr>
<th>Company</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pechiney Limited</td>
<td>Aeromagnetic and radiometric</td>
</tr>
<tr>
<td></td>
<td>exploration for uranium</td>
</tr>
<tr>
<td>Russgar Minerals NL</td>
<td>Base metal exploration, SA</td>
</tr>
<tr>
<td></td>
<td>using soil geochemistry</td>
</tr>
<tr>
<td>Petroleum Exploration Companies</td>
<td></td>
</tr>
<tr>
<td>Burmah Oil Company Aust. Ltd.</td>
<td>Aeromagnetic exploration North</td>
</tr>
<tr>
<td></td>
<td>West Shelf</td>
</tr>
<tr>
<td>AMAX</td>
<td>Aeromagnetic exploration North</td>
</tr>
<tr>
<td></td>
<td>West Shelf</td>
</tr>
<tr>
<td>Contracting Companies</td>
<td></td>
</tr>
<tr>
<td>McPhar Geophysics Ltd.</td>
<td>Uranium exploration using</td>
</tr>
<tr>
<td></td>
<td>seismic and electrical methods</td>
</tr>
<tr>
<td>Geosearch Pty. Ltd.</td>
<td>Petroleum exploration, WA</td>
</tr>
<tr>
<td></td>
<td>using aeromagnetic methods</td>
</tr>
<tr>
<td>Layton &amp; Associates</td>
<td>Radiometric exploration for</td>
</tr>
<tr>
<td></td>
<td>uranium, NT</td>
</tr>
<tr>
<td>Geometries International Corp.</td>
<td>Marketing and use of Nimbus</td>
</tr>
<tr>
<td></td>
<td>seismic equipment</td>
</tr>
<tr>
<td>Soilcrete Pty. Ltd.</td>
<td>Advisor on seismic equipment</td>
</tr>
<tr>
<td>Government Authorities</td>
<td></td>
</tr>
<tr>
<td>Electricity Commission of NSW</td>
<td>Foundation conditions, proposed</td>
</tr>
<tr>
<td></td>
<td>collieries using seismic methods</td>
</tr>
</tbody>
</table>
LARI C V. HAWKINS

EDUCATIONAL QUALIFICATIONS: MSc

POSITION:
Assoc. Professor, School of Applied Geology, University of New South Wales

EXPERIENCE:
1951 - 1952
Demonstrator, Dept. Geology & Geophysics, University of Sydney

1952 - 1958
Geophysicist, Bureau of Mineral Resources

1958 - present
Lecturer to Assoc. Professor in charge of Geophysics, School of Applied Geology, University of New South Wales

During this period, included was:
Dec 1963-July 1964 - Bursary holder of Royal Society of London at Imperial College

July 1964-February 1965 - Visiting scholar at Lamont Doherty Geological Observatory of Columbia University

August 1975-October 1977 - Senior Marine Geophysicist within United Nations Development Programme on Offshore Prospecting in East Asia (CCOP)

Field Survey Experience
Northern Territory (Darwin-Rum Jungle - South Alligator River area) 1953

Queensland (Dawson Valley, 1955, north east shelf and Queensland plateau, 1967)

South Australia (Maralinga 1954-55, Flinders Highway, 1974-75)

Western Australia (north west shelf and Exmouth plateau, 1969, also 1976)
Tasmania (Central Highlands 1953-54)

Victoria (Latrobe Valley 1957)

New South Wales (Condobolin 1956, Central West and throughout State 1958 on)

Australian Capital Territory (1956)

Experience in Conducting and Interpreting Seismic Surveys in Limestone Areas

Pillara Springs, W.A. 1979
Canberra, A.C.T. 1956
Calcrete in S.A. at Maralinga and on Flinders Highway 1954-55 and 1974-75
Northern delta area of New Guinea 1972

Experience in Conducting and Interpreting Surveys for Groundwater

Consultant geophysicist to both International Engineering Services Consortium (IESC) and NSW Water Conservation and Irrigation Commission (WC & IC - now Water Research Commission) for surveys in central western NSW, and University of NSW Fowlers Gap arid areas research station (Broken Hill)

Have been Consultant Geophysicist to:

BHP
Electricity Commission of NSW
International Engineering Services Consortium
Water Conservation & Irrigation Commission of NSW (now WRC)
NSW Department of Main Roads
Farley & Lewers
MacDonald Earthmovers
Peter H. Stitt & Associates
Shobu Corp.
Devex
Metals Investment Holdings
Planet Oil
Reef Oil
Munumba Oil
DR. B. C. BURMAN

2. DATE OF BIRTH
7th April, 1941

3. COUNTRY OF CITIZENSHIP
Australia

4. EDUCATIONAL QUALIFICATIONS
B.E. (Hons) University of Queensland 1964
University Medal.
M.Eng.Sc. University of Queensland 1966
PhD. James Cook University, North Queensland 1972
Fellow of Institution of Engineers, Australia, 1977
Warren Memorial Prize from Institution of Engineers, Aust., 1975

5. FIELDS OF SPECIAL COMPETENCE
Computer applications in geotechnical and water resource engineering. Mining studies including stability of open pit slopes and underground workings.

6. EXPERIENCE AND COUNTRIES WORKED IN

1964 - 1965
Coffey & Hollingsworth - site investigation work associated with civil and industrial developments.

1965 - 1966
Design engineer with Cardno & Davies for civil and structural projects - roads, bridges, multi-storey buildings, sewerage roadworks and canal developments.

1966 - 1968
Senior Engineer with Coffey & Hollingsworth on port site developments, road locations investigations in Australia and New Guinea, foundation investigation for Austral Pacific Fertiliser plant in Brisbane, rock slope stabilisation for King George Square car park.

1968 - 1971
A.M.I. R.A. Research Fellow and doctoral candidate at James Cook University, North Queensland. Research into numerical modelling for the mechanics of discontinuous masses and stability of slopes in jointed rock leading to the development of a finite element procedure to handle blockjointed materials.
1972 - 1973
Associate Director, Coffey & Partners Pty. Ltd. Brisbane

1973 - 1975
Director, Coffey & Partners Pty. Ltd. Brisbane

1975 - 1979
Managing Director, Coffey & Partners Pty. Ltd. Sydney

MAJOR PROJECTS:

1972 - 1973
Greenvale Nickel Plant, Townsville - investigation and design of foundations, excavation, water storage and tailings control dams for nickel treatment plant together with ore storage, handling and rail loading facilities at Greenvale mine site.

Weipa Bauxite Mine, Cape York - investigations and studies for railway embankment over soft soils; feasibility of dredging and deepening of Weipa Harbour; barrage across Embley River for water storage within tidal estuary involving foundations, material searches, stability and closure aspects.

Sungai Sarawak Road Bridge, Kuching, Malaysia - investigation and design of piled foundations and abutments to major prestressed concrete bridge.

1973 - 1975
Soroako Nickel Project, Sulawesi, Indonesia - investigation, design and testing for driven steel pile foundations for nickel treatment plant.

Central and Brunswick St. Railway Station Developments, Brisbane - investigation, design and supervision of bored pile foundations socketed into rock for multi-storey developments over existing railway stations.

Investigation and design for reconstruction and raising of puddle clay core dam built in 1866. Downstream rockfill construction and plastic diaphragm wall designed for raising existing dam by 11 m for flood mitigation purposes.

Hay Pt No. 2 Berth Project - investigation, design and construction aspects of sheet piled dry dock in Mackay Harbour for construction of concrete wharf caissons. Design and preparation of underwater foundations for caisson structures at Hay Pt.
Numerical modelling and computer analyses of various projects including seepage and stability studies for Ranger uranium tailings dam, Pancontinental uranium tailings dam, Woodlawn Mine tailings dam; stability and drainage for 300 m deep open cut coal mine at Leigh Ck. S.A; design of steel reinforced cement stabilised stacker-reclaimer banks for Pt Waratah coal loader, Newcastle; design of pavements and instrumented trial section of Monaro Highway, Canberra; simulation of dewatering and recharge system for dry dock excavation at Eraring Intake Canal.

Port Waratah Coal Loader, Newcastle involving investigations for materials handling structures, design of stacker-reclaimer support systems, total length 5 km on alluvial soils adjacent to Hunter River, investigation, design and supervision of foundations for coal loading berth with 25 m.t.p.a. capacity.

Intake Canal for Eraring Power Station, Lake Macquarie, NSW including investigation, design and construction monitoring of 2 km long open canal through soft clays with dewatered dry dock for construction of 300 m long concrete syphon structure, monitoring of construction.

Polypropylene Plant for ICI at Botany, Sydney - investigation, design and construction supervision of foundations for major chemical plant including pile loading test for large diameter (15 m) bored piles in sand cast under bentonite.

Goari 1 Oil Well, Papua New Guinea - investigation and design of driven pile foundations for oil rig platform in coastal swamp on Gulf of Papua, including driving and testing loading of piles.

Graving Dock, Newcastle - field investigation and numerical model studies of subsidence effects on piled concrete dock structure due to collapse of abandoned and flooded coal mine workings beneath Newcastle Harbour. Analyses carried out using jointed finite element technique produced criteria for dock structure design to withstand mine collapse.
M. JEFFREY FULTON

DATE OF BIRTH: 28th November 1955
COUNTRY OF CITIZENSHIP: Australia

EDUCATIONAL QUALIFICATIONS:
BE(Hons) 1976
James Cook University of North Queensland
Institution of Engineers Aust.
Northern Groups Award - 1976

EXPERIENCE:
1977
Northern Electric Authority of Queensland - construction supervision, high voltage transmission lines

1977 - 1978
Graduate student – James Cook University of North Queensland, Mount Isa Mines Ltd. Research Scholarship
Research into the application of discontinuum finite element models to problems of fill support of large underground openings.

1979
Geotechnical Computing Engineer, Coffey & Partners Pty. Ltd.

Finite element analysis of seepage loss for South Jabiluka tailings dam

Finite element study of piles on jointed rock foundations for Westgate Freeway, Melbourne

Finite element analysis of dewatering of caisson construction area, Eraring Power Station, NSW

Involved in a variety of other computer applications with emphasis on computer graphics and including reduction of field and laboratory test data, stability studies for pit and dam slopes, word processing and accounting.
RAYMOND E. VOLKER
Senior Lecturer in Engineering
James Cook University of North Queensland

PERSONAL:
Married, three children
Age - 34

EDUCATION:
BEng(Civil) with First Class Honours
University of Queensland - 1964
MEngSc, University of Queensland, 1966
MEngSc Thesis - "Flow Through Idealised Particle
Arrays" - the work involved a study of the regimes
of flow in porous media
PhD, James Cook University of Nth Qld, 1969
PhD Thesis - "Numerical Solutions to Problems of
Non Linear Flow Through Porous Materials" - the
work involved an application of finite difference
and finite element methods to solve seepage and
groundwater problems involving non linear flow.

EXPERIENCE:
1969 - 1971
Design Engineer, Government Railways, Brisbane Qld.

1971 - present
Lecturer and then Senior Lecturer in Engineering,
Civil Engineering Department, James Cook
University of North Queensland - responsible for:
Undergraduate courses in hydraulics, hydrology,
fluid mechanics and applied mechanics; Post-
graduate courses and supervision of research in
hydrology and groundwater studies; Supervision
of hydraulics laboratory and hydraulic model
studies.

1977.
Colorado State University - finite element river
models
University of Birmingham - groundwater models
(with Dr. K.R. Rushton)

PROFESSIONAL
AFFILIATIONS:
Member, Institution of Engineers, Australia
Member, American Society of Civil Engineers
SOME PUBLICATIONS


11. VOLKER, R.E. (1979) "Predicting the Extent of Sea Water Intrusion in a Coastal Aquifer" AWRC Groundwater Pollution Conference, Perth

12. GUVAASSEN, V and VOLKER, R.E. (1979) "Groundwater Quality Change in an Unconfined Aquifer due to an Inflow of Contaminated Water" AWRC Groundwater Pollution Conference, Perth


15. POWER, VOLKER, R.E. and STARK (1979) "Urban Water Consumption Patterns in Northern Australia", Institution of Engineers Hydrology Symposium, Perth
ATTACHMENT C

TERMS OF ENGAGEMENT AND SCALE OF FEES
I. INTRODUCTION
These Terms of Engagement and Scale of Fees apply to work carried out in Australia by Coffey & Partners Pty. Ltd. They are in accordance with the Terms of Engagement dated July 1977, and subsequently amended, of the Association of Consulting Engineers, Australia. Where an assignment carries unusual or special requirements, or where part of the work is to be carried out outside Australia, special rates may be negotiated.

2. CURRENCY OF FEE SCALES
This Scale of Fees applies to all work carried out in the six months period from 1st July 1979. The fees for professional staff, technical staff and for laboratory testing will be increased by the percentage indexation increase from the date of application of the indexation decision for all projects, regardless of their status at that time. The Company reserves the right to vary this scale of fees without notice.

3. PROFESSIONAL & TECHNICAL STAFF
All time spent on an assignment, including consultations, planning, supervision, inspection, preparing samples or equipment, travelling, field testing, sampling, surveying, correlations, special laboratory testing, drafting, preparation of results, interpretation and reporting will be charged at the following rates per hour, except for time spent on tests covered by the Schedule of Rates – see 4 (below).

- Principal Engineers & Geologists: $22.00 to $26.00
- Senior Engineers & Geologists: $22.00 to $28.00
- Senior Technical Officers: $24.00 to $28.00
- Technical Officers: $18.00 to $22.00
- Technicians: $13.00
- Tracing & Composer Operators: $15.00

4. LABORATORY TESTING
Laboratory tests commonly carried out in the Company’s work are charged in accordance with the attached Schedule of Rates for Standard Tests. Special tests not covered by the Schedule of Rates or procedures other than those shown will be charged at the hourly rates applicable to the personnel involved, at a previously negotiated rate. The minimum charge of $20 will apply to all laboratory testing. Where tests are carried out by others, charges will be in accordance with 6 “Reimbursable Expenses” (below).

5. SPECIALISED EQUIPMENT
Specialised equipment will be charged at the following rates. Fees for operator and for office interpretation will be charged at standard hourly rates (Sections 2 and 3) and reimbursable expenses will be charged as per Section 6.

- Static Cone Penetrometers: $175/day
- 2.5 tonne penetrometer: $100/day
- Manual penetrometer: $50/day
- Penetrometer used with drilling: $100/day

- Pressurerometers: $150/test
- Self boring pressuremeter (SBPM): $100/day
- High capacity pressuremeter (PMX-20): $100/day plus $30/test

- Seismic and Well Logging Equipment: $50/day
- Nurnous signal enhancement telemageograph: $50/day
- Electric resistivity meter: $25/day
- Australian borehole logger: self potential gamma: $100/day
- Pollution meter: $50/day

- Firefighting & Sampling Equipment: $30/day
- Vane shear apparatus: $30/day
- Piston sampler: $30/day
- Borehole impression and orientation device: $30/day

- Eclipse 5130 Computer: $20/hr
- Machine time: $60/hr

6. REIMBURSABLE EXPENSES
Expenses incurred by the Company or its employees in the course of, or attributable to, a particular assignment will be charged for as set out below:

6.1 Motor Vehicle Use
Use of motor vehicles in the course of an assignment will be charged at the following rates. These rates do not cover the travelling time of personnel.

- Motor car: $0.25 per km
- Four wheel drive: $40.00 per day (or part day) plus $0.50 per km

6.2 Communications
(a) Long distance telephone calls, telegrams, cables, overseas telex messages etc. will be charged at cost.
(b) Telex messages within Australia will be charged at the rate of two cents per second.

6.3 Other Expenses
All other expenses are the responsibility of the Client. Where invoices for such expenses are processed and paid by Coffey & Partners Pty. Ltd, the cost of such expenses will be charged for, together with a service fee of 7% of the cost of the expenses. Such expenses include:

(a) Services of other Consultants, Contractors, Laboratories, Computer Bureaux, Printing Services and the like
(b) Hire of plant such as drilling equipment, earthmoving equipment or other plant required for the assignment
(c) Transportation of personnel, equipment and samples
(d) Living expenses of personnel involved in assignments away from the city in which the office of Coffey & Partners Pty. Ltd, undertaking the assignment is situated.
(e) Rental charges for hired equipment or vehicles
(f) “Expendable” items or items installed in the ground or works, for example piezometers, settlement plates, instruments, strain gauges etc.
(g) Unusual equipment specifically purchased for the particular assignment
(h) Miscellaneous items or services specifically required for the assignment, e.g. maps, charts or aerial photographs, special stationery, printing, photography, permit fees
(i) Restoration of any damage to property or services not readily avoidable
(j) Special insurance required for particular projects

7. MISCELLANEOUS

7.1 Reports
Three copies of each report will be issued and if additional copies are required these will be charged at commercial copying rates or treated as “Reimbursable Expenses” – see 6 above.

7.2 Sample Storage
Samples will not be stored more than six months unless special arrangements are made by the Client at the time of commissioning.

7.3 Invoicing and Payment
Progress invoices are normally issued at approximately monthly intervals and payment in full of each invoice is due within 30 days of issue. At the option of the Company, interest may be charged on overdue accounts at the same rate as the maximum overdraft rate fixed by the Reserve Bank, plus 2%, without relieving the Client of his obligation to pay the account.

7.4 Proposals
Where the Company has submitted a proposal for an assignment certain unforeseen circumstances may require departure from the method or personnel proposed. Where it is expected that such departure will affect the interests of the Client we will endeavour to seek the approval of the Client in advance.

7.5 Liability
The liability of the Company shall be limited to the amount of fees associated with the particular part of the work which may be the subject of a claim. Additional cover is available at the Client’s request and will be charged at cost.
ATTACHMENT D

GROUNDWATER BROCHURE
Fields of Operation
Water resource engineering  
Geotechnical engineering  
Engineering geology  
Digital modelling & computer studies  
Terrain evaluation & site investigation  
Environmental studies  
Construction control & monitoring

Office Locations
Head office in Sydney, NSW, Australia. Major branch offices in all Australian capital cities – Brisbane, Canberra, Melbourne, Adelaide, Perth and in the major regional centres of Southport, Newcastle and Albury/Wodonga; also in Jakarta, Indonesia, in association with P.T. Sucofindo.

Areas of Activity
All states of Australia  
Papua-New Guinea  
South-east Asia  
Africa  
Western Pacific Region

Client Range
Federal, state, local government and statutory authorities;  
Mining industry;  
Industrial, commercial and land development companies;  
International design and construction groups;  
Architects, consulting engineers and contractors; and  
International and Australian aid agencies

Equipment & Facilities
Fully equipped NATA registered soils laboratories are maintained in all offices. Specialised field testing equipment includes pressuremeters, static cones, shear boxes, borehole survey and impression devices, seismic, bore logging and radiometric equipment.

An Eclipse S130 computer used for modelling in soil, rock and water resource studies is fully supported by advanced software and graphics facilities.
Management

Corporate group
D.D. Coffey, BE, FIE Aust.
B.C. Burman, BE, MEngSc, PhD, FIE Aust.
P.C. Thomson
P.J. Hitchcox, MIAA, AAIM, ACIS

Chairman of directors
Managing director
General manager
Company secretary

Australian operations
C.P. Thorne, BE, MEngSc, FIE Aust.
G.R. Padgett
M.G. Philip, BE, MEngSc, MIE Aust.
S. Lo
G.K. Spencer, BE, MEngSc, PhD, MIE Aust.
A.P. Edwards
C.F.R. Fitzhardinge, BE, BSc, MIE Aust.
I.L. McKenzie, BE, MEngSc, MIE Aust.
J.G. Lucas, BE, MIE Aust.

Manager, New South Wales
Manager, Newcastle Region
Manager, Queensland
Manager, Gold Coast Region
Manager, Australian Capital Territory
Manager, Albury/Wodonga Region
Manager, South Australia
Manager, Victoria & Tasmania
Manager, Western Australia

Special technical operations
I.R. Binch, QCE, MIE Aust.
J.P. MacGregor, BSc, DIC FGS
Professor E.H. Davis, BSc (Eng), FIE Aust.
J.M.O. Hughes, MIE, PhD (Chem), MNZIE

Manager, Water Resources Group
Principal engineering geologist
Special consultant
Special consultant

Indonesia – In association with P.T. Sucofindo
Ir. A. Ganis
R. Sweetman, BSc, PhD, MIMM (Aust.), MIMM

Director of operations
Consulting Director Technical Services

Viewed at 23:02:51 on 17/02/2010
Groundwater — its study & development

Slurry trench cutoff to minimize water seepage through embankment and foundations of Grahamstown Reservoir, NSW

To be fully effective many water resource studies must take in the associated field of geotechnical engineering — the discipline dealing with the natural elements of earth and water. For this reason Coffey & Partners has built up in-house expertise in all aspects of geotechnical engineering and engineering geology. Combined with our hydrological skills, this facility ensures that our clients obtain the broadest possible input to their problems and not one specialized viewpoint alone. The significance of these services becomes evident when it is realized that water is both the most common substance and the most vital resource in our environment. Dependent upon its location and use it can be the source of water supply, the conveyor of pollutants and disease, or a major problem for construction operations.

Groundwater forms an important and integral part of the hydrologic cycle, the science of groundwater hydrology being concerned with evaluating the occurrence, availability and quality of groundwater. But scientists and engineers engaged in groundwater development must deal with many other facets of the industry. They must also be familiar with the practical aspects of drilling, borehole design, field testing of bores and the range of pumping equipment needed to bring the groundwater to the surface.

Coffey & Partners' hydrogeologists and engineers have wide experience in all phases of groundwater investigation, assessment and development, their experience having been gained both through academic training and through practical experience on numerous projects throughout Australia and overseas. We can provide services ranging from full-scale regional hydrogeological investigations, through feasibility studies and groundwater development programmes, to special services for the mining, construction, process and rural industries.
Our range of consulting services can be grouped as follows:

**Groundwater exploration, development and management**
- Regional groundwater studies
- Water chemistry and water quality studies
- Design of bores, wellfields, drilling programmes, and pump installations
- Supervision of drilling and pump testing, contract administration
- Well and well field hydraulics
- Groundwater basin management
- Saltwater intrusion studies

**Water management and pollution control**
- Water pollution studies
- Design of mine and mill water circuits
- Mine waste retention schemes
- Corrosion studies
- Deepwell injection for waste disposal

**Dewatering and drainage**
- Design of construction dewatering systems
- Groundwater control in open pit mines
- Subsurface drainage systems
- Mine dewatering and drainage

**Specialist services**
- Numerical modelling and computer studies in hydrogeology
- Drilling supervision
- Rural water supplies
- Environmental impact studies
- Training of professional and technical counterpart staff
- Geophysical studies
Trends in groundwater practice

Over the past decade it has become apparent that certain trends are developing in the field of groundwater hydrology.

Firstly, it is clear that the use of groundwater throughout the world is increasing rapidly. As the construction of surface water storage installations continues, so the economics of utilizing underground water as an alternative for urban and rural water supplies will also come into greater prominence.

In the developing countries there are perhaps millions of rural communities with inadequate water supplies. There is a growing awareness within these countries, and within the various international agencies assisting them, that one of the simplest and most cost-effective ways to improve the health and quality of life of the villagers is to provide a reliable, safe water supply. In a large proportion of cases, this can best be effected by development of groundwater resources.

Secondly, there is a growing interest in using aquifers for storing excess surface waters. Using artificial recharge, aquifer systems can be expected to play an increasing role as a water management facility for the combined use of surface and groundwater resources.

The third trend is the use of aquifers for the subsurface disposal of waste products. The principle of liquid waste injection underground through specially designed wells is presently in the formative stages but can be expected to expand significantly over the years ahead.

Fourthly, there is a growing interest in the subsurface environment by a wide range of professions. This will inevitably lead to a growing need for involvement by groundwater hydrologists in such fields as land subsidence, environmental geology, geopollution management, geothermal energy, mining and other engineering undertakings.
Planning and programming a groundwater investigation

The scope of a groundwater investigation can range from the construction and testing of a single bore to a full-scale hydrologic and geologic investigation of an area, culminating in recommendations for optimum development of the groundwater resources.

Level of investigation

The time, effort and expense devoted to such an investigation must, of economic necessity, be geared to the scale of the operation or development using the groundwater resources. Even on the smaller projects all the principal elements of a comprehensive investigation must be covered, even though only a brief reconnaissance is feasible and data must be gathered more rapidly and therefore less accurately. This data must include geologic and hydrologic information, and be sufficient to allow an adequate assessment of hydrogeologic conditions.

In the comprehensive investigation much more thorough and accurate quantitative research must be carried out, so as to provide maximum assurance that the conclusions and recommendations arrived at are both correct and properly determined.

Objective

The ultimate objective of the comprehensive investigation of a region for groundwater is normally to determine how much groundwater can be pumped within the safe yield without exhausting the supply, or without bringing about some other undesirable effect, such as deterioration of water quality and interference with competing consumers.

In a less comprehensive investigation, a satisfactory objective is to delineate areas where groundwater can be developed by bores and to indicate the degree of development. For example, certain areas can be shown to contain aquifers which will yield sufficient water for irrigation, whereas other areas may contain less permeable aquifers which can only be developed for limited domestic use or, perhaps, for livestock. On the basis of his experience a groundwater hydrologist can suggest a degree of development for the area in question that can be expected to be within the safe yield of the basin.

Whether based on reconnaissance or comprehensive investigation, any estimate of this yield must be made as a result of accurate evaluation of the factors underlying the hydrologic balance of the area concerned. Quantitative data derived from such factors as rainfall, river flow and changes in groundwater storage must be fully taken into account.

In arid areas, such as cover most of Australia, where recharge to the groundwater body is extremely limited, even a moderate development of the basin may be beyond safe yield. Where this is the case, it may be desirable to 'mine' groundwater just like any other mineral commodity (e.g., oil) that is not naturally replenished. A comprehensive groundwater investigation in such an area should evaluate the amount of water in storage, its quality, and the rate of use under present and projected conditions. The length of time that groundwater can be economically extracted from the area can thus be accurately computed.

Essential information — geology and hydrology

The key to successful programming for a groundwater investigation is the obtaining of essential information on the hydrology and geology of the area. Knowledge of the hydrology is needed to determine the sources of supply and discharge of groundwater, while data on geologic formations is of equivalent relevance. These formations form the reservoirs that contain groundwater and their conditions of permeability and storage capacity determine the quantity of water yielded by bores and the amount of groundwater available.

Programming an investigation

Data collection

The first step in programming a groundwater investigation should be an office study to obtain all available existing data on the hydrology and the geology of the area.

Diagrammatic cross-section showing occurrence of groundwater.
Geological mapping
After collection of basic data, the next step is to map the geology of the area in question. The mapping can be done entirely in the field, or on aerial photos supplemented by field mapping.

Drilling and geophysical studies
It is generally highly desirable to supplement surface geologic studies with drilling and/or geophysical work, especially in those areas where little existing data are available. Geophysical surveys should supplement drilling, and vice versa in subsurface investigations for groundwater. The various types of geophysical methods commonly used are:
• resistivity surveys
• seismic surveys
• bore logging

Pumping tests
These are required to provide information on the water storage and transmission capacity of the aquifer system. In addition, they provide information on bore construction and bore yield. The type of pumping test and its duration depends on the type of aquifer being tested.

Water quality
Sampling and analysis of water quality is essential. The intensity of sampling should be gauged by the needs of the investigation, and the severity of any water quality problems. Sampling and testing in an area with some good quality and some poor quality water should serve to differentiate areas and aquifers of varying quality; on the results of this study recommendations can be made regarding different uses for water in various areas and aquifers.

Evaluation of information
Continuous evaluation must be carried out of all information obtained during an investigation. As this evaluation progresses an increasingly clear picture is built up of the hydrogeologic relationships in the area.

At the end of a field investigation sufficient data must be in hand for a final evaluation; this data must include hydrological information in proper form for analysis, together with geologic maps and cross-sections. The results of the drilling, geophysical, aquifer testing and water quality programmes must also be known.

Basin modelling
After a comprehensive investigation of a groundwater region or basin has been completed, it is sometimes useful to construct a model of the basin. Various kinds of physical, electrical, and computer models of groundwater basins have been constructed in recent years according to the type and intensity of the overall investigation.

Economic studies
An engineering-economic appraisal of various possible schemes for groundwater development may be desired as a final stage of an investigation. The economic evaluation may consider groundwater development for various purposes in different parts of the region. Economic studies may be made to compare the costs of the groundwater development with those of surface water development.
Some recent projects

Groundwater availability: Aurukun, North Queensland

A groundwater investigation at Aurukun was undertaken between 1971 and 1975 for a mining consortium comprising H.A. Bauxite Australia; Pechiney Compagnie and Tipperary Land and Exploration Company.

The consortium planned bauxite mining operations within a lease area which covers approximately 2000 km² on the western margin of Cape York Peninsula, south of Weipa. In order to carry out this mining a reliable water supply of 10,000 megalitres/annum was sought.

Coffey & Partners were commissioned to report on:

(i) shallow groundwater resources in the area;

(ii) the availability and quality of groundwater from the artesian aquifer which was known to underlie the area at a depth of some 1000 metres.

Shallow aquifer

A comprehensive investigation, including aerial photo interpretation, geological mapping, geophysics (resistivity), drilling, pump testing and water balance studies, was carried out over the lease. The strata comprises an in situ weathering profile of clays and silty clays of Tertiary age, some 30 metres thick, overlying Cretaceous siltstone and shales 1000 metres thick.

This investigation was confined to the upper 30 metres or so in order to test for the presence of permeable sand horizons that had been intersected in the same formation on Weipa Peninsula 50 km to the north.

Permeable sand beds were located in the lateritized Tertiary sequence but their thickness and areal extent were found to be small. While these aquifers would have been suitable for limited development (e.g., cattle watering and small domestic supplies) it was concluded that they could not be utilized for the large supplies needed for the mining operation.

Deep artesian aquifer

Aurukun is located on the northern extension of the Gulf subbasin that is in turn an extension of the Great Artesian Basin. It is underlain by some 1000 m of Cretaceous sediments that overlie granite and metamorphic basement rocks.

A series of relatively thin permeable sandstone beds had been intersected in the Cretaceous rocks at a depth of 850 metres at Weipa, 50 km north of Aurukun, and these had proved to be a useful aquifer.

Well tests were initially carried out utilizing the natural flow of the two wells and from these data a transmissivity of 980 m²/day and a storage coefficient of 10⁻³ were computed. Subsequent long-term pumping tests using a turbine pump confirmed these aquifer characteristics.

A wellfield system was proposed comprising twelve production wells, each pumping at a rate of 3.6 megalitres per day.

[Diagram of flow test on Aurukun artesian bore - water temperature 77°C]
Reception from villagers in the central Dry Zone of Burma for the Coffey & Partners team investigating Australian aid to provide groundwater supplies for 1700 villages in the region

Burma village water supplies project

In January 1977 Coffey & Partners Pty Ltd were commissioned by the Australian Development Assistance Bureau (ADAB) to carry out a technical appraisal of a proposed village water supply project in Burma.

The project as envisaged by the Burmese Government involved the construction of tubewells (bores) in 1700 villages and the extension and upgrading of an existing piped water system to supply an extra 65 villages, all in the Dry Zone of Central Burma. It was estimated by the Burmese that the project would provide some 1.3 million people with a safe, reliable water supply.

Our appraisal team examined the technical feasibility of the project, the ability of the Burmese constructing authority (Rural Water Supplies Division) to cope with such an ambitious programme, the effect which the work might have on the social life of the Dry Zone villagers and its effect on agricultural production. They also carried out an economic analysis of the project.

It was concluded that the project was worthwhile having regard to its impact on the social and economic welfare of the rural population of the Dry Zone and that indeed some 3.5 million people would benefit by having a safe supply of water.

This project was considered so important that UNICEF decided that it should be expanded. They have provided funds to boost the coverage of the programme from 1700 to 3100 villages, to be supplied with water over an eight-year period from 1978 to 1985. The total cost of the project is estimated to be in the order of $A40 million.

The Burma Village Water Supplies Project is now under way with the Rural Water Supplies Division as the constructing authority, working with assistance from UNICEF and ADAB. Coffey & Partners have been retained by ADAB to act as their technical advisers and in this role we are working in close co-operation with the Burmese Government and UNICEF.

We are responsible for the supply of plant, equipment and materials provided by ADAB, standardization of equipment, supervision of technical matters and liaison with other agencies.

Monitoring and evaluation

In a project as large as the Burma Village Water Supplies Project it is imperative that progress be closely monitored and that the project be evaluated to ensure that its planned objectives are achieved. A programme is therefore under way that incorporates the design and implementation of a monitoring system in order to measure the project's efficiency, together with an ongoing evaluation of its effectiveness in achieving planned outputs and purpose.

Coffey and Partners is heading up a team including rural sociologists, agricultural economists and others to carry out this important phase of the project.

Villagers carting water from distribution point in the Dry Zone of Central Burma
Construction basin – Mackay, Queensland

During 1972 and 1973 a large construction drydock was constructed on the foreshore at Mackay. The dock was some 150 metres long, 90 metres wide and 12 metres deep, excavated in unconsolidated sands and gravels on a 8 ha. site adjacent to Mackay Harbour.

The site investigation was carried out by Coffey & Partners Pty Ltd for Utah Development Company as part of Utah’s coal loading development facility at nearby Hay Point.

Concrete caissons forming the coal loading berth were built in the construction basin, then floated to Hay Point and sunk on specially prepared foundations.

The objective of the site investigation was to carry out test boring and sampling together with static cone penetrometer soundings, detailed test pumping and laboratory testing to determine the geometry and physical characteristics of the strata beneath the site area. From this information a dewatering system and excavation batter slopes were to be designed to ensure stability under the range of conditions likely to be encountered during the operation of the basin.

Another aspect for consideration was the effect, particularly with regard to settlement, that any dewatering might have on the three bulk sugar terminal buildings located nearby.

Drilling and testing showed the area to be underlain to a depth of approximately twenty metres by alluvial sediments. Two quite distinct water bearing zones, existing over a significant portion of the construction site, were delineated.

An upper unconfined aquifer of medium-dense, medium-to-coarse grained sand with some gravel layers was encountered between depths of five and ten metres. This was underlain by a firm clayey-silt, silty-clay bed approximately two metres thick, beneath which was a lower confined aquifer system of sand and gravel varying in thickness between two and seven metres.

Pumping tests showed the upper aquifer to have a hydraulic conductivity of 0.2 cm/sec and the lower aquifer $1.8 \times 10^{-2}$ cm/sec.

A number of dewatering systems were designed to take into account the presence of multiple aquifers, particular care being taken with pressure relief of the lower aquifers, necessary to avoid heave in the base of the excavation.

Alternative construction methods were considered, including a sheet pile cutoff, and in this case we carried out finite element analyses to assess seepage and stability aspects.

This project is typical of so many engineering works where the different skills of the geotechnical engineer and the groundwater hydrologist need to be combined in order to arrive at a proper and informed geotechnical solution. A similar approach has been used on the cooling water intake canal, Eraring power station at Lake Macquarie, NSW; the Waisi Copper Project at Viti Levu, Fiji, the Leigh Creek Coalfield Development, SA, and other major projects.
Groundwater in coastal sand areas

Coffey & Partners have been involved in numerous hydrogeological investigations related to sand deposits along the east coast of Australia. The objectives of these investigations have included:

- provision of water supplies for mining or residential development;
- examination and assessment of the environmental impact of developmental projects on the groundwater regime;
- advice on water availability, quality and treatment for tourist and other development facilities;
- advice on water management procedures during mining operations to limit environmental impact; and
- general hydrogeological surveys.

A number of specific projects in which we have participated over the past few years are as follows:

Myall Lakes environmental study

Coffey and Partners were responsible to Mineral Deposits Ltd for the compilation of the environmental impact study on the sand mining operations on Bridge Hill Ridge in the Myall Lakes area in NSW. As part of this study, we carried out a comprehensive investigation of the occurrence of underground water in the area and its relationship to the lake system, and assessed the impact which the then-proposed mining would have on the groundwater regime.

Bribie Island canal development, Qld

Bribie Island, located approximately 65 km north of Brisbane, forms part of a chain of sand islands fringing the south-east Queensland coast, the chain also including Moreton Island, Fraser Island, North Stradbroke Island and South Stradbroke Island. The island's water supply is obtained from a large pond that has been formed by excavating below the water table. The Queensland Lands Administration Commission plans to construct a residential canal development between the island's water source and the coastline.

Coffey & Partners were engaged by the Commission to examine the influence that a canal system might have on water quality and availability. In particular, it was feared that canal construction would cause shortening of groundwater seepage paths and, hence, a general landward movement of the freshwater/saltwater interface, which, in turn, could result in a significant decrease in available groundwater, particularly during drought periods.

Our comprehensive investigation concluded that the proposed work would not significantly affect water availability or water quality in the area of the Bribie Island Water Reserve.
Water supplies for sand mining — North Stradbroke Island

We have carried out a number of detailed groundwater studies on North Stradbroke Island for Consolidated Rutile Ltd. The aims of these investigations have always been to assess availability of water for mining operations while at the same time ensuring that extraction of this water does not upset the hydrology or environment of the island.

Hydrogeology of Moreton Island

During 1975-76 the Queensland Co-ordinator General's Department commissioned A.A. Heath and Partners Pty Ltd to carry out an environmental impact study and strategic plan for Moreton Island, a 185 km² sand island-off the southeast Queensland coast. Coffey & Partners were, in turn, commissioned to report on the hydrogeology of the island, assess water availability for mining and other potential development projects and to propose a water management system to protect the island's valuable groundwater resources.

Other hydrogeological work carried out in coastal sand environments include:

- Moreton Island, Qld
  Hydrology of a proposed sand mining operation for Dilllingham Mining Company of Australia.
- Wooli, NSW
  Report on the hydrology of Wooli area in NSW in relation to proposed sand mining operations for Dilllingham Mining Company of Australia.
- South Stradbroke Island, Qld
  Investigation to assess groundwater availability for large subdivisional development; advice on groundwater extraction, treatment and management.
- Fraser Island, Qld
  Report on the hydrology of Fraser Island with particular reference to sand mining operations; monitoring of mining activities and environmental studies.
Special areas of activity

Groundwater basin management
As with any water supply system, a water supply based on groundwater requires operational management. A system of piezometers to measure water levels in the basin must be established and continuously monitored. Water usage and water quality must also be monitored so that aquifer performance under operational conditions can be related to performance predicted from investigations. Apart from enabling day-to-day control over extraction to be maintained, the results of such observations will allow for continuing reassessments of the capacity of the groundwater system to be made.

Coffey and Partners Pty Ltd carry out basin management functions for a number of clients. This commonly involves periodic collation and interpretation of field data collected by the client according to instructions laid down by the consultant. We envisage an expanding need for this service as the rate of groundwater development increases.

Village water supplies
Over the past years we have become increasingly involved in the provision of water supplies to rural villages in developing countries. Current work in this field includes the Burma Village Water Supplies Project, which aims at providing groundwater supplies to over 3000 villages in the Dry Zone of central Burma. Other rural water supply projects currently under way include the Singida Groundwater Development Project in Tanzania, the Magarini Land Settlement Project in Kenya and a number of groundwater development projects in Southern Sumatra, Indonesia.

As a result of these and other projects, we have built up a breadth of experience — probably unique among Australian consultants — in the appreciation of the problems facing developing countries in establishing village groundwater supplies and in the selection of appropriate techniques for overcoming these problems. Much remains to be done in this area, in order to relieve untold suffering and hardship, and we look forward to playing our full part in this vital work.
Groundwater pollution

With the increased usage of groundwater and the upsurge of interest in the subsurface generally, risks of water pollution are steadily increasing. This, coupled with greater community awareness of the environmental implications of development, means that increased recognition and attention will have to be given to the question of groundwater pollution.

Obviously it is better to prevent such pollution rather than attempt to eliminate it, and it is worth remembering that pollution can occur in many ways, including:

- septic tank effluent
- waste holding ponds or lagoons
- stockpiles and waste dumps
- infiltration of polluted surface water
- land disposal of wastes
- sanitary landfill
- waste disposal in wet excavations
- leakage from underground pipelines and storage tanks
- migration of poor quality water in abandoned boreholes
- accidental spills of hazardous materials
- fertilizers and pesticides
- overpumping of groundwater.

Should you have a groundwater pollution problem, or even suspect that this might be the case, our hydrogeologists have the expertise to assist you.

Groundwater modelling

Groundwater systems may be simulated using:

- scaled physical models;
- analogue models;
- digital computer models.

The solution to complex regional flow assessments, seepage analyses, wellflow analysis, mine dewatering and many other groundwater flow problems is commonly best suited to some form of modelling. Coffey & Partners have an in-house Eclipse S130 computer that we use for modelling in soil, rock and water resources studies. It is fully supported by advanced software and graphics facilities.

Groundwater flow programmes, developed by the company's computer specialists, have been used on such projects as: seepage analysis of tailings dams for the Ranger and Jabiluka uranium mines, dewatering studies for two 300 metre deep open-cut copper mines in Fiji for Amax Exploration (Australia) Inc. and seepage analysis for gossan and tailings disposal dams at Woodlawn, NSW, for Jododex Pty Ltd and Minenco Ltd. The analysis of test results from two 1000 metre deep artesian wells at Aurukun, North Queensland, was also carried out using digital computer modelling techniques.
### Selected job list

<table>
<thead>
<tr>
<th>Mining Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aurukun Bauxite Project, Aurukun, North Queensland</strong></td>
<td>Tipperary Land &amp; Exploration Company, H.A. Bauxite Australie &amp; Pechiney Compagnie</td>
<td>Investigation of the groundwater potential of shallow aquifers in an area of 2000 km². Establishment of two artesian wells each 1000 m deep for the proposed bauxite mine.</td>
</tr>
<tr>
<td><strong>Beverley Uranium Prospect, Lake Frome, SA</strong></td>
<td>Western Nuclear (Aust) Ltd</td>
<td>Hydrogeological investigations for the assessment of dewatering requirements and slope stability in proposed opencut mine.</td>
</tr>
<tr>
<td><strong>Fanning River Limestone Deposit, North Queensland</strong></td>
<td>North Australian Cement Ltd</td>
<td>Investigation and development of 1.5 ML/day groundwater supply for limestone slurry pipeline to major cement mill at Townsville.</td>
</tr>
<tr>
<td><strong>Fraser Island Sand Mining, Queensland</strong></td>
<td>Murphyores – Dillingham Mining</td>
<td>Examination of impact of sand mining on hydrogeology, water balance and environmental studies; tailings control system on major Queensland sand island.</td>
</tr>
<tr>
<td><strong>Mysall Lakes Sand Mining Project, Bridge Hill Ridge, NSW</strong></td>
<td>Mineral Deposits Ltd</td>
<td>Deposition of hydrogeology of Mysall Lakes area and assessment of effects of proposed sand mining operations.</td>
</tr>
<tr>
<td><strong>Nabarlek Uranium Project, Arnhem Land, NT</strong></td>
<td>Queensland Mines Ltd</td>
<td>Design of tailings dam; studies of water management and mine waste movements.</td>
</tr>
<tr>
<td><strong>North Stradbroke Island, Queensland</strong></td>
<td>Consolidated Rutile Ltd</td>
<td>Evaluation of potential water supply for mineral sand mining purposes on coastal sand island.</td>
</tr>
<tr>
<td><strong>Jabiluka Uranium Project, Northern Territory</strong></td>
<td>Pancontinental Mining Ltd</td>
<td>Preliminary design of tailing retention and of deep well seepage interception system for 6 km long tailings dam. The system is to intercept all seepage from the dam.</td>
</tr>
<tr>
<td><strong>Ranger Uranium Project, Jabiru, Northern Territory</strong></td>
<td>Ranger Uranium Mines Pty Ltd</td>
<td>Seepage analyses of tailings dam system for complete retention of radioactive and heavy metal contaminants by finite element methods; evaluation of effects of pollutants on the regional groundwater system.</td>
</tr>
<tr>
<td><strong>Renison Tin Mine, Tasmania</strong></td>
<td>Renison Ltd</td>
<td>Study of base flows in the Argent River during drought periods as water supply source to west coast tin mining operation.</td>
</tr>
<tr>
<td><strong>Weipa Bauxite Mine, Weipa Peninsula, Queensland</strong></td>
<td>Comalco Ltd</td>
<td>Design of dewatering system for large construction excavation for ore unloading facility.</td>
</tr>
<tr>
<td><strong>Weipa Water Supply, Weipa Peninsula, Queensland</strong></td>
<td>Comalco Ltd</td>
<td>Investigation and staged development of shallow aquifer in the Weipa Peninsula as water supply source for bauxite mine and township.</td>
</tr>
<tr>
<td><strong>Woodlawn Mine Project, Goulburn, NSW</strong></td>
<td>Jododex Pty Ltd Minenco Ltd</td>
<td>Seepage analyses for gossan and tailing disposal dams by finite element methods.</td>
</tr>
</tbody>
</table>
### Engineering and Development

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bribie Island Canal Development, Sunshine Coast, Queensland</td>
<td>Lands Administration Commission</td>
<td>Study of effect of canal development on groundwater reserves on coastal sand island.</td>
</tr>
<tr>
<td>Cataract Reservoir, New South Wales</td>
<td>Metropolitan Water, Sewerage and Drainage Board</td>
<td>Evaluation of potential reservoir leakage resulting from proposed coal mining activities below the reservoir.</td>
</tr>
<tr>
<td>Central Queensland Salt Field, Port Alma, Queensland</td>
<td>ICI Australia Ltd</td>
<td>Study of brine reserves for solar salt works as affected by aquifer leakage and adjacent bore fields.</td>
</tr>
<tr>
<td>City of Sale Water Supply, Sale, Victoria</td>
<td>D.H.P. Consultants Pty Ltd</td>
<td>Consultations on rehabilitation of deep artesian production wells severely affected by corrosion.</td>
</tr>
<tr>
<td>Eraring Power Station, Lake Macquarie, New South Wales</td>
<td>Electricity Commission of NSW</td>
<td>Investigation and design of dewatering system for 300 m long concrete caisson construction area.</td>
</tr>
<tr>
<td>Gascoyne River Development, Carnarvon, WA</td>
<td>Dept of Public Works, WA Snowy Mountains Engineering Corporation</td>
<td>Review of groundwater development from alluvium in Gascoyne River Valley as part of proposed conjunctive use development.</td>
</tr>
<tr>
<td>Grahamstown Reservoir Project, Raymond Terrace, NSW</td>
<td>Hunter District Water Board</td>
<td>Estimation of seepage loss through embankment foundation of water supply dam for Newcastle and Hunter Region. Design and construction of slurry trench with 95% cutoff efficiency.</td>
</tr>
<tr>
<td>Graving Dock, Newcastle, NSW</td>
<td>Posford Pavy Sinclair &amp; Knight</td>
<td>Investigation for construction dewatering schemes of proposed graving dock at Newcastle Harbour.</td>
</tr>
<tr>
<td>Groundwater Supply, Toongabbie, NSW</td>
<td>Stafford Moor and Farrington</td>
<td>Assessment of possible groundwater source for pharmaceutical products factory.</td>
</tr>
<tr>
<td>Hay Pt. No. 2 Berth Project, Mackay, Queensland</td>
<td>Utah Development Company Rendel &amp; Partners</td>
<td>Investigation and design of dewatering system for 10 m sheet-piled excavation as temporary dry dock for construction of concrete gravity caissons for berth No. 2 of Hay Point coal loader.</td>
</tr>
<tr>
<td>Hope Island, SE Queensland</td>
<td>Antony Tod &amp; Partners Pty Ltd</td>
<td>Investigation and assessment of groundwater for proposed tourist development project on small sand island.</td>
</tr>
<tr>
<td>Monarto New Town, Monarto, SA</td>
<td>Kinnaird Hill de Rohan &amp; Young Pty Ltd</td>
<td>Studies of the hydrogeology of the semi-arid town site and surrounding areas, and assessment of likely changes in the groundwater regime as a result of urbanization. Advice on hydrogeology of proposed artificial lake. Broad-scale studies of existing and potential soil salinity problems and of erosion.</td>
</tr>
<tr>
<td>Ormeau, Queensland</td>
<td>Antony Tod &amp; Partners Pty Ltd</td>
<td>Groundwater investigation for proposed land development project.</td>
</tr>
<tr>
<td>South Stradbroke Island, Queensland</td>
<td>Co-ownership Land Development Pty Ltd</td>
<td>Investigation, pump testing and assessment of aquifer recharge and salt water intrusion on coastal sand island associated with residential canal development.</td>
</tr>
<tr>
<td>Overseas Project/location</td>
<td>Owner and client</td>
<td>Scope of Work</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Bedak LNG Project, East Kalimantan, Indonesia</td>
<td>Bechtel Inc. P.N. Pertamina</td>
<td>Assessment of groundwater resources and construction of production wells for plant water supply.</td>
</tr>
<tr>
<td>Groundwater Resources Investigation, Singida, Tanzania</td>
<td>Australian Development Assistance Bureau</td>
<td>Investigation of the regional groundwater resources of a 50,000 km² region comprising 5% of the total area of Tanzania as part of a national water resources development plan. Activities included hydrogeological data collection, exploratory drilling and testing.</td>
</tr>
<tr>
<td>Kota Bumi Water Supply, South Sumatra, Indonesia</td>
<td>Australian Development Assistance Bureau Dept of Construction</td>
<td>Investigation and development of groundwater resources for supplying the city of Kota Bumi (population 60,000).</td>
</tr>
<tr>
<td>Namosi Copper Project, Viti Levu, Fiji</td>
<td>Amex Exploration (Australia) Inc.</td>
<td>Hydrological and hydrogeological investigations for proposed 300 m deep opencut copper mine.</td>
</tr>
<tr>
<td>Tanjung Karang - Teluk Betung Water Supply, South Sumatra, Indonesia</td>
<td>Australian Development Assistance Bureau Dept of Construction</td>
<td>Investigation of groundwater resource potential for supplying these cities (total combined population 400,000).</td>
</tr>
<tr>
<td>Tanzania Village Water Supply Project, Singida, Tanzania</td>
<td>Australian Development Assistance Bureau SMEC</td>
<td>Provision of water supplies in Singida Region of East Africa to about 300 villages by development of groundwater resources under Australian Aid Programme.</td>
</tr>
<tr>
<td>Thai Office of Accelerated Rural Development, Thailand</td>
<td>Australian Development Assistance Bureau SMEC</td>
<td>Report on groundwater availability for the TARD Works Centre, Ban Phu Noi; advice on drilling techniques and purchase of drilling rigs.</td>
</tr>
<tr>
<td>Village Water Supply Project, Dry Zone, Burma</td>
<td>Australian Development Assistance Bureau</td>
<td>Monitoring and evaluation of a 3100-village water supply project being carried out jointly by the Burmese Government, UNICEF and the Australian Development Assistance Bureau.</td>
</tr>
<tr>
<td>Village Water Supply Project, Mandalay, Burma</td>
<td>Australian Development Assistance Bureau</td>
<td>Appraisal of extent and nature of Australian aid for water supplies to 1700 villages in Central Dry Region of Burma, including development of groundwater resources and of pumped water supply from Irrawaddy River with associated economic and sociologic aspects. Present activities include assistance in the purchase of suitable drilling rigs and well equipment in addition to continuing assistance on drilling technology and maintenance programming.</td>
</tr>
<tr>
<td>Wagina Island Project, Solomon Islands</td>
<td>C.R.A. Alumina Pty Ltd</td>
<td>Geohydrological investigation to assess influence of groundwater on proposed bauxite mining operations.</td>
</tr>
</tbody>
</table>
Office locations

AUSTRALIA
Head Office — Sydney
12 Waterloo Road,
NORTH RYDE, NSW 2113
Phone (02) 888 7444
Telex Coffey AA22650

Brisbane
151 Wellington Road,
EAST BRISBANE, Qld 4169
Phone (07) 391 7165
Telex Coffey AA40442

Canberra
47 Newcastle Street,
FYSHWICK, ACT 2609
Phone (062) 306 7976

Melbourne
1533 Malvern Road,
GLEN IRIS, Vic. 3146
Phone (03) 20 2521
Telex Coffey AA32230

Adelaide
14A Henley Beach Road,
MILE END, SA 5031
Phone (08) 352 1744
Telex Coffey AA82737

Perth
2 Bagot Road,
SUSIACO, WA 6008
Phone (09) 381 4551
Telex AAM AA92903

Newcastle
Cnr Union & Bishopgate Roads,
WICKHAM, NSW 2293
Phone (06) 61 5130

Southport
45 Margaret Street,
SOUTHPORT, Qld 4215
Phone (075) 31 4623

Albury/Wodonga
456 Swift Street,
ALBURY, NSW 2640
Phone (060) 21 6399

INDONESIA
In association with P.T. Sucofindo
P.T. Superintending Company of Indonesia,
Jalan Letjen S. Parman 102,
GROGOL, JAKARTA.
Phone 021 354 745
Telex Suco JKT-46723

Our Sydney head office and laboratory

Head office of P.T. Sucofindo, Jakarta
P664
29th August 1979

ATTACHMENT E

JOB LISTING
### DIGITAL MODELLING & COMPUTER ANALYSES

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ranger Tailing Dam, Jabiru, NT</td>
<td>Ranger Uranium Mines Ltd.</td>
<td>Seepage analyses of Stage 2 constructed tailing system for complete retention of radioactive and heavy metal contaminants by finite element methods. Including effects of pollutants on groundwater regime.</td>
</tr>
<tr>
<td>Goonyella Mine, Mackay, Q'D</td>
<td>Utah Development Co.</td>
<td>Finite element analyses for stability of high wall of operating coal mine involving explicit modelling of jointed rock structure.</td>
</tr>
<tr>
<td>Enoggera Dam Reconstruction, Brisbane, Q'D</td>
<td>Brisbane City Council</td>
<td>Finite element analysis of behavior of plastic concrete cutoff wall installed through century old operating reservoir under structural and hydraulic loads produced by downstream extension.</td>
</tr>
<tr>
<td>Woodlawn Tailing Dams, Goulburn, NSW</td>
<td>Jododox Pty. Ltd.</td>
<td>Seepage analyses for gossan and tailing disposal dams by finite element methods.</td>
</tr>
<tr>
<td>Newcastle Graving Dock, Newcastle, NSW</td>
<td>Dept. of Public Works, NSW</td>
<td>Study of effects on pile support concrete dock due to collapse of abandoned coal mine. This analysis was carried out by finite element procedures and accounted for jointed nature of bedrock.</td>
</tr>
<tr>
<td>Sugarloaf Reservoir, Melbourne, Vic</td>
<td>Melbourne &amp; Metropolitan Board of Works</td>
<td>Structural analysis of reinforced concrete outlet conduit beneath 85 m high rockfill dam using finite element techniques.</td>
</tr>
<tr>
<td>Monaro Highway, Canberra, ACT</td>
<td>National Capital Development Commission</td>
<td>Design of pavements and instrumented trial sections for major arterial highway involving stress analysis of multilayered pavements by finite element procedure.</td>
</tr>
<tr>
<td>Coal Loading Wharf, Pt. Waratah, NSW</td>
<td>Docker &amp; Smith Pty. Ltd.</td>
<td>Dynamic analysis of pile driving operations to overcome buckling problems associated with driving steel tube piles into bedrock.</td>
</tr>
<tr>
<td>Newcastle Graving Dock, Newcastle, NSW</td>
<td>Dept. of Public Works, NSW</td>
<td>Finite element analyses of dewatering operations for proposed dock excavation at Newcastle Harbour and elastic-plastic analyses for stability of sheet piled excavation into fissured clays.</td>
</tr>
</tbody>
</table>

---

**DIGITAL MODELLING & COMPUTER ANALYSES**

Technical Report WRD79024

Viewed at 23:02:51 on 17/02/2010 Page 82 of 88.
<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt. Waratah Coal Handling Facilities</td>
<td>Docker &amp; Smith Pty. Ltd.</td>
<td>Finite element analysis and design of 5 km of stacker/reciprocator banks</td>
</tr>
<tr>
<td>Newcastie, NSW</td>
<td></td>
<td>constructed from steel-reinforced, cement stabilised sand over soft alluvial</td>
</tr>
<tr>
<td></td>
<td></td>
<td>deposits. Analysis included no tension criterion for failure of stabilised sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td>by cracking.</td>
</tr>
<tr>
<td>Brotherson Dock, Botany Bay</td>
<td>Maritime Services Board</td>
<td>Stability analyses of elasto-plastic deep</td>
</tr>
<tr>
<td>Sydney, NSW</td>
<td>of NSW</td>
<td>water berths in fissured clays by finite element and limit equilibrium methods</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for all stages of construction using intrinsic parameters determined from</td>
</tr>
<tr>
<td></td>
<td></td>
<td>camberometer testing.</td>
</tr>
<tr>
<td>Wallerawang Power Station</td>
<td>Electricity Commission</td>
<td>Use of computer methods in studying</td>
</tr>
<tr>
<td>NSW</td>
<td>of NSW</td>
<td>hydrology of planned flyash dam, especially flood routing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grahamstown Reservoir Project</td>
<td>Hunter District Water</td>
<td>Analysis of seepage through sand embankment dam for design of slurry wall</td>
</tr>
<tr>
<td>Newcastle, NSW</td>
<td>Board</td>
<td>cut-off.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commonwealth-State Law Courts</td>
<td>Commonwealth Dept. of</td>
<td>Finite element study of interaction</td>
</tr>
<tr>
<td>Sydney, NSW</td>
<td>Works</td>
<td>between existing shallow railway tunnel in jointed rock and proposed excavations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for construction of adjacent building.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commonwealth Centre</td>
<td>Commonwealth Dept. of</td>
<td>Finite element study of interaction</td>
</tr>
<tr>
<td>Melbourne, Vic.</td>
<td>Works</td>
<td>between proposed complexes of multi-storey buildings and proposed tunnel</td>
</tr>
<tr>
<td></td>
<td></td>
<td>construction for Melbourne Underground</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rail Loop.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leigh Creek Coal Mine</td>
<td>Electricity Trust of SA</td>
<td>Computer analyses of distribution and orientation of defects in rock mass.</td>
</tr>
<tr>
<td>SA</td>
<td></td>
<td>Planning for finite element studies of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>stability of jointed rock slopes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### ENVIRONMENTAL & POLLUTION STUDIES

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myall Lakes Sand Mining Project,</td>
<td>Mineral Deposits Ltd</td>
<td>Environmental impact study for proposed sand mining operations.</td>
</tr>
<tr>
<td>Bridge Hill Ridge, NSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Darwin, NT</td>
<td>Cities Commission</td>
<td>Preliminary environmental impact study for proposed town plan.</td>
</tr>
<tr>
<td>Cleveland Bay Development Study,</td>
<td>Townsville Harbour Board, Geoffrey Mill</td>
<td>Planning and environmental study for development south of Townsville.</td>
</tr>
<tr>
<td>Townsville, Q'ld</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dayboro, Q'ld</td>
<td>Antony Tod &amp; Partners Pty Ltd</td>
<td>Environmental impact study for proposed residential development.</td>
</tr>
<tr>
<td>Lithgow Coal Mining Division,</td>
<td>State Pollution Control Commission, NSW</td>
<td>Inventory of all derelict open-cut mines in district detailing effects on the environment and study of practicable measures to remedy environmental problems and to reinstate mined areas to productive uses.</td>
</tr>
<tr>
<td>Lithgow, NSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wellington Point and Victoria Point, Q'ld</td>
<td>Department of Urban &amp; Regional Development, Redland Shire Council</td>
<td>Environmental impact study of proposed land reclamation and development of recreation areas, includes alternative plans to maximise social gains and minimise environmental costs.</td>
</tr>
<tr>
<td>Dayboro, Q'ld</td>
<td>W.O.V. Wall</td>
<td>Environmental impact study of proposed gravel quarrying on North Pine River. Design of procedures for minimising impacts.</td>
</tr>
<tr>
<td>Sand Mining Study, Moreton Island, Q'ld</td>
<td>Co-Ordinator General's Department, Q'ld, A.A. Heath &amp; Partners Pty Ltd</td>
<td>Study of existing hydrological environment on Moreton Island, and assessment of likely impacts of mining and other planning proposals.</td>
</tr>
<tr>
<td>Radio Transmission Installation,</td>
<td>Transcontinental Broadcasting Corp</td>
<td>Assessment of environment impact of 5 MW radio transmitter at Yellowrock and translator stations at Blackheath and Katoomba for Radio Station 2KA.</td>
</tr>
<tr>
<td>Blue Mountains, NSW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monarto New Town, Monarto, SA</td>
<td>Kinnaird Hill deRahen &amp; Young Pty Ltd, Highways Department of South Australia,</td>
<td>Studies of the hydrogeology of the semi and town site and surrounding areas, and assessment of likely changes in the groundwater regime as a result of urbanisation. Advice on hydrogeology of proposed artificial lake. Broad scale studies of existing and potential soil salinity problems, and of erosion.</td>
</tr>
<tr>
<td></td>
<td>Gutteridge Haskins &amp; Davey Pty Ltd, Monarto Development Commission</td>
<td></td>
</tr>
</tbody>
</table>

SEE ALSO SEPARATE SECTIONS ON WATER AND WASTE WATER TREATMENT WORKS AND WASTE DISPOSAL AND TAILINGS DAMS
## ENVIRONMENTAL & POLLUTION STUDIES

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tamborine Mountain Development, Queensland</td>
<td>Herrings &amp; Grey Aust Pty Ltd George Ennever</td>
<td>Assessment of environmental effects of a number of subdivision developments. (In association with Environment Science &amp; Services).</td>
</tr>
<tr>
<td>Paper Mill, Millicent, SA</td>
<td>Aceel Ltd Mackav &amp; Potter</td>
<td>Tracing of acid seepage into limestone formation and assessment of effects on groundwater and foundations.</td>
</tr>
<tr>
<td>Fertilizer Plant, Kooringa Island, NSW</td>
<td>Eastern Nitrogen Ltd</td>
<td>Investigation of contamination of ground by acid effluent.</td>
</tr>
<tr>
<td>Belconnen Ornamental Lake, Canberra, ACT</td>
<td>National Capital Development Commission</td>
<td>Study of potential turbidity of water in proposed Belconnen Lake.</td>
</tr>
<tr>
<td>Solar Salt Works, Port Augusta, SA</td>
<td>Vam-Delhi-Hardman Chemicals</td>
<td>Study of potential brine leakage through soils affected by root holes and burrowing animals.</td>
</tr>
<tr>
<td>Ranger Uranium Project, Jabiru, NT</td>
<td>Ranger Uranium Mines Pty Ltd</td>
<td>Assessment of generation of heavy metals and radioactive elements associated with mining and processing of uranium ore and their impact on surface streams and groundwater.</td>
</tr>
<tr>
<td>Tarong, Qld</td>
<td>C.R.A. Ltd</td>
<td>Environmental impact study for proposed open cut coal mine as supply to proposed major Queensland power station.</td>
</tr>
<tr>
<td>Sellicks Hill Quarry, Adelaide, SA</td>
<td>Southern Quarries Pty Ltd</td>
<td>Investigations for feasibility and design of proposed quarry in dolomite. Design of earthworks, site landscaping, water storage and erosion control facilities. Assistance to owner in preparation of case for obtaining consent for use of land for quarrying operations.</td>
</tr>
</tbody>
</table>
## HYDROLOGY - GROUNDWATER STUDIES

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renison Tin Mine, Tasmania</td>
<td>Renison Ltd</td>
<td>Study of base flows in the Argent River during drought periods as water supply source to west coast tin mining operation.</td>
</tr>
<tr>
<td>Weipa Water Supply, Weipa Peninsula, Qld</td>
<td>Comalco Ltd</td>
<td>Investigation and staged development of shallow aquifer in the Weipa Peninsula as water supply source for bauxite mine and township.</td>
</tr>
<tr>
<td>Sth. Stradbroke Is., Qld</td>
<td>Co-ownership Land Development Pty Ltd</td>
<td>Investigation, pump testing and assessment of aquifer recharge and salt water intrusion on coastal sand island associated with residential canal development.</td>
</tr>
<tr>
<td>Aurukun Bauxite Project, Aurukun Nth., Qld</td>
<td>Tipperary Land &amp; Exploration Company</td>
<td>Investigation of the groundwater potential of shallow aquifers and pump testing of two deep artesian wells for proposed bauxite mine.</td>
</tr>
<tr>
<td>Nth. Stradbroke Is., Qld</td>
<td>Consolidated Rutile Ltd</td>
<td>Evaluation of potential water supply for mineral sand mining purposes on coastal sand island.</td>
</tr>
<tr>
<td>Hay Point Project, Mackay, Qld</td>
<td>Utah Development Company</td>
<td>Investigation and design of dewatering system for 10 m sheet piled excavation as temporary dry dock for construction of concrete-gravity caissons for Berth No. 2 of Hay Point Coal Loader.</td>
</tr>
<tr>
<td>Grahamstown Reservoir Project, Raymond Terrace, NSW</td>
<td>Hunter District Water Board</td>
<td>Estimation of seepage loss through embankment foundation of water supply dam for Newcastle and Hunter Region, Design of slurry trench with 95% cut-off efficiency.</td>
</tr>
<tr>
<td>Groundwater Supply, Toongabbie, NSW</td>
<td>Stafford Moor and Farrington</td>
<td>Assessment of possible groundwater source for Pharmaceutical Products Factory.</td>
</tr>
<tr>
<td>Fanning River Limestone Deposit, North Queensland</td>
<td>North Australian Cement Ltd</td>
<td>Investigation of groundwater supply for limestone slurry pipeline to major cement mill at Townsville.</td>
</tr>
<tr>
<td>Wagina Is. Project, British Solomon</td>
<td>C.R.A. Alumina Pty Ltd</td>
<td>Groundwater study for proposed bauxite mining operation.</td>
</tr>
<tr>
<td>Gascoyne River Development, Carnarvon, WA</td>
<td>Snowy Mountains Engineering Corporation</td>
<td>Review of groundwater development on Gascoyne River as part of proposed conjunctive use development.</td>
</tr>
<tr>
<td>Project/Location</td>
<td>Owner and Client</td>
<td>Scope of Work</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>-------------------------------------------</td>
<td>-------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ormea, Q'd</td>
<td>Antony Tod &amp; Partners Pty Ltd</td>
<td>Groundwater investigation for development project.</td>
</tr>
<tr>
<td>Graving Dock, Newcastle, NSW</td>
<td>Posford Pavy Sinclair &amp; Knight</td>
<td>Investigation for construction dewatering schemes of proposed graving dock at Newcastle Harbour.</td>
</tr>
<tr>
<td>Bribie Is. Canal Development, Sunshine Coast, Q'd</td>
<td>Lands Administration Commission</td>
<td>Study of effect of canal development on groundwater reserves on coastal sand island.</td>
</tr>
<tr>
<td>Beverley Uranium Prospect, Lake Frome, SA</td>
<td>Western Nuclear (Aust) Ltd</td>
<td>Groundwater investigation for dewatering open cut mine.</td>
</tr>
<tr>
<td>Myall Lakes Sand Mining Project, Bridge Hill Ridge, NSW</td>
<td>Mineral Deposits Ltd</td>
<td>Description of hydrology of Myall Lakes area and assessment of effects of proposed sand mining operations.</td>
</tr>
<tr>
<td>Central Queensland Salt Field, Port Alma, Q'd</td>
<td>I.C.I. Aust Ltd</td>
<td>Study of brine reserves for solar salt works as affected by aquifer leakage and adjacent bore fields.</td>
</tr>
<tr>
<td>Tanzania Village Water Supply Project, Singida, Tanzania</td>
<td>Australian Development Assistance Agency</td>
<td>Provision of water supplies in Singida Region of East Africa to about 300 villages by development of groundwater resources under Australian Aid Program.</td>
</tr>
<tr>
<td>Fraser Is. Sand Mining, Queensland</td>
<td>Murphyores – Dillingham</td>
<td>Examination of impact of sand mining on geohydrology, water balance and environmental studies, tailings control system on major Queensland sand island.</td>
</tr>
<tr>
<td>Village Water Supply Project, Mandalay, Burma</td>
<td>Australian Development Assistance Agency</td>
<td>Appraisal of extent and nature of Australian aid for water supplies to 1700 villages in Central Dry Region, Burma, including development of groundwater resources and of pumped water supply from Irrawaddy River with associated economic and sociologic aspects.</td>
</tr>
</tbody>
</table>
## HYDROLOGY -- GROUNDWATER STUDIES

<table>
<thead>
<tr>
<th>Project/Location</th>
<th>Owner and Client</th>
<th>Scope of Work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monarto New Town, Monarto, SA</td>
<td>Kinnaird Hills de Rohan &amp; Young Pty Ltd</td>
<td>Studies of the hydrogeology of the semi-arid town site and surrounding areas, and assessment of likely changes in the groundwater regime as a result of urbanisation. Advice on hydrogeology of proposed artificial lake. Broad scale studies of existing and potential soil salinity problems, and of erosion.</td>
</tr>
<tr>
<td>Naharkak Uranium Project, Arnhem Land, NT</td>
<td>Queensland Mines Ltd</td>
<td>Investigation of site conditions and construction materials for airfield, haul roads, camps, and tailings dams. Design of tailings dam; studies of water management and mine waste movements; preparation of specifications for mine overburden removal, tailings dam, and haul road construction.</td>
</tr>
<tr>
<td>Ranger Uranium Project</td>
<td>Ranger Uranium Mines Pty Ltd</td>
<td>Assessment of generation of heavy metals and radioactive elements associated with mining and processing of uranium ore and their impact on surface streams and groundwater.</td>
</tr>
</tbody>
</table>