The Institution of Engineers, Australia

CENTRAL QUEENSLAND ENGINEERING CONFERENCE

ROCKHAMPTON / GLADSTONE

MAY 2-4, 1981

Central Queensland Engineering Conference

CONFERENCE PROGRAMME

SATURDAY, MAY 2, 1981

10.00 a.m.	Registration Morning Tea - C.I.A.E. Creative Arts Theatre
11.15 a.m.	OFFICIAL OPENING AND ADDRESS

Session 1 - Energy Resources

12 noon	*"COAL DEVELOPMENT: FUTURE PROSPECTS IN CENTRAL QUEENSLAND AND TRENDS IN OPEN CUT AND UNDERGROUND MINING" - J T Woods, Under Secretary, Queensland Department of Mines.*
12.45 p.m.	Lunch - C.I.A.E.
2.00 p.m.	*"COAL LIQUEFACTION" - Prof. D J Nicklin, University of Queensland.*
2.45 p.m.	*"AUSTRALIA'S DEVELOPING OIL SHALE INDUSTRY" - J S Turner, General Manager, Southern Pacific Petroleum N.L.*
3.30 p.m.	Afternoon Tea - C.I.A.E.
4.00 p.m.	*"PROVISION OF ELECTRICAL ENERGY" - N A Galwey, Commissioner, State Electricity Commission of Queensland.*
4.45 p.m.	Conference Adjourns
7.30 p.m.	Conference Dinner - C.I.A.E. Speaker - S K Langley, President, The Institution of Engineers, Aust.

SUNDAY, MAY 3, 1981

Session 2 - Infrastructure

9.00 a.m.	*"PORT FACILITIES" - A H Britton, Assistant Director, Queensland Department of Harbours and Marine.*
9.45 a.m.	*"RAIL TRANSPORT INNOVATIONS" - P J Goldston, Commissioner Queensland Railways.*
10.30 a.m.	Morning Tea - C.I.A.E.
11.00 a.m.	*"WATER RESOURCES OF THE CENTRAL QUEENSLAND REGION" - B L Credlin, Assistant Commissioner, Queensland Water Resources Commission.*
11.45 a.m.	*"EDUCATION AND TRAINING RESOURCES IN CENTRAL QUEENSLAND" - J Allen, Chairman, Queensland Board of Advanced Education.*

Session 3 - Industries

1.45 p.m.	*"CHEMICAL AND PROCESS INDUSTRIES" - G Baker Presented by J Ward.*
2.30 p.m.	*"ALUMINA PRODUCTION AT QUEENSLAND ALUMINA" - Dr P McIntosh, Technical Manager, Queensland Alumina Limited.*
3.00 p.m.	*"ALUMINIUM PRODUCTION" - D Brodie, Comalco.*
3.30 p.m.	Afternoon Tea - C.I.A.E.
4.00 p.m.	*"ALTERNATIVE ENERGY RESOURCES" - Dr R Boothroyd, Head, Department of Mechanical Engineering, Capricornia Institute of Advanced Education.*
4.45 p.m.	CLOSING ADDRESS - J McG McIntyre, Senior Vice President, The Institution of Engineers, Australia.
7.30 p.m.	BARBEQUE - C.I.A.E.

COAL DEVELOPMENT; FUTURE PROSPECTS IN CENTRAL QUEENSLAND AND TRENDS IN OPEN CUT AND UNDERGROUND MINING

JACK T. WOODS

UNDER SECRETARY, QUEENSLAND DEPARTMENT OF MINES, BRISBANE.

INTRODUCTION

Queensland has the potential to become established as the major Australian coal exporting State. In the calendar year 1980, despite the loss of about 4 million tonnes production through extended industrial problems, 19 917 049 tonnes, virtually all coking coal, were exported overseas, including 14 725 908 tonnes to Japan, the largest customer. Detailed statistics for the industry for the fiscal year ending 30th June, 1980 are available in the Annual Report of the Queensland Coal Board (1981).

The coal industry is based on very large reserves which are widespread in several sedimentary basins in the eastern part of the State (Fig. 1). Coal has been worked since the early days of settlement in the 1840's. With the spread of the railway system, numerous but mostly small underground mines were opened up. In fact, the wide availability of coal was responsible for the decentralisation of both the railway and port system, which has been of immense benefit to the subsequent development of Queensland.

After several decades of steady, if unspectacular growth, the coal industry in Queensland, in common with that in many parts of the world, began to lose ground in the 1950's owing to the dieselisation of the railway system and the trend to the use of fuel oil generally. For a time it appeared that the industry would become almost entirely dependent on domestic requirements for steaming coal for electricity generation, which continued to expand. However the industry progressed rapidly in the 1960's with the emergence of Japan as a major importer of coking coal and its subsequent growth has been spectacular (Fig. 2).

EXPLORATION

While the basic geological structure of Queensland has been understood from the turn of the century, coal exploration until the last two decades was rather haphazard. The method of mining coal was by shallow underground workings, and these were based on outcrops or intersections in wells or water bores. Some Government drilling was carried out as early as 1885, but for many years there was no comprehensive attempt, and neither was there a pressing need, to evaluate the coal resources of the State.

Several events which took place just after the Second World War set the stage for the revolution in Queensland coal mining, to be triggered by the opening-up of world export markets.

In 1947 the Government commissioned Powell Duffryn Technical Services Ltd., a leading group of British fuel consultants, to undertake a thorough study of the Queensland coal industry. Its report (1949) drew attention to the need for detailed exploration, as well as recommending the introduction of modern coal mining technology into the industry.

About the same time, the Queensland Coal Board was set up under the terms of The Coal Industry (Control) Act of 1948. The Board's functions include the provision of financial assistance to the State's coal industry, research, price fixation for domestic coal, quality control, and the compilation of statistics relating to the industry. It works in close liaison with the Queensland Department of Mines.

Two important consequences of the Powell Duffryn Report were the establishment of a Coal Section within the Geological Survey of Queensland and the expansion of the Drilling Branch of the Department of Mines. Subsequent exploration by both Government and industry has also been well served by the wealth of stratigraphic data produced as a result of the joint regional mapping programme initiated in the mid-1950's by the Commonwealth Bureau of Mineral Resources and the Geological Survey of Queensland, and the deep core drilling program begun by the Geological Survey in 1965.

Exploration by the Department has been progressively extended into every significant coal-bearing basin. The procedure involves detailed geological mapping, followed by reconnaissance drilling to locate coal seams and subsequent evaluation of reserves to measured or indicated status. This evaluation involves pattern drilling at no more than 1 or 2 kilometre centres, respectively, and coring of significant coal-bearing sections employing wire-line recovery methods and triple-tube core barrels. Coal properties are determined primarily by chemical analyses, mainly using the facilities of the Australian Coal Industry Research Laboratories. A coal petrology laboratory has been maintained by the Geological Survey and it also has the basic equipment to carry out proximate analyses and small-scale washability and coking tests. In 1980 the Drilling Branch carried out 55 319 metres of coal exploration drilling, making a total of some 809 500 metres since activities were stepped up in the 1950's. The field investigations are supported by electric logging and other geophysical techniques. The Queensland Coal Board also carries out investigations into the physical and chemical properties of Queensland coals and has published comprehensive data (1980).

The primary aims of these programs have been to provide the basic knowledge of the coal resources of the State in order to further the development of the coal industry and at the same time to provide the necessary background for the formulation of Governmental policy for the industry. In Queensland the electricity industry is administered by the State Electricity Commission and a number of semi-governmental authorities which handle generation and distribution. Some Departmental drilling programs have been directed specifically towards proving suitable reserves for future power station developments.

Company exploration for coal also was placed on a more systematic basis in the 1950's with the introduction of prospecting titles. The present Authority to Prospect system for large scale exploration began in 1964. Exploration by Government and industry in the last two decades has resulted in a number of major discoveries, as well as leading to a better appreciation of the extent of earlier known fields. There are 90 current Authorities to Prospect for coal.

Not all coal-bearing areas are open for company exploration. The grant of Authorities to Prospect in the Central Queensland Coal Area, comprising the region between latitudes 20°30' South and 25°30' South, and east of longitude 145°00' East, has been strictly controlled since 1971 by Cabinet policy. This region covers the Bowen and Galilee Basins, where most of the State's coal reserves occur. Applications for new areas there are normally considered only when they are released for advertisement for competitive application, or in cases where the Government responds to an outstanding developmental proposal, or where additional coal reserves are required to enhance the viability of existing projects. Where the release of an area has been preceded by Departmental exploration, these exploration costs are recouped from the successful applicant.

Recently a deposit at Curragh, with important reserves of both coking and steaming coal, previously explored for the State Electricity Commission was the subject of tenders for the provision of coal for the State's electricity generating program.

Beyond the Central Queensland Coal Area the normal priority system for the granting of Authorities under the Mining Act 1968-1980 applies, but most of the prospective areas have been already taken up.

All Authorities to Prospect are issued for fixed terms, normally three years, with annual relinquishments, but may be renewed. They attract sizable expenditure commitments and results must be reported at six-monthly intervals. On relinquishment or expiry, all reports, except on those areas taken to mining lease, are placed on open-file and are available for examination and copying by new explorers.

Most of the State's coal areas are now fairly well delineated, but much detailed work remains to be carried out. Deposits of economic interest occur in several basins (Figs. 3 and 4). Almost all of the coking coal and most of the proven reserves of non-coking coal occur in the Bowen Basin of Permian age in the eastern part of Central Queensland. The coals range from anthracite to sub-bituminous in the west, with most of the coking coals being found in the median part of the basin where suitable structural conditions elevated coals to the requisite rank. There were several phases of deposition of coal-bearing sediment in the Permian.

Very large reserves of sub-bituminous non-coking coals occur in the Galilee Basin to the west. Some thick seams are present, but a veneer of freshwater Tertiary sediments limits the amount of potentially open-cut coal. Petroleum exploration has revealed coal at depth further into the Galilee Basin to the west and this is also true of the Cooper Basin in the far south-west of the State.

Important deposits of non-coking bituminous coals occur in the Ipswich, Tarong, and Callide Basins of Triassic age. While these basins of intermontane origin are not large, and ash tends to be rather high, they contain important coals for steam-raising.

Jurassic coals are widespread in the Moreton and Surat Basins in the south. At present they are little worked and, while in many places they are banded and lenticular, several very significant shallow and potentially open-cut deposits have been found. The coals are perhydrous and have potential uses for conversion to synthetic fuels as well as for steam-raising.

Coals of Cretaceous age have been worked in the Maryborough and Styx Basins, but the deposits are of minor economic importance.

The literature of Queensland coal deposits is voluminous. The most comprehensive coverage available is in papers presented in Traves and King (1975).

As a result of exploration by Government and industry present totals of reserves, proved to measured and indicated status in terms of parameters adopted by the Department of Mines, are 14 152 million tonnes of coking coal and 12 469 million tonnes of non-coking coal. These figures, representing raw coal in situ, are set out in Tables I and II for deposits in the Permian and Mesozoic Basins, respectively. More detailed tables, showing a dissection on an Authority to Prospect and Mining Lease basis are published twice yearly in the Queensland Government Mining Journal.

In the tables, "large" is used for those inferred reserves believed to be between 100 million and 10 000 million tonnes and "very large" for those thought to exceed 10 000 million tonnes. Present figures for proven reserves are conservative, and further exploration will result in vastly increased totals for several areas.

On the assumption that 90 per cent of open-cut coal and 50 per cent of underground coal may be extracted by mining, and using existing experimental data or otherwise an arbitrary figure of 65 per cent for the recovery of coking coal after washing, recoverable reserves are estimated to be 5 510 million tonnes of coking coal and 6 775 million tonnes of non-coking coal.

DEVELOPMENT

It was the tremendous expansion of the Japanese steel-making industry and the availability of easily accessible open-cut reserves that provided the impetus for the rapid growth of coking coal production over the last two decades. The first trial shipment of coking coal was sent to Japan by a Queensland company, Thiess Brothers Pty. Ltd., from its Kianga mine in 1959. Regular shipments began in 1960 when total production in the State was a mere 2.7 million tonnes.

Development of the Kianga and Moura coking coal deposits was continued by Thiess Peabody Mitsui Coal Pty. Ltd., now Thiess Dampier Mitsui Coal Pty. Ltd. Subsequently, export coking coal operations were developed by the Utah Development Company at Blackwater, Thiess Brothers Pty. Ltd. at South Blackwater, Central Queensland Coal Associates at Goonyella, Peak Downs, Saraji, Norwich Park and Harrow Creek, and subsidiaries of The Broken Hill Proprietary Co. Ltd. at Cook, Leichhardt and Gregory.

Only minor amounts of coking coal are consumed within the State. Metallurgical coke is produced at the State Coke Works, Bowen, from coal mined at Collinsville.

The export trade in steaming coal has only started to grow in the last two years and in the 1980 calendar year a total of 759 000 tonnes were shipped mainly from the Moura-Kianga and West Moreton areas.

Overseas companies have played a very important role in the development of these deposits and the associated rail and port facilities, but the level of foreign equity in projects is now subject to Commonwealth Government approvals through the Foreign Investment Review Board. The Commonwealth also exercises controls through its export licencing system.

However the grant of Mining Leases for coal in Queensland, even on freehold land, is entirely within the prerogative of the State Government. Similarly it is the State Department of Mines which formulates and administers mining lease conditions, which cover good mining practice, safety, and environmental management. Royalty is payable at the rate of 5 per cent of net F.O.R. value for open-cut coal for export and 4 per cent of net F.O.R. value for underground coal for export. For domestic coal it is levied at a flat rate of 5 cents per tonne.

Where new railways developments are required for coal development the policy of the Queensland Government has required that these be State owned and controlled, and this policy applies also in part to new harbour developments. The developer is required to lodge with the State a security deposit to provide the capital for construction and purchase of rolling stock and these security deposits plus interest are refunded to the companies over fixed terms. Where an agreement is entered into between the developer and the State on the provision of infrastructure or if there are other matters not covered by existing legislation, the special provisions may be consolidated and ratified by Parliament in the form of a franchise agreement act. The Central Queensland Coal Associates Agreement Act 1968 is a comprehensive piece of legislation of this nature.

The growth of Queensland's coal industry since 1960 has been achieved mainly by the development of new open-cut mines and in 1980 about 89 per cent of the total production of 28 539 562 tonnes was won by this method. This trend, of course, has not been without its critics, on the grounds that reserves of the more easily mineable coal will be depleted disproportionately. However, open-cut coal mining in Queensland has had considerable economic benefits to the nation and it has enabled new projects to be developed quickly. Furthermore many of the seams in the Bowen Basin are thick and there are some problems associated with the presence of gas and difficult roof and floor conditions. The emphasis on open-cut mining will enable suitable underground mining technology to be developed to provide for more efficient and safer mining, when this needs to become more widespread. At the same time open-cut technology is certain to be refined with the present limits on dragline operations being overcome by the use of bucket-wheel excavators where conditions are favourable, or truck and shovel stripping with conveyors to remove overburden from the pit. A bucket-wheel excavator is currently being assembled for Central Queensland Coal Associates at Goonyella.

FUTURE DEVELOPMENTS

With the overall downturn in the world's steel industry it cannot be expected that the rate of growth of exports of coking coal will be maintained during this decade. Nevertheless, the quality, price competitiveness, and deliverability of Queensland coking coals are such that it can confidently be anticipated that they will maintain a significant share of any growth or substitution in the Japanese market and any new markets in Europe and elsewhere. This has been recently demonstrated by the winning of contracts which will enable the German Creek (Capricorn Coal Joint Venture), Oaky Creek (Mount Isa Mines Limited Joint Venture), Riverside (Thiess Dampier Mitsui Coal Pty. Ltd.) to commence production in the next few years, as well as expansion of operations at Collinsville (Collinsville Coal Company Pty. Ltd.).

If the demand allowed, Queensland would have the capacity to substantially increase its coking coal production in the years to come, with several other projects awaiting the opportunity to proceed. There is also a potential for utilisation of some of the State's coking coal resources for coke manufacture within the State for export or in a domestic steel industry. Proposals have been put to the Queensland Government by an international consortium headed by Lend Lease Engineering Pty. Ltd. for the construction of a merchant coke plant at Gladstone.

At present the export trade in steaming coal is small, but there are indications that this will begin to develop rapidly from the middle of the 1980's. As the world's oil resources face depletion in the decades to come, and crude oil prices increase substantially and unpredictably, it is certain that there will be considerable substitution by coal as the fuel for thermal electricity generation in many countries, particularly when new stations are built. The uncertainties facing nuclear power on environmental and other grounds could also increase the demand for steaming coals.

As a result of this increase in demand and the inevitable rise in steaming coal prices as a consequence, Queensland, by virtue of its large reserves, will be well positioned to become a major exporter of steaming coal, as well as coking coal. Japan and other countries in the Far East are likely to constitute the primary markets initially, but the European market is also likely to be very important. The first major steaming coal development will be at Blair Athol, which is now scheduled to begin exports in 1984 at a rate escalating to at least 5 million tonnes a year. It is confidently anticipated that other large projects will quickly follow. As with coking coal, the economics of steaming coal production for export will require that most operations initially be open-cut rather than underground.

It is foreseen that some of the State's future steaming coal developments will have a marketing advantage in that they can be associated on a company or locality basis with coking coal projects. Furthermore, because of the good commercial record of the State, its coal industry can be expected to continue to enjoy a favourable response from established customers.

Specialist markets for anthracite and low volatile thermal coals are also likely to become available. The first such project is the Yarrabee mine of CSR Limited which is now being developed for an initial production rate of 300 000 tonnes per year.

However, while the outlook for further development gives cause for optimism, it should be recognised that the growing costs of infrastructure pose serious threats to the economics of new developments, particularly for steaming coal, where capital returns are likely to be quite marginal. This is recognised by the Government, coal mining companies and potential consumers, who are giving earnest consideration to how the infrastructure burden may be reduced by such factors as sharing and alternative methods of financing.

To accommodate anticipated growth in coal exports, planning and development of new deepwater ports in Queensland is being given high priority. The new Clinton port at Gladstone is to be deepened to take vessels of up to 120 000 tonnes. Its annual loading capacity will be 10 000 000 to 12 000 000 million tonnes. Construction is proceeding on the first phase of the duplication of Hay Point, with initial additional capacity of about 12 000 000 tonnes per year for ships of 150 000 to 200 000 tonnes. This common user facility is scheduled for completion in mid-1983. A feasibility study has been completed for the construction of a new coal port at Abbot Point, near

Bowen, to serve both coking and steaming coal developments on the Collinsville and Newlands fields. This port is planned to take vessels of over 120 000 tonnes. There are also proposals to introduce coal loading facilities at the new port of Brisbane to serve vessels of up to 60 000 tonnes to allow for future increases in exports from fields in southeastern Queensland.

Queensland is indeed fortunate that its steaming coal resources are sufficiently large that it should have no serious difficulties in meeting large demands for export and at the same time satisfying growing domestic requirements, mostly for electricity generation, provided planning takes into account the required lead times for mine development and the attendant infrastructure.

Last year 5 142 290 tonnes of steaming coal, representing about 70 per cent of production in this category, were consumed for electricity generation within the State. The abundance of coal suitable for this purpose in situations not very distant from the main population centres will mean there should be little difficulty in providing relatively cheap electric power from coal-fired generating stations to serve future expansion in population and industry in Queensland. Generating capacity is in the course of rapid expansion. Four of the 275MW sets for the 1650MW station at Gladstone have been installed, a new 1400MW station is under construction at Tarong, and approval has been granted for a 700MW station at Callide and a 1400MW station at a site still to be determined, to use coal from Curragh. Along with coking coals most non-coking coals in Queensland have relatively low sulphur content and air pollution from coal-fired stations is not a serious problem.

There is also growing interest in the future utilisation of some non-coking coals for conversion to synthetic fuels. A joint Australian/Federal Republic of Germany study undertaken over a period of two years on the basis of technology available to the Imhausen Consortium is now nearing completion. The Australian participants include the Commonwealth, Victorian, New South Wales, and Queensland Government and the study is examining the feasibility of developing a conversion plant at a nominated priority site in each of the three States. The Wandoan-Taroom area was selected for this purpose in Queensland.

The perhydrous coals of the Moreton and Surat Basins, by virtue of their chemical properties and availability, would appear to be suitable for several conversion processes and are attracting considerable interest from industry on that basis. A sample trial shipment of 1 000 tonnes of washed coal from Millmerran was shipped for evaluation at the Mitsui solvent refined coal pilot plant at Ohmuta, Japan and it is proposed to send a further sample of some 15 000 tonnes for testing by the Sasol process in South Africa. Samples for other areas have also been tested in laboratory and pilot plants employing other processes in Great Britain and the United States.

In the longer term, utilisation of vast resources of deep or low quality coal by in situ gasification, if this can be made an economic reality, would add still further to the State's position as a major energy base for domestic and overseas supply.

LITERATURE CITED

POWELL DUFFRYN TECHNICAL SERVICES LTD.: 1949, First report on the coal industry of Queensland. Powell Duffryn Tech. Servs. Ltd.

QUEENSLAND COAL BOARD, 1980: Queensland coals. Physical and chemical properties and classification. 6th ed. (amended)

____________________, 1981: 29th Annual Report, 30th June, 1980.

TRAVES, D.M. and KING, D. (eds), 1975: Economic geology of Australia and Papua New Guinea. 2. Coal. Australas. Inst. Min. Metall., Monogr. Ser. 6.

TABLE I : COAL RESERVES - PERMIAN

(million tonnes in situ)

Basin	Coking					Non-Coking				
	Measured		Indicated First Class		Inferred	Measured		Indicated First Class		Inferred
	OC	UG	OC	UG		OC	UG	OC	UG	
Bowen	1 445	2 430	727	9 550	Very Large	1 077	1 119	324	5 787	Very Large
Galilee	-	-	-	-	-	125	675	-	-	Very Large
Total	1 445	2 430	727	9 550	Very Large	1 202	1 794	324	5 787	Very Large

TABLE II : COAL RESERVES - MESOZOIC

(million tonnes in situ; all non-coking)

Basin	Measured		Indicated First Class		Inferred
	OC	UG	OC	UG	
Ipswich	-	390	-	100	-
Tarong	175	25	25	35	Large
Callide	105	20	10	95	Large
Moreton & Surat	860	18	1 335	150	Large
Mulgildie	-	-	-	15	-
Styx	-	4	-	-	-
Total	1 140	457	1 370	395	Large

CAPTIONS FOR FIGURES 1 - 4

Fig. 1 - Map showing coal measures in Queensland, in relation to railway system and major cities and towns.

Fig. 2 - Graph showing growth of Queensland coal production, exports and domestic consumption, 1971-1980.

Fig. 3 - Map showing coal mines, prospects, railways and ports in northern and central districts of Queensland.

Fig. 4 - Map showing coal mines, prospects, railways and ports in southern district of Queensland.

FIGURE 1

QUEENSLAND COAL

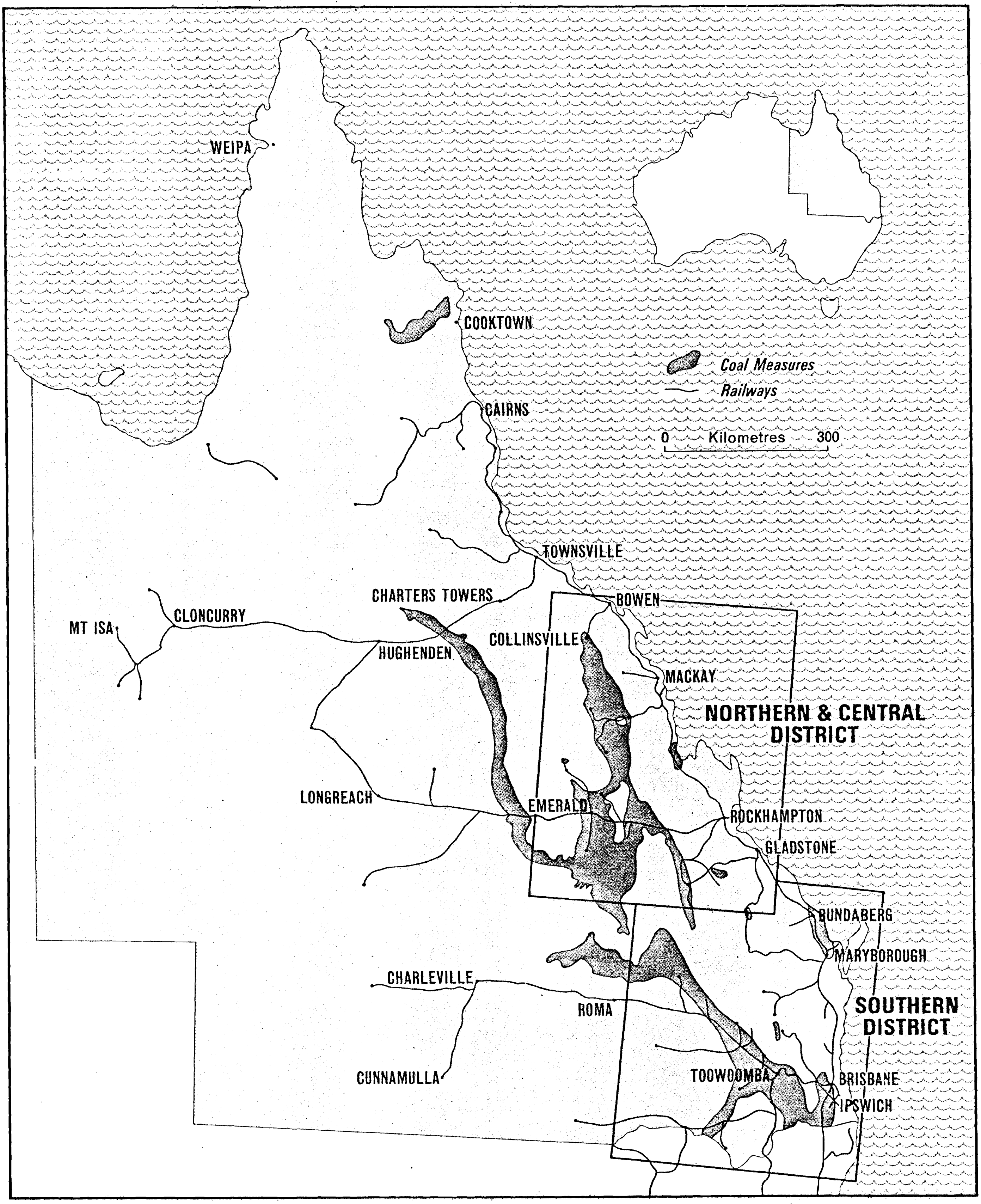


FIGURE 2

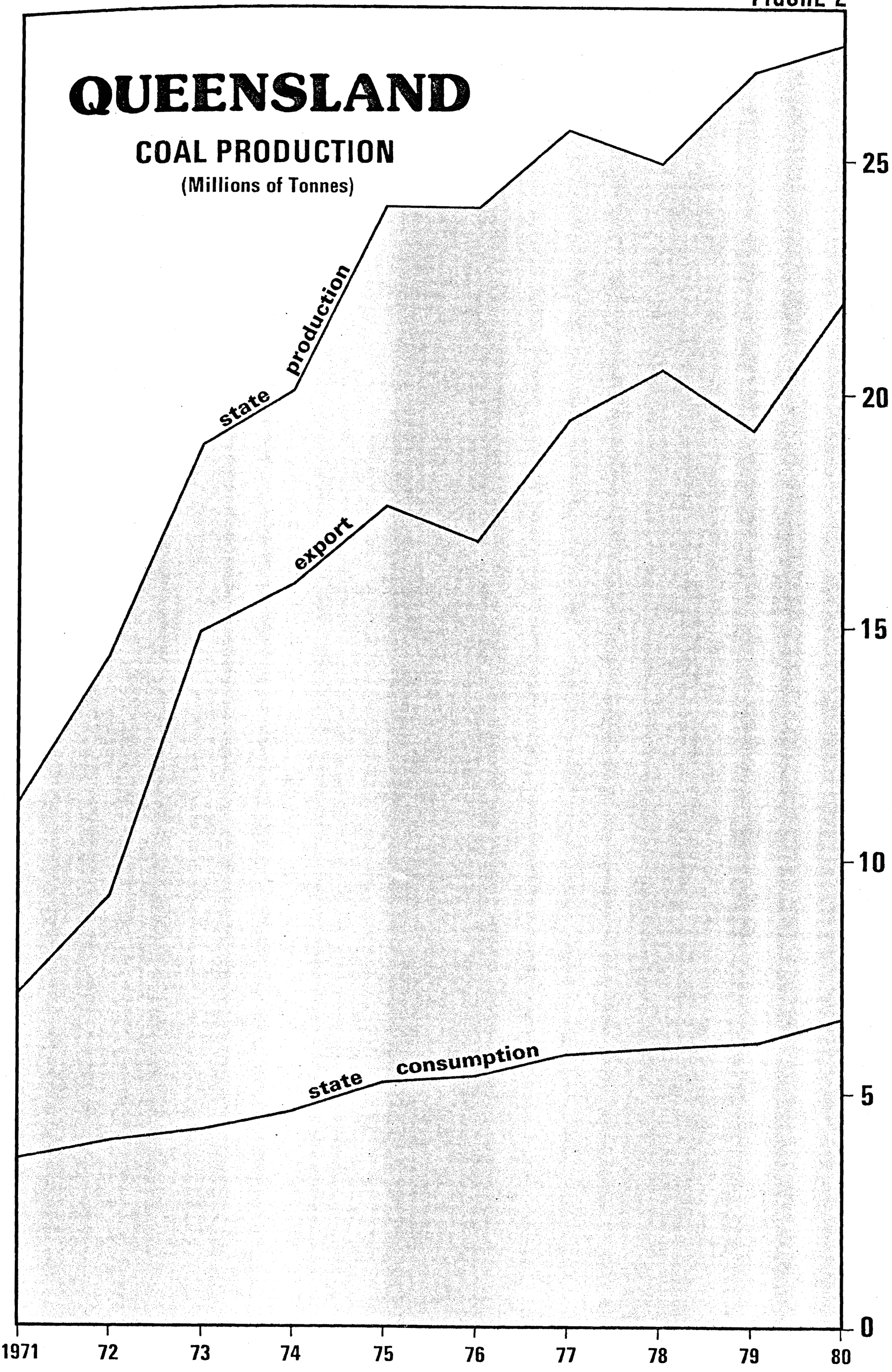

QUEENSLAND
COAL PRODUCTION
(Millions of Tonnes)
state production
export
state consumption
25
20
15
10
5
0
1971
72
73
74
75
76
77
78
79
80

FIGURE 3

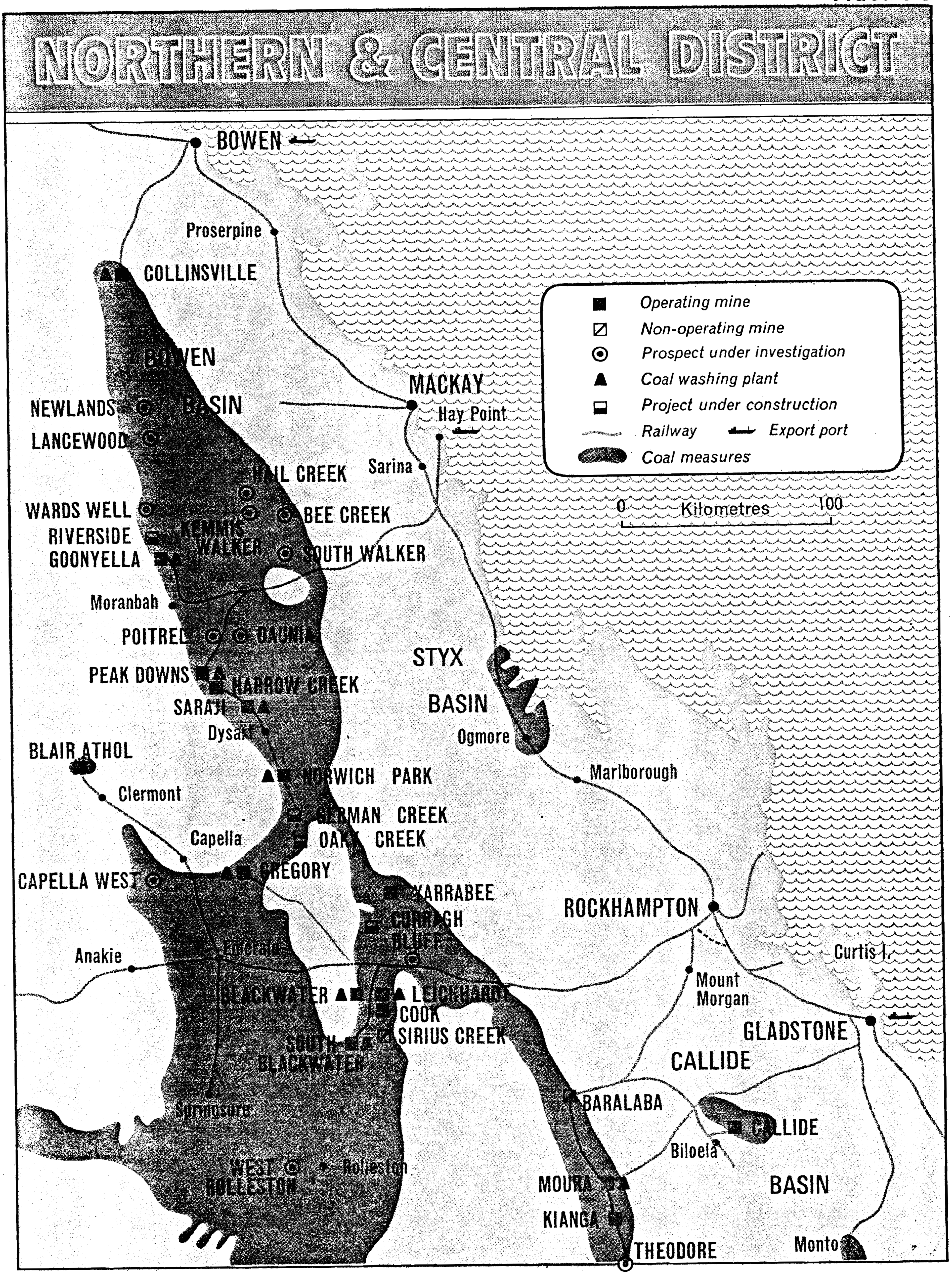
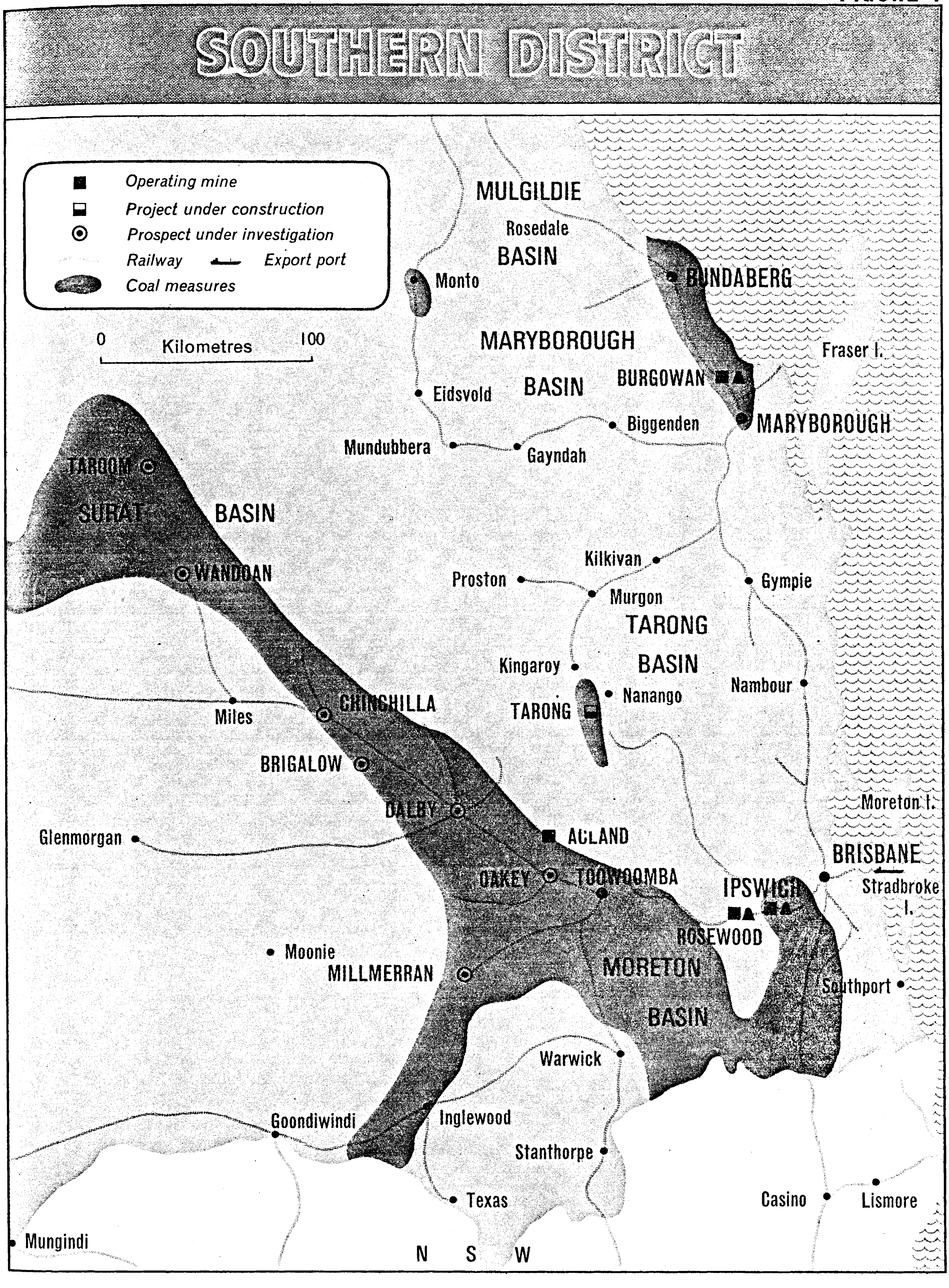

NORTHERN & CENTRAL DISTRICT
BOWEN
Proserpine
COLLINSVILLE
BOWEN
BASIN
NEWLANDS
LANCEWOOD
HAIL CREEK
WARDS WELL
RIVERSIDE
GOONYELLA
KEMMIS
WALKER
BEE CREEK
SOUTH WALKER
Moranbah
POITREL
DAUNIA
PEAK DOWNS
HARROW CREEK
SARAJI
Dysart
BLAIR ATHOL
Clermont
NORWICH PARK
GERMAN CREEK
OAKY CREEK
Capella
CAPELLA WEST
GREGORY
YARRABEE
CURRAGH
BLUFF
Anakie
Emerald
BLACKWATER
LEICHHARDT
COOK
SIRIUS CREEK
SOUTH
BLACKWATER
Springsure
WEST
ROLLESTON
Rolleston
MACKAY
Hay Point
Sarina
STYX
BASIN
Ogmore
Marlborough
ROCKHAMPTON
Mount
Morgan
Curtis I.
GLADSTONE
CALLIDE
BARALABA
CALLIDE
Biloela
BASIN
MOURA
KIANGA
THEODORE
Monto
Operating mine
Non-operating mine
Prospect under investigation
Coal washing plant
Project under construction
Railway
Export port
Coal measures
0
Kilometres
100

FIGURE 4


SOUTHERN DISTRICT
Operating mine
Project under construction
Prospect under investigation
Railway
Export port
Coal measures
0
Kilometres
100
MULGILDIE
Rosedale
BASIN
Monto
BUNDABERG
MARYBOROUGH
BASIN
Fraser I.
BURGOWAN
Eidsvold
Biggenden
MARYBOROUGH
Mundubbera
Gayndah
TAROOM
SURAT
BASIN
WANDOAN
Kilkivan
Proston
Murgon
Gympie
TARONG
BASIN
Kingaroy
Nanango
Nambour
TARONG
Miles
CHINCHILLA
BRIGALOW
DALBY
Moreton I.
Glenmorgan
ACLAND
BRISBANE
OAKEY
TOOWOOMBA
IPSWICH
Stradbroke I.
ROSEWOOD
Moonie
MILLMERRAN
MORETON
BASIN
Southport
Warwick
Goondiwindi
Inglewood
Stanthorpe
Texas
Casino
Lismore
Mungindi
N S W

COAL LIQUEFACTION

D.J. Nicklin, PhD, BScApp, BSc, BEcon, FIChemE, FIEAust

Professor of Chemical Engineering - University of Queensland

Professor Don Nicklin is Professor of Chemical Engineering at the University of Queensland. He has degrees in Applied Science and Economics from the University of Queensland, and a PhD in Chemical Engineering from Cambridge. He worked with du Pont in Canada (1962-63) and in USA (1963-65), and joined the staff of the University of Queensland as a Senior Lecturer in 1965. He served as Head of the Department of Chemical Engineering from 1969-1980, and Dean of the Faculty of Engineering from 1976-79. He has been a member of the National Energy Advisory Committee since it was established and chairs the standing committee of NEAC which was responsible for the preparation of Report No 12 "Alternative Liquid Fuels". Professor Nicklin is a member of the Board of Advanced Education, and the Queensland Air Pollution Council.

1. ABSTRACT

The production of liquid fuels from coal is technologically feasible, and was demonstrated on a large scale in Germany nearly 50 years ago. Such processes, while technologically proven, have generally not been competitive. However, the rapid increases in the price of crude oil since 1973, the risk of disruption to supplies, and the increasingly fragile trading of crude oil have all resulted in renewed interest in the production of liquid fuels from coal. This paper describes briefly the processes which are under consideration. Long lead times are required for such processes, particularly as much of the technology remains to be proven. Plants of the size envisaged for a substitution industry cost billions of dollars. The private sector can be expected to move cautiously into this area - given the long period of the projects, the scope for government interference, and the high economic and technological risk.

2. INTRODUCTION

Different countries have different energy problems, but in most cases crude oil is the crucial element. This is simply because crude oil, of all the energy sources, is the most versatile - and crude oil, of all the energy sources, is traded least competitively. (The cost to Arabia of a barrel of crude oil is about 20 cents, and the selling price is about $30.)

Thus in most countries energy discussions inexorably return to liquid fuels as the lifeblood of industry, to the key role of the automobile in our way of life, and to the OPEC (Organisation of Petroleum Exporting Countries) cartel. Put bluntly, we are uncomfortable with the high level of dependence on the Middle East for such an important product. The Middle East is an area with a poor record of political stability. What to do?

3. BASIC OPTIONS TO SECURE CONTINUITY OF LIQUID FUELS SUPPLIES

A wide range of suggestions has been made for ensuring the continuity of crude oil supplies:

From the non-thinkers: 'Do nothing'

From the thinkers: They argue 'We must extend our supplies of crude oil' and they make the following suggestions:

'Reduce consumption
Look for more oil
Get more oil out of existing fields
Treaties with Saudi Arabia
Convert coal to oil
Convert solar energy to oil (*Botryococcus braunii)*
Extract oil from shale
Convert natural gas to oil
Better traffic management
Carry out research and development to devise new processes
Stockpile'.

From the lateral thinkers: This group argues 'It's not oil you want but stored energy'. They suggest:

'Methanol from coal or natural gas
Ethanol from crops
Burn coal directly - steam engines
Batteries
Hydrogen'.

From the second order lateral thinkers: This group argues 'It's not stored energy you want, but transportation'. They suggest:

'Electric trains
Pipelines
Bicycle tracks'.

From the third order lateral thinkers: They argue 'It's not transportation you want, but productivity with careful optimisation of transportation'. They suggest:

'Decentralization'.

From the fourth order lateral thinkers: They argue 'I don't want productivity, I want a satisfying life style'. They suggest:

'New life styles'.

From the fifth order lateral thinkers: They argue 'True happiness comes not through satisfying man's selfish needs - but only through service to God'.

My endeavour in this paper is not to present the strategy for selecting the best mix of all the above solutions to a complicated problem. (Dare I say that I am attracted to 'doing nothing' as a good starting point - provided this is taken to mean *laissez-faire* along the lines that attracted Adam Smith).

My task is to present the story of coal utilisation but it is vital that I stress that when we discuss the role of coal we must recognise that it is only one of the many candidates in this competition to supply our energy needs. We must keep an open mind and even be prepared to concede defeat graciously if better alternatives emerge.

Most of this paper is concerned with the specific problem of converting coal to liquid fuels for use as substitutes for the products derived from crude oil.

4. THE INCENTIVE TO SUBSTITUTE

It is well known that coal can be converted to liquid fuels and the usual evidence in support of this is the German experience of the 1920s and 1930s - and the SASOL experience in South Africa.

Given that it is now seven years since the first series of OPEC-inspired price rises, it is perhaps surprising that more conversion plants have not been commissioned. Only South Africa has made the firm commitment to seek self-sufficiency this way.

It is worth considering the driving forces or incentives which can encourage substitution. There are basically two (though many hybrids are possible), government edict and market forces.

The first of these is well understood. For reasons of national security, or for other reasons, a government may decide to build substitution plants (South Africa), or to produce ethanol (Brazil) or to convert natural gas to gasoline (New Zealand).

The second of the basic incentives - market forces or the price system - is, I believe, less well understood. It can be described in terms of the supply and demand relationships shown in Figure 1.

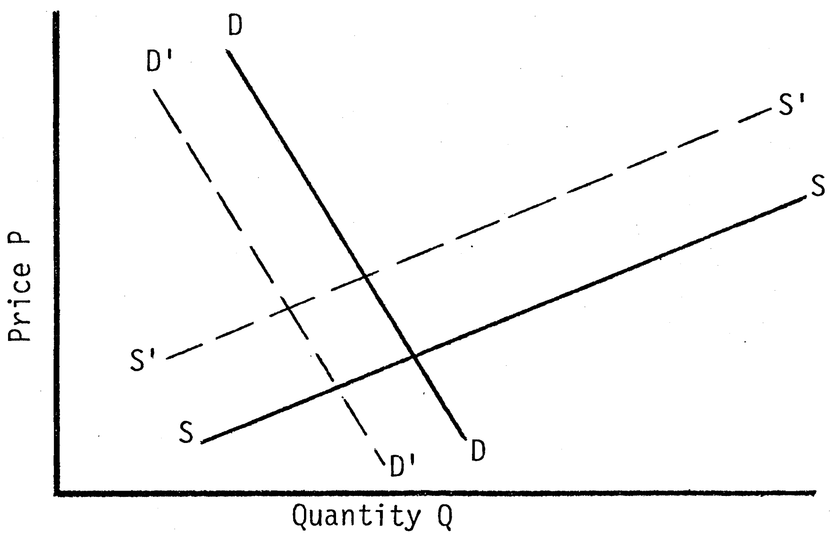


Figure 1. Supply and Demand

The 'Demand Line' DD shows how much of a particular product (say oil) we would buy at any price. Note that it slopes downwards - the mathematical expression of the fairly obvious fact that if the price of a commodity is increased then we buy less of it (all other things being equal). Buyers are rational people.

The 'Supply Line' SS shows what quantity of a product producers are willing to make at a particular price. The upwards slope is the mathematical evidence of the enterprise of the supplier: the higher the price the more he is willing to divert resources to production of this product. He will look for oil in ever-deeper water! The curves intersect in a very stable way at point X, where supply equals demand.

The depletion of reserves makes the supply more expensive, and less is produced at any price. The line thus moves 'upwards to the left' to S'S' and the equilibrium price rises. Note that market forces resolve the 'oil crisis' simply by an increase in price. Movement of the supply line 'downwards to the right' corresponds to a new discovery, or a new and cheaper technology of production, or a weakening of the OPEC cartel.

The demand line is a succinct way of expressing consumer tastes. If you feel concerned that society is so very wasteful in its use of energy, and you mount a successful conservation program, the demand line will move 'downwards to the left' to D'D'. Less of our product (oil in this case) will be consumed. Of course the same argument would apply to any product - peas, beer or leather coats. If you use public monies in a conservation program - to change people's tastes - you must be very confident that you are right.

It is important to realise that in a wealthy society, by the very meaning of the word, we can afford luxuries. For example, because we are wealthy we do not ask eleven-year-olds to work in mines. Because we are wealthy we take holidays, we drink wine, we go to concerts.

Because we are wealthy we can afford personal mobility - we value the automobile. I wonder is it really the ogre that some paint it, or is it just a manifestation of our wealth and our values? We value it highly and would fight dearly to retain it. Think of a young mother with a baby, and the independence a car gives her. She will pay a very high price for gasoline rather than forfeit the car. In terms of Figure 1 the demand line is very steep, probably rather steeper than for most products.

I say this to remind you that individual values are inextricably woven into the energy equations. I am not prepared to say these are 'bad' values. If you say they are 'bad' you must be willing to defend your position, and perhaps it is better that you do not do this with a cigarette in one hand and a glass of scotch in the other.

5. LEAD TIMES AND THE SPEED OF RESPONSE TO MARKET SIGNALS

Sadly neither government edicts nor market forces can respond instantaneously. A fundamental difficulty arises because although a source of crude oil can be cut off instantly (a war in the Middle East, sabotage in Bass Strait) - a new supply takes years to bring on stream.

Part of the problem is the time needed for design and construction. Following the decision to build a synthetic fuels plant, it might take eight years to bring the plant on stream. This period could be reduced in an emergency situation - but it is difficult to imagine that it could be more than halved.

There may also be delays in the decision stage arising from reluctance to make the commitment. If it is national policy to rely on market forces to bring substitutes into production, an important question is whether the private sector is likely to respond quickly to the market signals. It would be comforting if this were the case - but in fact the opposite seems to be true. For a number of reasons it seems likely that the market will respond relatively slowly:

- uncertain but massive capital costs
- uncertain crude oil prices
- uncertain technology
- uncertainty regarding government policy
- environment barriers

This is just another way of saying the risk is high. Furthermore, the risks are synergistic - and an unsuccessful venture could send any Australian company bankrupt.

Thus we are dealing with a system which has inbuilt delays in both the decision-making and the construction phases.

6. THE CONVENIENCE OF HYDROCARBONS

Those lateral thinkers who seek to replace hydrocarbon fuels must recognise that they are up against a formidable opponent.

Because carbon bonds happily with itself and with hydrogen, we get families of hydrocarbons in which the properties change systematically. This systematic change of properties is of great importance because once we have learnt how to manipulate the molecules we can devise mixtures of hydrocarbons with properties suitable for almost any purpose. And we can call upon the members of other homologous series of hydrocarbons to give really good blends.

Dr David Warren of the National Aeronautical Laboratories has a nice patter on 'the intrinsic beauty of a bucket of kerosene'. His arguments include:

- wide availability
- cheapest liquid in the world bar water (no longer perhaps)
- easy tankage
- easy handling
- non-corrosive
- highest energy per unit volume of any liquid
- ease of energy conversion

Petroleum is a mixture of hydrocarbons, and all this means that our commitment to petroleum is hardly a coincidence. Hydrocarbons are very convenient molecules, and lateral thinkers of any order must recognise that you have a most formidable opponent in this challenge of storing energy.

7. COAL CONVERSION VIA THE INTERNATIONAL MARKET PLACE

The traditional way of converting one product to another is by trading - and coal can be traded for oil. The beauty of the international market place is that it will also convert butter, wool, meat and alumina to oil, but for the moment we look at coal-oil conversion, and compare the performance with a chemical conversion plant.

One tonne of coal will produce about two and a half barrels of oil in a synthetic fuels plant - or it will generate perhaps $45 on the international market place. This is equivalent to about one and a half barrels of oil. Not quite as good perhaps - but we save all the capital and operating charges associated with the conversion plant, and these are usually the major components.

Trading is clearly an efficient way of converting coal to oil. In times when Australia has reasonable access to imported crude oil, it is almost certainly the most efficient. In addition, because coal is itself an energy product, its price is likely to rise in sympathy with the price of oil. It provides a nice buffer to violent rises in the price of imported crude oil.

But - you say - China may flood the world with coal ... and imported crude oil simply may not be available ... and you want to talk about insurance policies!! One insurance policy is the synthesis of liquid fuels from coal.

8. THE TWO BASIC ROUTES TO COAL LIQUIDS

Coal has a complex molecular structure with numerous carbon-hydrogen bonds. The first decision we must make is whether to use this existing structure as the starting point from which to build our desired molecules, or whether to destroy it and rebuild. In the first case we would expect to have to handle the bonds with kid gloves, and we would expect some coals to be much better starting material than others. The second alternative is much more brutal. It involves reducing the coal to some lowest common denominator (the carbon monoxide molecule) and rebuilding from this base. Both options are being seriously considered.

The first approach is really the more elegant, and potentially the most efficient. The idea is to 'slide down the free energy gradient'. However, as is so often the case, it has its own set of problems. One problem is that of the variability of the feed. If you look closely at even one piece of coal you will see that it is by no means homogeneous. It is made up of a series of 'macerals' (equivalent to minerals in a rock) and any process designed selectively to treat one is likely to be much less efficient for the others. There is also the problem of the inert material, ash, which must be separated after the first reaction is complete. Separation of the ash has proved to be a major stumbling block in some processes. A further problem is that we may have to develop an associated hydrogen plant, and tonnage hydrogen is not easy to produce.

The 'lowest common denominator' approach gets rid of the problem of variability and of ash, and of hydrogen, but the penalty is loss of efficiency. 'A good bargain' say the proponents of this process, who are happy to trade a little more coal for a rather more tractable process.

The two approaches are usually called 'direct' or 'indirect' conversion, and processes of both types are under consideration.

9. SASOL PROCESS - SOUTH AFRICA'S ANSWER

The SASOL plant in South Africa is the only commercial liquefaction plant currently in operation, and it therefore deserves to be mentioned first. In this process, low quality coal is gasified to form a synthesis gas of essentially carbon monoxide and hydrogen. Gasoline molecules are built up using the so called Fischer-Tropsch synthesis, and large plants of this basic-design date back to the 1930s.

The coal is gasified using steam and oxygen, rather than steam and air (the nitrogen would be a nuisance), and the synthesis gas so produced (consisting largely of CO and H_2) is cleansed of impurities such as tar, sulphur, CO_2, H_2S etc. These impurities would poison the catalyst in the synthesis step. Our 'lowest common denominator' is thus this mixture of CO and H_2 molecules.

We must work our way back up to the longer chain gasoline molecules and this is done at temperatures in the range of 230°-330°C and pressures of about twenty-five atmospheres in two different reactors.

A wide range of products is produced, separated and marketed. These streams are now well integrated into the South African chemical trade and no doubt fetch a good market price. The process is less than 50 per cent energy efficient, and it is difficult to say what the price of the synthetic crude is. This is always a problem when the revenue from by-products is substantial.

The South Africans have already built Sasol II, and Sasol III is on the way. We believe that if these plants were built in Australia, they would be competitive only if the price of crude oil rose to rather more than $50 per barrel.

An important advantage of the Sasol process is that it can produce diesel fuel. Many of the other synthesis routes do not, and this could be a very important consideration in Australia in the 1980s.

10. H-COAL FROM 200 ATMOSPHERES

In this process crushed coal is mixed with process-derived oil and catalyst, and reacted with hydrogen at about 200 atmospheres and 450°C. You can picture how thick the walls of the pressure vessels must be, and you can imagine the challenge of designing a safe plant.

The process is very sensitive to the cost of hydrogen, and if we built such a plant in Australia we might even choose to make our hydrogen from natural gas.

No full size plant has been built, and it is worth relating the research and development effort that has already gone into the process. The work began in 1965, firstly on the bench scale (10 kilograms of coal per day) and later in a pilot plant (three tonnes of coal per day). A 600 tonnes per day pilot plant has just been completed, costing in excess of $100 million. H-coal is a good example of how costs escalate once we move out of the bench scale.

Research is cheap. Development is expensive. Demonstration is very expensive indeed.

11. COED (CHAR OIL ENERGY DEVELOPMENT)

There is an interesting philosophy behind the COED process as follows: given that the hydrogen-carbon ratio is lower in coal than in crude oil, is it possible to split the coal into two fractions, one rich in hydrogen, one lean in hydrogen? The fraction rich in hydrogen is likely to be a much better starting material for producing synthetic crude than the coal itself, and we can always use the hydrogen-lean fraction (called 'char') in a process such as SASOL, or possibly as fuel. Given that we already burn millions of tonnes of coal per year in power stations, it makes good sense to separate out the hydrogen-rich components, send these to a synthetic crude oil plant and burn the char. 'Skimming off the cream' so to speak!

The obvious way to achieve the separation is by heating the coal to drive off the volatiles. (The more volatile components tend to be rich in hydrogen). This pyrolysis is a very similar step to that which converts coal to coke. In the COED process, the pyrolysis is accomplished in four stages, with an increase in temperature from stage to stage. This means that sensitive high volatile molecules can be driven off without damage - the argument used previously that we should handle the molecules with care.

The pyrolysis stage of the COED process splits the coal into a solid fraction (char containing little hydrogen, and most of the ash), a liquid fraction which will be hydrogenated to give synthetic crude oil, and some gas.

The success of COED will be very sensitive to the type of coal used. Coals that have a high percentage of volatiles are good prospects; coals such as anthracite are poor prospects.

The COED process and similar processes show some promise, and we in Australia are carefully examining their feasibility. COED was developed in the USA, where it was not greeted with great enthusiasm. The reason for their relative lack of interest relates to the disposal of the gas and the char, particularly the char. Most of the coals found in the eastern half of the USA have a high sulphur content (about 5 per cent) and most of the sulphur stays in the char. The USA has very real problems with sulphur in the atmosphere, and the char is not acceptable fuel. In Australia, because our coals are low in sulphur, and because our population density is so much lower than that of the USA, the sulphur problem is not serious.

This simply highlights the point that arguments which are perfectly valid in one country may not be valid in another. Each country must appraise very critically the relevance of the research elsewhere, and be prepared to do its own evaluation.

COED has its disadvantages, not the least of which is that the yield of synthetic crude oil is only about one barrel per tonne. However it is a fairly simple process, and in an energy-frugal world it could easily find favour.

12. THE CONSOL AND EXXON PROCESSES

Our ingenuity is not yet exhausted. Would it be possible to dissolve the coal in liquid, and could this be the starting point for a synthetic crude process? It is possible, and there are many variations of this theme.

In the Consol process, the coal is dissolved in a process derived oil at high temperature and pressure, (400°C, twenty-five atmospheres). The ash remains undissolved, but separation is difficult. A nice 'engineering problem' is to filter the inerts from the liquid, and the separation has to be achieved at high temperatures and pressures.

Once again the process is sensitive to the type of coal fed to it. Clearly low ash coals would be best.

In the Exxon process the solvent which dissolves the coal plays a key role in the hydrogenation step. The solvent itself is hydrogenated, then mixed with fresh coal, and it donates its hydrogen to the coal ('donor solvent'). The process has the advantage that the actual hydrogenation step does not involve the coal and should therefore be much more controllable and much cleaner.

Work on these processes continues, with interest also in the idea of refining coal to a cleaner fuel with less ash and sulphur, (so called Solvent Refined Coal, SRCI), and in an intermediate process called SRCII. Demonstration plants for both SRCI and SRCII are under construction.

13. METHANOL - IMPROVING PROSPECTS

The liquid medium preferred by nature to store the solar energy of millions of years ago is crude oil. Crude oil is stored energy, and if we have to synthesise a liquid fuel, our choice and nature's may not coincide. (Just as we do not use flapping wings in our aeroplanes, and we use wheels rather than legs for mobility). We can look to other molecules, and methanol is an obvious candidate. (I have of course pointed out that nature's candidate has lots to recommend it).

Methanol is produced from a synthesis gas containing CO and H_2. The process is well established and coal is a possible feedstock for the process. (It is not the most convenient, and the traditional pattern has been to use petroleum to make methanol rather than to produce methanol as a substitute for petroleum).

One of the important developments of the 1970s was the so-called 'Mobil Process' in which we can convert methanol to gasoline using a zeolite catalyst. The process may soon be commercial and it now seems certain that New Zealand will proceed with such a plant. Prospects for methanol certainly improved with the development of this process.

I believe that methanol will become an important medium by which energy is traded around the world. My reasons for arguing this way are that, more and more, methanol seems to be at the centre of the action.

You can make methanol by so many routes: coal, oil, LPG, natural gas, or even methane produced in the anaerobic digestion of plants. It transports easily, and you can use it in so many ways.

- to produce gasoline (Mobil Process)
- to produce methane (virtually no losses)
- to produce methyl tertiary butyl ether, MTBE, a useful gasoline additive
- burn it directly as a fuel
- mix with petrol (so called M15)
- use straight in cars and diesel engines

Methanol may prove to be the medium by which the OPEC countries export the natural gas that accompanies their oil reserves, and which at present is flared.

14. ESTIMATING THE COST OF COAL-DERIVED FUELS

It is convenient to subdivide the cost of substitute fuels into three components as follow:

- raw material cost (the coal)
- capital charges
- operating costs other than raw materials (labour, maintenance, etc.)

A typical coal conversion plant operates at about 40 per cent thermal efficiency and produces about two and a half barrels of oil per tonne of coal. If the coal costs $25 per tonne, we see that the raw material cost is about $10 per barrel.

The capital cost of a plant is most conveniently expressed as the 'specific capital cost', which is the capital cost per unit of production per unit time. A specific capital cost of '$70,000 per daily barrel' is typical of current estimates for coal conversion plants such as the SASOL plant. This corresponds to about $200 per annual barrel. Put another way - each barrel of oil must provide annually the return on $200 of invested capital. Depending on what return on investment is deemed to be appropriate, we can calculate the cost of capital as follows:

5 per cent - $10
15 per cent - $30
30 per cent - $60

Companies will do their sums on the basis of a DCF (discounted cash flow) return, and they will not forget the 46 per cent tax they must pay on gross profits.

The remaining operating costs would be carefully evaluated in any feasibility study - but often they are related back to the specific capital cost and typically might be in the range of 10-15 per cent or about $25 per barrel.

A company could reasonably argue that coal conversion is a very high risk venture, and that 30 per cent is a very low rate of return for such a venture. Using these figures they would conclude that synthetic oil costs about $100 per barrel.

These brief calculations bring out the idea that a process can be technically feasible but not economically feasible. They show the relative importance of raw material costs and capital costs and in view of the small contribution of the cost of coal explain why a low thermal efficiency can be tolerated if the capital charges can be kept low.

Added to all these costs are the 'externalities' or social costs of a major project - the pollution, the loss of plant and animal life, and the ugliness.

14.1 Comparative Costs

The National Energy Advisory Committee, in its recent report 'Alternative Liquid Fuels' published estimates of the cost of various substitute fuels, and the cost of alternativesderived from coal by the various routes.

The Committee implies that coal-derived liquids are a long way from being competitive at the current prices of crude oil of about $30 per barrel. In addition the cost estimates for all routes other than the SASOL-type synthesis, have a low level of reliability - simply because the technology is not yet commercial.

14.2 Errors in Comparative Cost Estimates

The cynics have already postulated a law which says that 'the cost of synthetic fuel is always $5 per barrel greater than current OPEC oil prices'. I do not wish to make excuses for the poor record of my profession in estimating costs. Nevertheless it is worth listing briefly some of the traditional pitfalls in making cost comparisons.

The currency: There is a tendency to treat all dollars as equal value, without specifying whether they are for example US dollars or Australian dollars, 1978 dollars or 1980 dollars. In these inflationary times it takes only about six years for costs to double.

The location: US Gulf coast capital cost figures are rather lower than Australian costs, and much lower than costs for a remote Australian site.

Greenfield or existing site: Construction on a 'greenfield' site is likely to cost perhaps 1.8 times the cost of a plant built as part of an existing developed site.

The cost of feedstock: This factor is likely to be more important for processes using natural gas feedstock - where prices in the range 30 cents to $5.00 per gigajoule are used.

The cost of infrastructure: Does the capital estimate include the cost of the mine, and infrastructure generally?

The degree of processing: It is unrealistic to compare a simple process such as a solvent refined coal process (2 per cent hydrogen addition) with a much more intensive process such as H-coal (6 per cent hydrogen addition).

Crude product or refined product: The Mobil process produces the refined product gasoline, and it should not be compared directly with a process producing synthetic crude.

State of development: If the technology is proven (methanol from natural gas, SASOL) capital cost estimates should be within ± 30 per cent. For processes at an early stage of development, estimates are likely to be low by 50-250 per cent. We have learnt to distrust the eternal optimism of the researcher.

Return on investment: A realistic commercial return might be 40 per cent before tax for a high-risk venture of this type. The suggestion that 10 per cent is a more reasonable figure because this is a 'national project' simply begs the issue and transfers the risk to the public.

Credit for by-products: One of the artificial ways of reducing the apparent cost of a particular product stream is by generous credit for the by-products. By-products create marketing problems and in general a limited number of product streams is desirable.

15. SOME OTHER POSSIBILITIES

Because Australia's and the world's reserves of coal are so much greater than the reserves of oil, and because the reserves are more widely distributed the recent trend has been to re-examine on the broad front the role of coal as an energy source.

In many countries the first step was the examine the potential to convert oil-fired power stations to coal firing. Following this, other major end uses were scrutinised in turn: domestic heating, industrial boilers, ships.

In Australia the scope for such substitution is limited, because so much of crude oil barrel is devoted to the production of transport fuels. In Australia our energy problems centre around 'liquid fuels for transportation'. Very little of our electric power is derived from crude oil. Much of our space heating is based on natural gas.

Nevertheless we see the market pressures working in their elegant way. It did not take legislation for the Australian public to see the advantages of small rather than large cars. Nor to encourage coastal tankers to switch to coal firing. Nor to trigger an upsurge of interest in the electrification of railways. The big users - private firms and state authorities - saw the writing on the wall very quickly.

Solar heaters and electric cars - both hopelessly uneconomic while the price of oil hovered around $2 per barrel - suddenly became the centre of attention. Their place in an efficient energy economy became clear. Any paranoia of their proponents was cured by the market forces.

One of the problems of coal conversion plants such as SASOL II is the 'lumpiness' of the capital outlay. We may not get our first drop of synthetic oil until $5000 million has been spent. It is a nice challenge to investigate prospects for 'mini-conversion' plants along the following lines:

- electrification of a section of railway;
- construction of a length of freeway;
- improved traffic management;
- coal firing in oil refineries;
- coal oil slurries in boilers and furnaces; and
- insulation in buildings

  ... and many others.

16. POSSIBLE REPERCUSSIONS IN AUSTRALIA OF A MAJOR COAL-CONVERSION INDUSTRY

When we mention the possibility of satisfying Australia's liquid fuel needs by converting coal to liquid fuels, these questions are asked:

- Where will we find the capital?
- How can we protect the environment?
- How can our refineries cope?

These are all fair questions - indeed they are major issues requiring thorough examination. Nevertheless I hope I shall be excused for glossing over them in this paper, and coming straight to a fourth question which for me is somewhat closer to home:

- Where will we get the technicians and engineers?

We talk of a 'resources boom' for Australia during the 1980s, and mention is made of projects already authorised or likely to be authorised of a capital value of $30 billion. These include the N-W shelf, Rundle, the bauxite and aluminium industry and associated power stations, expansion of coal mining, Roxby Downs, Redcliffe, etc. etc.

If Australia elects to move into coal conversion an additional expenditure of billions of dollars will be involved. The very pressures that forced the relatively secure Australia into coal conversion, (the third Middle East crisis?) will almost certainly trigger a massive world-wide movement towards alternative fuels.

Where are the contractors to undertake these billion dollar projects? What engineers are in the Australian pipeline?

For several reasons - one of which must surely be the relatively poor employment prospects in the early 1970s - the numbers of engineers graduating each year is falling. From 2900 per year in recent years, the number will shortly drop to 1900. The market forces will operate on this system also - but the lead times are slow. Australian industry is soon to feel the hidden cost of its treatment of the graduating classes of 1972-73-74.

17. THE OPTIONS FOR AUSTRALIA

Australia can respond in a variety of ways to its dependence on the Middle East for an important fraction of its crude oil supplies. Figure 2 shows how the dependence can be reduced from four different directions:

Conservation (from the North in Figure 2)
Stockpiling (from the West)
Substitution (from the East)
Exploration (from the South)

Alternatively Australia can simply accept this dependence on the Middle East. Report No. 9 by the National Energy Advisory Committee entitled 'Liquid Fuels: Longer Term Needs, Prospects and Issues' suggests that major balance of payment problems are unlikely to result if this course of action is followed, even in very extreme circumstances. Australia expects to be a net energy exporter for many years, and in a sense is a beneficiary from the high crude oil prices.

Nevertheless, accepting a risk that crude oil may simply not be available, we are forced to consider an insurance policy, and Figure 2 shows in a very approximate way how our dependence on the Middle East can be reduced for different annual insurance premiums, expressed in units of 1 per cent of the GDP or about $1000 million per year.

An interesting aspect of Figure 2 is the 'Zone of Vulnerability' shown cross-hatched. No matter how much money we pour into coal conversion we still cannot eliminate this zone. We simply cannot respond to a sudden reduction in supply with quick remedial action because of the long lead times to bring on substitutes. I recall that, following the Iranian crisis, Professor M.A. Adelman was asked - 'what can we do?' His reply - 'There's not a Goddam thing we can do' - just about sums it up. Our only response in this zone of vulnerability is to do without!

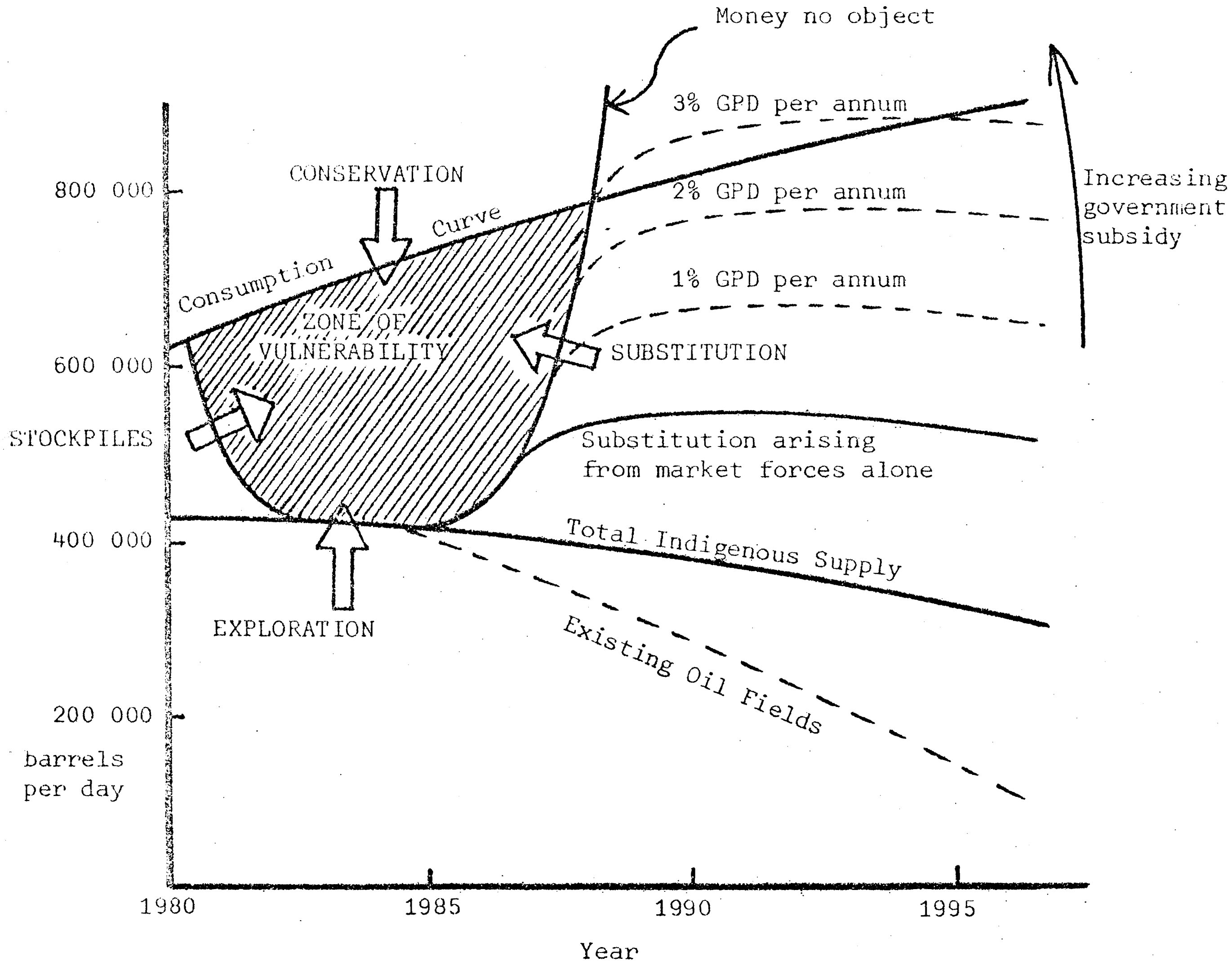


Fig. 2 Methods of Increasing Australia's Self Sufficiency in Oil

What should Australia's stance be as regards liquid fuels synthesised from coal. We must first remind ourselves of the status of the technology:

- SASOL technology is the only proven technology, a plant would take five years to build, and product would not be competitive until crude oil prices doubled.

- Numerous other processes are at various stages of development and design data for commercial plants is expected in the mid-1980s, with likely commercialisation about 1990.

There would appear to be three options:

- Invest $7 billion in a Sasol plant to be on stream in 1986 producing 10 per cent of Australia's liquid fuel needs.

- Invest perhaps $300 million on pilot plants to generate design data and develop expertise

- Continue to rely on market forces to bring alternative fuels on stream in accordance with conventional commercial criteria.

The Government is of course generating about $3 billion per year by virtue of the application of parity pricing to Bass Strait oil, and in a sense it can be argued that the money is there for a 'project independence'. On the other hand the Government has shown little interest in buying insurance policies labelled 'synthetic fuels from coal'.

I happen to support the view that while Australia has reasonable access to imported crude oil, then market forces - the price system - should provide the primary stimulus for the production of synthetic fuels in Australia.

If the Government adopts this stance, and if independence is claimed to be a desirable goal, then the Government role can be simply stated - it is to provide an investment climate conducive to the commercial development of alternative fuels and other substitutes. As I see it, this means:

- stable and rational price guidelines;
- tax guidelines which recognise the need for profits commensurate with the risk;
- realistic foreign investment guidelines;
- willingness to make decisions on environmental issues; and
- avoiding capricious changes of policy.

Are the market forces really working? In terms of Figure 2: From the North, the high price of liquid fuels has certainly reduced consumption; From the South the reserves of existing oil fields are increasing as a result of higher prices, known small fields are becoming economic and exploration is at a healthy level; From the East we see a major oil shale industry on the horizon, and a lively interest in the private sector and the electricity industry in coal liquefaction; From the West, under pressure from the International Energy Agency, we are at least thinking about stockpiling and any sensible farmer and major consumer has already acted in this direction. The Government probably argues that this is a fairly satisfactory picture.

The question will still be asked as to whether the market forces are working quickly enough. And if they are not, how should the Government provide the stimulus for accelerated action? You will get many answers to these questions. I happen to support the policy of 'market forces - private sector - stable policy - attractive investment climate', at least while crude oil continues to be traded.

When I ask myself 'What should we have done in 1973-75 (in response to the jump in oil prices) that we did not do, given the wisdom of hind-sight?' my answer is - 'not much!'

Nevertheless some insurance would appear to be desirable. Any project whose basic objective is to shorten the lead-time for commercialisation in the event of a crisis is a form of insurance. This seems to be a sensible criterion for judging Australian commitment. Significant shortening of the lead times is however not an easy task and the 'zone of vulnerability' is likely to be with us for quite some time.

18. PROSPECTS FOR CENTRAL QUEENSLAND

If a commitment were made during 1981, a SASOL-type liquid fuels plant could be operating in Central Queensland in 1987. SASOL is the only technology currently available and any decision to wait for a new process would delay production at least until the 1990s.

However for several reasons it appears that Australia is not in the mood to rush quickly into coal conversion.

- SASOL technology does not appear to be competitive at current world oil prices
- Australia does not have a balance-of-payments problem
- There is no major strategic issue at stake
- A shale oil industry is developing at an encouraging pace.

It therefore appears that the decision to build the first Australian production facility may still be some years away. Central Queensland must be a strong candidate for this plant. In the longer term it is hard to imagine Australia without a major coal conversion industry, and similarly it is hard to imagine that Central Queensland will not have a major role to play.

No doubt one of the key factors delaying an entry into coal conversion is the general air of optimism regarding an oil shale industry - and here Central Queensland is very much the front runner.

AUSTRALIA'S DEVELOPING OIL SHALE INDUSTRY

John S. Turner, BE, MIE Aust.

General Manager - Oil Shale, Southern Pacific Petroleum N.L.

1. SYNOPSIS

Almost half of Australia's energy consumption is provided by crude oil, but crude oil comprises less than one per cent of our energy reserves. It is unlikely that new discoveries will satisfy even the forecast slower growth in demand for this resource. In the search for synthetic alternatives, oil from shale is a more advanced process than from other large scale fuel sources.

This paper outlines the driving forces behind the development of an oil shale industry in Australia and describes the planning for this country's first potential oil shale project at Gladstone in Central Queensland. It also identifies some practical problems the new industry faces, as well the opportunities it should provide for Australian engineers.

2. INTRODUCTION

Although endowed with large reserves of most traditional energy sources, Australia's crude oil reserves are relatively small. This shortfall, along with the uncertainty and high price of imported supply have provided incentive to develop a synthetic fuels industry.

Of the two principal base materials - coal and oil shale - from which synthetic fuels may be derived, shale appears to be the economic front runner at this stage. Our companies have been prominent in exploration for oil shale over the past decade and are strongly committed to demonstrating the technology and viability of an Australian oil shale industry. In this paper, much of the material has been derived from our own experience but we are also grateful to the Queensland Government and Esso Australia Ltd. for informative publications on the general subject.

3. AUSTRALIAN ENERGY - DEMAND AND SUPPLY

In overview, Australia's known energy reserves very substantially exceed likely national demand in the next 20 years. This would be comforting were it not for the fact that, taken individually, our available energy sources do not match the pattern of our demand. As with many other Western nations, Australia's consumption of oil is greatly in excess of present and forecast local reserves.

The imbalance is demonstrated in Figure 1 on the next page, taken from a recent Exxon survey.

FIGURE 1: Australian Primary Energy Reserves and Consumption - 1980 to 2000

	RESERVES (a)	CONSUMPTION (b)
OIL	2.5	5.3
LPG	0.9	0.5
GAS	4.8	2.3
URANIUM	26	-
COAL	170	7.4

(a) Billions of barrels of oil equivalent. Oil includes condensate.
(b) Billions of barrels of oil equivalent consumed at forecast rates over period 1980 to 2000.

The anomaly is further highlighted by the fact that crude oil comprises less than one percent of Australia's energy reserves but fulfills almost half of the country's energy demand. According to the Exxon survey, our oil consumption pattern is changing and a much slower growth rate is forecast over the next two decades, but still at a rate much greater than can be satisfied by current and future crude oil discoveries. Figure 2 below illustrates the point.

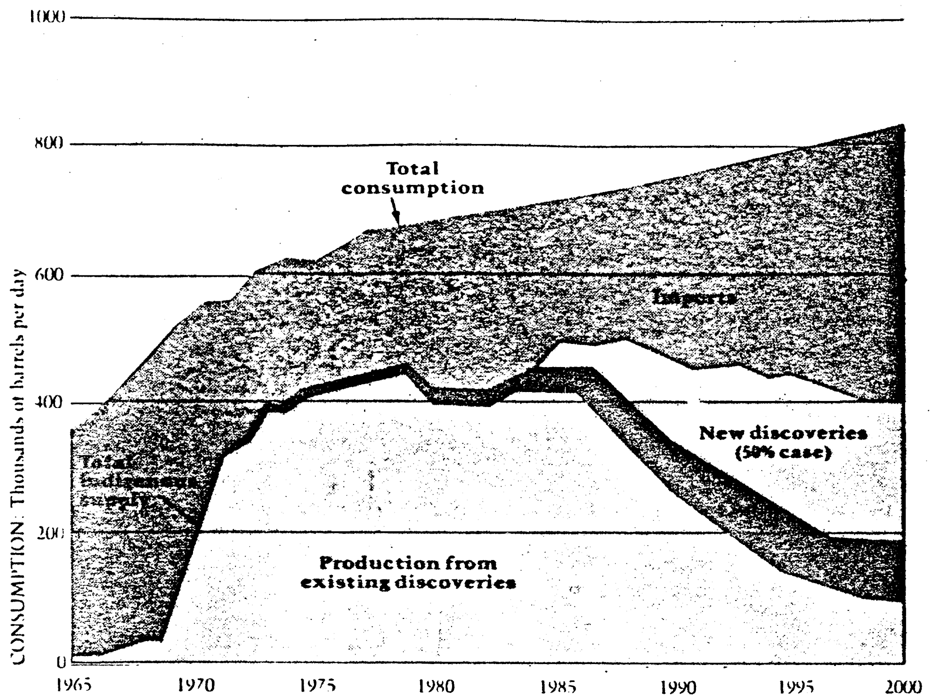


FIGURE 2: Australian Oil Supply and Demand (Courtesy Exxon Corp.)

In the 15 years since 1965, consumption has risen from some 360,000 to nearly 700,000 bbls per day. Over the past 10 years, about two-thirds of our requirements have been met by indigenous supplies, mostly from Bass

Strait, so that today we are self-sufficient to the level of some 400,000 bbls per day. With reasonable expectation of new crude discoveries and a steady increase in the use of liquefied petroleum gas (LPG), this level should be maintained and, at times exceeded, through to the turn of the century.

The economic and strategic question remains however, to what extent will Australia rely on crude oil imports which by 1995 would amount to almost half its daily demand.

Australian oil consumption is dominated by the transport sector, which in the past and for the foreseeable future will continue to absorb some 60% of the nation's liquid fuel demand. Indigenous oil is of high quality and is particularly suited for conversion to motor spirit and aviation fuel. Thus the expected decline in the proportion of local crude resources relative to overall needs has special impact on the transport sector. This in turn enhances the demand for alternatives to petroleum-based transport fuels.

The search for such alternatives follows two main paths:

- fuels suitable for existing or slightly modified vehicles.
- new propulsion systems to replace internal combustion engines.

Alternative fuels are themselves in two categories:

- synthetic crudes from coal, shale or hydrocarbon plants to yield petrol or distillate.
- methanol, ethanol, hydrogen or vegetable oils for use in modified internal combustion engines.

Of these, the synthetic crudes clearly best suit the transport sector with their ability to utilise the existing storage and distribution network and to fuel present vehicles without modification.

In a view confirmed by the Australian National Energy Advisory Committee recently, in its report on alternative liquid fuels (1), the conversion of coal to oil and the extraction of oil from shale are the two best prospects for significant substitutes to crude oil in the medium to long term. Australia is fortunately endowed with large reserves of both coal and oil shale, and the processes for producing synthetic crude from them are substantially researched and well understood. Progress towards commercial production is well in hand, particularly in the case of shale oil.

4. AUSTRALIAN SHALE OIL - DEVELOPMENT OF AN INDUSTRY

As early as 1865, oil was being extracted from shale in Australia. Mining and retorting of the rich shale seams related to coal measures within 150 km of Sydney was carried out until 1952, when the last of the mines (Glen Davis) closed. Total production is thought to have exceeded 6 million barrels of shale oil.

These deposits, the Palaeozoic Torbanites, represent one of three main types of oil shale found in Australia. Although they are the richest found anywhere in the world, the New South Wales deposits are of limited extent and thus commercially unattractive.

Marine deposits, mostly Mesozoic, are represented by the Toolebuc formation which extends from Queensland into South Australia and New South Wales. It is generally about 30 metres thick of which 15 metres may be low grade oil shale. An outcrop of this formation occurs at Julia Creek.

Lake deposits are also relatively low in oil content but are often hundreds of metres thick. They are typified by a series of Tertiary deposits in north-east Queensland which are the most important commercially. With the exception of Julia Creek, all the known oil shale projects under study are of this type.

Exploration in Australia for large scale commercial deposits has gained pace only in the last seven years or so and has focussed mainly on the Queensland Tertiary shales. Those which have been announced and for which some data is available are listed in Figure 3.

The total of 17,000 million barrels of recoverable oil indicated by these seven deposits is a relatively small amount compared with the 700,000 million barrels high grade reserves contained in, for example, the remote and mountainous terrain of the USA where the borders of Colorado, Wyoming and Utah meet. However, the location and nature of the Australian deposits should offer considerable advantages over most others elsewhere in the world. In summary, these advantages are as follows:

- They are generally situated in more favourable terrain and climate, i.e. near sea level, relatively flat, semi-tropical climate.
- Most deposits are in thick seams near the surface and thus particularly suited to large scale low cost mining.
- Most are reasonably close to deep water harbour facilities, to rail and road networks, and to other supportive infrastructure.
- Since they are often located near the coast, the oil shale regions here are conducive to living and working - an important factor in attracting the many new workers and their families to an oil shale industry.
- As an added bonus, oil from our tertiary shales has lower nitrogen (0.9% vs 2.0%) and arsenic (0.1ppm vs 40 ppm) content, as well as lower pour point than its Colorado counterpart.

Enhanced by these desirable characteristics, several Australian deposits are proceeding towards active development. From public announcements to date, the scorecard reads as follows:

1. Julia Creek - a feasibility study is complete and CSR is seeking partners to share in the development.
2. Yamba - Peabody Coal Co. is arranging to start a feasibility study.
3. Condor - preliminary studies are in progress and the Japanese National Oil Corporation, in association with several leading Japanese industrial companies, has announced its intention to proceed towards substantial feasibility investment with a view to full project participation thereafter.
4. Rundle - a joint venture between Esso and the "Rundle twins" SPP/CPM (Southern Pacific Petroleum N.L. and Central Pacific Minerals N.L.) has been formed to implement this project. Preliminary engineering studies are complete and an execution plan is shortly to be finalised.

Since Rundle is the most advanced in planning, this potential project is described in more detail.

FIGURE 3

LIST OF AUSTRALIAN OIL SHALE DEPOSITS

PLANNED FOR COMMERCIAL DEVELOPMENT

Name of Deposit	Owners	Thickness of Deposit (meters)	Overburden Ratio	Estimated Average Oil Yield (litres/tonne)	Estimated Recoverable Oil (millions of barrels)
1. Rundle	50% Exxon 50% SPP	300+	1.2:1	100	2,000
2. Julia Creek	CSR	15	variable	85+	1,500+
3. Condor	SPP/CPM	400+	1:1	60	6,000+
4. Stuart	SPP/CPM	200+	1.2:1	100	2,000+
5. Nagoorin	50% Esperance Greenvale 50% SPP/CPM	200+	not announced	110	1,000+
6. Yamba	50% Peabody 40% Private Investors 10% SPP/CPM	200+	not announced	100	1,500+
7. Duaringa	SPP/CPM		4:1	70	3,000+
			Total Possible recoverable reserves (minimum)		17,000

SPP/CPM means Southern Pacific Petroleum and Central Pacific Minerals Companies.

5. PLANNING FOR RUNDLE

Located 27 km north of Gladstone, Rundle's oil shale seams are arranged in a semi-ellipse 4km wide which deepens and thickens toward the centre of the structure where a western fault forms a linear boundary 10 km long. Some five seams have been identified extending to a depth of 400 m and containing more than 2,000 million recoverable barrels of crude shale oil, naphtha and gas (measured as fuel oil equivalent).

The top seam in the deposit sequence averages 125 litres of oil per tonne of shale as measured by the Modified Fischer Assay. The whole deposit averages some 100 l/t.

The companies SPP and CPM commenced exploratory drilling in 1973 and completed a feasibility study on its potential for commercial development in 1979. Early in 1980 an unincorporated joint venture was formed with Esso Exploration and Production Australia Inc. (EEPA) on a 50-50 basis. Now EEPA as Operator, with active SPP/CPM participation, is just completing preliminary engineering studies prior to definitive planning for development of the deposit to full commercial production.

Until these studies are fully evaluated no confirmatory data is available with regard to costs or schedules. Hence the information which follows is based on preliminary studies published previously, but which may be modified when additional data is to hand.

Retorting

Present planning calls for an ultimate production level of around 200,000 barrels per stream day of upgraded shale oil, at which rate the reserves would permit operation for 20 years or more. At the core of such production are the retort units, which extract hydrocarbons by pyrolysis from the kerogen bonded within the oil shale, i.e. heating to around 500^{o}C. One of the features of oil shale development is that it can grow in a modular fashion by replicating the basic production unit as many times as economic or other constraints may dictate.

There are at least six retorting methods currently under development in the Western world, but few of them are yet beyond pilot plant stage and some are providing fully commercial production of shale oil. The two retorting technologies under most active consideration for Rundle are the Lurgi - Ruhrgas (L-R) method and the circular grate systems represented by the Superior and Dravo retorts.

Much has already been written on the characteristics of these two methods (references 2 and 3) so a brief summary will suffice.

The L-R process utilising fine feed material, represents the indirect method of heating the raw oil shale to the temperatures required for pyrolysis. The process was first developed more than 40 years ago in Germany for the production of synthetic fuels and has been well proven outside the oil shale industry. Hot spent shale acting as the heat transfer medium, is mixed with dried raw shale feed in screw mixers. The various oil grades, in vapour form, and gases then pass through separators and condensers. Condensed heavy oil traps most of the dust contained in the vapour-gas stream and is then processed for dust removal. The gas product is drawn through clean-up and desulphurisation units, after which it is suitable for use as an industrial fuel.

The concept for the Superior process derives from circular grate technology used in sintering of iron ore. It is an example of the direct heating method of pyrolysis in that the oil shale is subjected to cross currents of process gas and air as it is moved through four zones on a 60m dia. anular path. Raw shale is fed to the grate, in three layers of particle sizes ranging from 13 to 100 mm, which moves at about 2 m per minute. In the first zone the shale is heated to retorting temperature and most of the distilled oil flows out with process gas below the grate. In succeeding zones retorting is completed, combustion of residual carbon in the spent shale occurs, and shale cooling then takes place, transferring heat back to process gas and air for use in the retorting and carbon recovery zones.

Either the L-R process alone or in combination with Superior process are presently being considered for planning purposes, but other processes may later prove to be suitable for Rundle shale. Each L-R retort could process 10,000 tonnes of oil shale daily at the scale currently in design, while the Superior retort would handle 27,000 tonnes per day.

Upgrading

The shale oil thus produced may be used as a fuel oil provided it is stabilised and impurities, particularly sulphur and nitrogen, are removed. However its real potential is realised when it is upgraded to become feedstock for petroleum refineries.

The favoured process for upgrading is hydrogenation, which involves stabilising the hydrocarbons and removing impurities through reaction with hydrogen in the presence of a metal oxide catalyst. Studies to date indicate that this step, undertaken at the plant site, is practical and economically attractive, producing a high quality synthetic crude for subsequent refining to transportation fuels.

Mining

The scale of the mining operation in support of oil production will be dependent on the pattern of overall development chosen. At present, it is envisaged that full production will require mining of one million tonnes of material per day, half of which would be overburden and waste shale. Equipment would include bucketwheel excavators, in-pit crushers, conveyors, and waste dump stackers, but considerable further study is required before deciding on the mining plan to ensure compatibility with local environmental conditions and the long range development of the resource.

In the early years of operation, the waste material dumps would be located outside the pit. Later when the bottom of the mineable resource is reached, waste material and spent shale would be returned to the mined out areas. When operations are completed the working pit, some 300 m deep, will be at the western edge of the deposit, mining having followed in a westerly direction down the dip of the shale seams. The refilled pit surface would then be recontoured in preparation for the area's rehabilitation.

Tests indicate that the deposit with its soft shale and moderate seam dips is well suited to the use of bucket-wheel excavators. Machines comparable to those favoured for Rundle, with capacities in the range 130,000 to 250,000 tonnes per day, are currently operating at the Fortuna Mine in Germany. Production there has consistently exceeded 650,000 tonnes per day. Similarly the Hambach Mine in the same area has a planned capacity of 360,000 tonnes per machine per day, for a mine capacity of more than one million tonnes daily.

Infrastructure and Environment

The Rundle project will require significant investment infrastructure items ranging from new roads to the site and additional power and water supplies, to upgraded port facilities at Gladstone. Water requirements will be met by financial contribution to the Awoonga Dam enhancement and by installation of a new pipeline from there to the site. Synthetic crude oil will be pumped to marine tank farm storage near Gladstone and from there to 60,000 DWT vessels at the existing petroleum berth in Gladstone Harbour.

Detailed planning for environmental management is already under way. Data gathering equipment is installed for baseline studies of water and air quality at the site, and reference data for mangrove and marine life studies in nearby coastal areas is being collected. Monitoring is to continue throughout the life of the project. In summary, a commitment is already established for careful management of the natural environment so as to minimise the effects in balance with the importance of the project.

Community planning is also being addressed in various ways beginning with assistance to the Gladstone City Council to undertake a study of the implications for Gladstone of the major industrial developments taking place in the area. It is intended to achieve integration of the Rundle workforce into the community and to promote individual home purchase. In this way, the objective of a stable workforce within a healthy community environment is expected to be established.

6. POTENTIAL PROBLEMS AND SOLUTIONS

Naturally there are difficulties to be overcome before the full potential of a synthetic fuel industry from oil shale can be realised. They are in four categories:

1. The availability of labour is a serious concern. While there is no clear agreement about the value of resource project expenditures during the next five years, the figure is undoubtedly larger than Australia has faced before. The most recent study, by the Federal Department of Trade and Resources values mining and mineral processing projects firmly in prospect at $17.7 billion. The level of this investment in the year 1982-83 is forecast to represent 4.1 per cent of Australia's GDP, some 0.5 percent higher than occurred in the peaks of the early 1970s. Concurrently, other studies have predicted a shortfall of up to 10,000 skilled tradesmen in the same period.
   In keeping with their policy of supporting Australian development, Governments are expanding their apprenticeship and training programmes and reviewing immigration rules to meet this problem. Nevertheless, an adequate supply of skilled labour must remain the primary concern of synthetic fuel industry developers.

2. The opportunities for Australian contractors, manufacturers and engineering firms in a project such as Rundle will be enormous. The scale of some of these work areas will also be large and will require imaginative pooling of expertise and resources in joint venture if Australian firms are to compete adequately with large international bidders. The competence of national and local firms is unquestioned, merely their capacity to marshal enough resources to match the timing and procurement demands now in prospect.

3. The technical and engineering problems associated with synthetic fuel projects are mostly those of larger scale and continuous plant operation for techniques evolved from centuries of oil shale experience. The processes themselves are well understood and we foresee no major difficulty in achieving proficiency after a preliminary period of testing and correlations at smaller scale.

4. Synthetic fuel projects require huge amounts of capital. The Australian capital market certainly cannot meet demands of this magnitude and we must rely upon infusions of capital from overseas to supply such funds. Fortunately, the favourable Australian investment setting and the lure of profitable ventures have operated to attract more than enough foreign capital to date. There is a need however to maintain Australian competitiveness in terms of its cost structures, workforce productivity and industrial harmony.

We believe all of these problem areas are capable of satisfactory solution given the willingness of Australian industry to organise itself effectively for large single site development, and the co-operation of both Government and labour in private enterprise ventures of this magnitude.

7. OUTLOOK FOR ENGINEERS

For Central Queensland, the impact of oil shale projects such as Rundle and Condor will be very considerable indeed. One of the key areas of greatest importance to engineers will be that of employment. Rundle, for example, is likely to require at least 1,500 man years of engineering design and documentation, and will employ a field construction workforce of more than 4,000 people for perhaps 5 to 10 years depending on ultimate capacity. Operating personnel will number around 3,000. Such activity will rely heavily on engineering skills from all branches of the profession. Expertise in process technology will no doubt be a predominant need with mining, civil, and other engineering qualifications much in demand.

Testing and research facilities offered by tertiary institutions and other Government sponsored research bodies, particularly those established in Queensland, will be in a favourable position to develop know-how relevant to the growing oil shale industry.

Today's projects however place extra emphasis on the inputs of other disciplines - sociological, environmental, legal - so a challenge which now faces engineers is their ability to understand, work with and manage multi-discipline professional teams. The oil shale industry will be especially demanding in this regard.

8. AUTHOR

A graduate of the University of Western Australia in civil engineering (1960), John Turner has a background in construction and project management. After six years with international contractors Christiani & Nielsen on projects such as the Ord River Scheme in North Western Australia and marine works in UK, he worked as a project manager in U.K. and the Middle East. In 1974, he returned to Australia to form McLachlan Turner, providing project co-ordination services for industrial and commercial developments. As a General Manager with the Rundle Oil Shale co-venturers, he is now assisting in the preparatory studies for Rundle.

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"PROVISION OF ELECTRICAL ENERGY"

N. A. Galwey, B.E., M.I.E. Aust., A.A.U.Q. (Prov.), F.A.I.M.

State Electricity Commissioner

Neil Galwey commenced his career in the electricity supply industry in 1949 as an engineering cadet with the City Electric Light Company which was the forerunner to The Southern Electric Authority of Queensland. Following graduation in 1954 as a Bachelor of Engineering from the University of Queensland with honours in electrical engineering he became Assistant Southern District Engineer and held various positions with the Authority until 1977. In April of that year he was appointed Deputy State Electricity Commissioner (Engineering) and in July 1980 was appointed State Electricity Commissioner.

1. SUMMARY

With the rapidly changing world energy scene resulting from the increasing price of oil and natural gas, there is increasing urgency to secure alternative large scale energy sources. Electricity supply, although it is not a primary energy source, is taking an increasing share of the energy market place.The early expectations of a nuclear fuelled electric energy economy have not yet been realized on a world scale. To meet the immediate demands for increasing electrical energy, attention has turned to conventional soures of hydro-electric and coal fired electricity generation which is now more economic than the convenience fuels, gas and oil.

2. CONCLUSION

Because of its abundant resources of readily accessible high grade coal, Queensland is now in a favourable position to supply the electricity requirements of power-intensive manufacturing industries. The resulting expansion of electricity supply capacity will increase the demand for other infrastructure facilities and provide additional employment opportunities to the State.

3. ORGANISATION OF THE ELECTRICITY SUPPLY INDUSTRY

Responsibility for electricity supply in Queensland rests with a number of statutory electricity authorities governed by a common Electricity Act. These authorities include:-

(i) Seven Electricity Boards responsible for the distribution and sale of electricity within defined areas throughout the State;

(ii) One Electricity Generating Board responsible for the generation of electricity, operation of the main transmission grid and the supply of electricity to bulk consumers, in particular, the seven Electricity Boards and the northern rivers district of New South Wales;

(iii) The State Electricity Commission of Queensland which is responsible to the Minister for Mines and Energy in matters relating to electricity and for the co-ordination of electricity supply in Queensland.

In its co-ordinating role, the State Electricity Commission plans the development of new generation and transmission facilities and the utilisatiion of primary energy resources for electricity production, and in addition, raises capital borrowings for electricity works, determines electricity tariffs, regulates the safe use of electricity and advises the Government upon policy matters.

Indicative electricity purchases of the respective Electricity Boards for the financial years 1981/82 and 1986/87 are shown in Table 1. Electricity purchases from the Generation Board have been dominated by the south eastern region of the State which contains more than half of the State's population and most of the present industrial activity.

As well as supplying the statutory Electricity Boards, The Queensland Electricity Generating Board may supply electricity to special consumers from its bulk transmission grid if the characteristics of the load, such as its magnitude or other unusual requirements, warrant such a measure. Some of the power intensive industrial developments now under construction or planned in Queensland, including aluminium smelters, chemical processing plants and steel furnaces, will purchase more electricity than most of the State's Electricity Boards and will therefore be supplied from the main bulk transmission grid.

TABLE 1

ANTICIPATED ELECTRICITY PURCHASES
(millions of kilowatt hours)

Electricity Board	Financial Year 1981/82	Financial Year 1986/87
Far North Queensland	520	740
North Queensland	830	1 160
Mackay	560	760
Capricornia	1 130	2 130
Wide Bay Burnett	480	770
South West Queensland	590	820
South East Queensland	6 820	10 060
Direct Customers	1 020	8 730
Total	11 950	25 170

4. ELECTRICITY SUPPLY SYSTEM

Electricity requirements in Queensland are presently supplied from a high voltage transmission grid extending 1 750 km from the southern border along the heavily populated coastal strip to Cooktown. Electricity is supplied to the sparsely populated areas of western Queensland from a number of isolated low voltage networks and small diesel oil fuelled power stations apart from Roma, where natural gas is also available as a fuel for electricity generation.

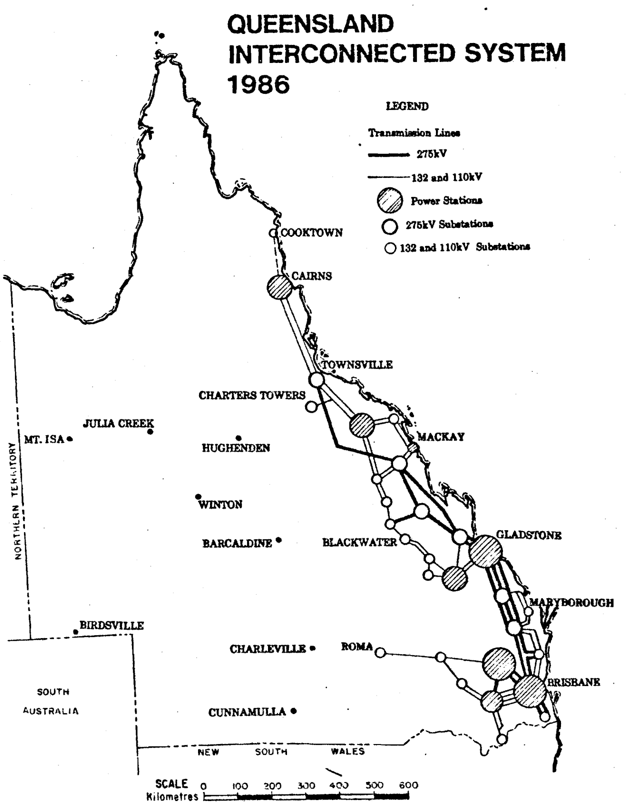

FIGURE 1.

The main coastal grid system as it will be developed in early 1986 is shown in Figure 1 and comprises 275 kilovolt and 132 kilovolt transmission lines forming a "backbone" transmission system which interconnects the major power stations and provides for the bulk transfer of electricity to meet regional load requirements. From the backbone transmission system, radial lines extend throughout the coastal region to individual bulk supply points where electricity produced by the Generating Board is "sold" to the Electricity Boards for distribution throughout their respective supply areas.

Electricity generation within the grid system is at present provided mainly by seven coal fired thermal power stations, two smaller hydro-electric stations and five oil-fuelled gas turbine generators which are employed for emergency generation and power station starting.

Construction is well advanced on two further major power stations, a pumped storage station at Wivenhoe on the Brisbane River due for completion in 1984 and a large coal fired thermal power station and a gas turbine at Tarong due for completion in 1986. Following completion of these stations, the installed generating capacity of Queensland's interconnected grid will be 5 500 megawatts, as shown in Table 2.

TABLE 2
INSTALLED GENERATING CAPACITY OF QUEENSLAND'S
INTERCONNECTED GRID UP TO 1986

Generating Station	Type of Fuel	Installed Capacity (megawatts)
Bulimba	Coal	187
Tennyson	"	250
Collinsville	"	180
Callide	"	124
Swanbank "A"	"	420
Swanbank "B"	"	480
Gladstone	"	1 650
Existing Gas Turbines	Oil	162
Barron Gorge	Hydro-Electric	60
Kareeya	" "	72
Wivenhoe	Pumped Storage	500
Tarong	Coal	1 400
Tarong Gas Turbine	Oil	15
Total		5 500

5. PLANNING FOR DEVELOPMENT

5.1 Generating Plant

The timing of the installation of new generating plant depends upon the rate of growth of electricity requirements as determined by consumers. In terms of supplying these requirements both the peak electricity demand and the annual consumption of electrical energy must be considered.

Estimates of growth in maximum demands and energy have been prepared from detailed analyses and projections of past trends and available information on future energy use, economic trends and prospective mining and industrial developments.

The forecasting process aims to produce the most probable estimates of demand and energy and provides for the requirement of aluminium smelters being constructed in Queensland, the pilot plant for the Rundle Oil Shale Project, and other mining and industrial loads as well as growth in both the number and per capita consumption of general consumers in Queensland. The forecast requirements up to the year 2000 are shown in Table 3 together with the growth in actual requirements over the past decade.

TABLE 3
ACTUAL AND FORECAST ELECTRICITY REQUIREMENTS IN QUEENSLAND

Calendar Year	Peak Demand (megawatts)	Energy (1) Production (millions of kilowatt hours)
1970	1 210	5 510
1980	2 310	11 570
1990	6 010	37 870
2000	9 360	55 770

NOTES: (1) These estimates refer to total electrical energy produced and therefore include electricity used in power stations and losses in the transmission system.

The different growth rates for demand and energy are due to the continuous nature of aluminium smelter and coal mining operations as well as a progressive change being encouraged in the retail sector towards using more electricity away from the peak load periods. The higher growth rate in energy consumption has a significant effect on the amount and type of new generating plant that must be installed as well as on the provision of fuel supplies for existing and new power stations. As an indication of the magnitude of the anticipated change in energy requirements, when the two new aluminium smelters now under construction reach full production in 1989, they alone will consume as much energy each day as was consumed during the day of highest demand on the whole State network in 1980.

Whilst electricity requirements are reasonably certain in the short term, there is considerable uncertainty in predicting growth in the longer term. Special consideration has therefore been given to possible effects of errors in predicting future loads. A very large potential user of electricity is the proposed Rundle Oil Shale Project. Provided certain qualifying conditions are met, the electricity industry could be required to supply up to 1 900 megawatts for this project by the mid-1990's, but the actual requirements and the timing of this project are still uncertain.

Load forecasting uncertainties are compounded by the difference in lead times required for construction of large power-dependent projects and the times required for development of generating plant. The lead times required from the date a firm commitment is made to first production is normally seven years for new generating plant whereas, power intensive industries typically require only three years for construction and have a considerable incentive to achieve full production quickly to provide a cash return on capital invested.

To accommodate these uncertainties, which assume greater proportions during a period of rapid industrial expansion, flexibility in timing major generating plant construction is built into the strategic plan wherever possible. Since these projects involve the co-ordination of contractors and supply of plant with long lead times, and require extensive resources of capital finance and manpower, the scope for altering construction programmes is limited. However, following a decision taken in August, 1979, it has proved possible to accelerate the construction programme for the Tarong Power Station. The commissioning dates have been advanced by 17 months for the first generating unit and by 23 months for the fourth unit to meet the forecast increase in demand and energy requirement to the end of 1986. Deferral of the generation construction programme is another option in planning for load uncertainty.

The prospect of large load increments occurring focuses attention on the lead times for generating capacity increments. Negotiations with contractors on specific contract provisions made with some fore-knowledge could increase flexibility at a price but as a basic guide, the following lead times are normal:-

ACTION	LEAD TIME
Steam power station at new site	Seven years between decision to proceed and commercial operation.
Additional steam units using established designs	Five years
Manufacture and commission steam unit as a contract option.	Three years
Order and install gas turbines.	Two years

These figures demonstrate that the ability to cater for significant unforeseen load increments varies from point to point through the plant installation programme.

A balance of several economic factors is required in the selection of the size of new generating units. Economies of scale generally make larger units more attractive in an enlarged system. The practical task of keeping pace with growth should also encourage an increase in set size. However, all the advantages of economies of scale could be eroded if new plant failed to achieve a satisfactory standard of reliability of performance early in its life. The reliability of generating units tends to decrease with increasing size.

Queensland power systems are too small by world standards to pioneer the largest set sizes and the units supplied for this State could be regarded as second-generation designs. Some benefits through improved reliability of "proven" designs should follow and it is reasonable to expect a higher standard of performance than statistics of first-generation plant suggest.

Other factors which tend to limit the economic size of new sets are the increase in the amount of operating reserve plant required to maintain reliable supply, and operating difficulties in the scheduling of maintenance, operation at light loads and system recovery following outages of generating units.

Reserve generating capacity is required to enable plant to be taken out of service for regular maintenance, to minimise the risks of load shedding due to breakdown of plant, and to provide for any unavoidable delays in construction of new plant.The power-intensive industries will generally take electricity at high load factor and require a high level of security, e.g. for aluminium production, and this increases the requirement for reserve plant.

Recent investigations both in Australia and overseas have revealed that a reserve plant margin between 25% and 30% is necessary to maintain reasonable reliability of supply standards.

Based upon this analysis and the load forecasts shown in Table 3, the projected requirements to the year 2000 for new generating capacity, is shown in Table 4.

TABLE 4

PROJECTED ELECTRICITY DEMAND AND GENERATING PLANT CAPACITY

Calendar Year	Peak Demand (megawatts)	New Generating Plant (megawatts)	Total Installed Capacity (megawatts)
1980	2 310		3 050
		2 450 (1)	
1986	4 390		5 500
		2 100 (2)	
1990	6 010		7 600
		4 900 (3) (400)	
2000	9 360		12 100

NOTES:

(1) Includes 2 x 275 MW units at Gladstone and plant under construction at Tarong 4 x 350 MW and Wivenhoe 2 x 250 MW.

(2) Developments approved in December 1980 comprising 6 x 350 MW units.

(3) Allowance is made for retirement of 400 MW of old generating plant; nett increase in capacity is 4 500 MW.

Approval was granted to proceed with the development of an additional 2 100 megawatts of new generating plant comprising six 350 megawatt units. Two 350 megawatt units will be constructed at Callide using coal from the Callide deposit and four 350 megawatt units will be located at a site in central Queensland and will use coal from the Curragh deposit.

The first of the new Callide units is scheduled to commence production in May 1986, before the fourth unit at the Tarong Power Station is completed. By proceeding with construction at Callide and the second central Queensland site simultaneously, it will be possible to commission a unit at each site during 1987.

An accelerated commissioning programme is scheduled for the four 350 megawatt unit station with first unit to commence operation in May 1987, (together with the second Callide unit) and the fourth and last unit in November 1989. By means of the compressed construction programme, which is never-the-less practical, the installation of 2 100 megawatts of new generating plant can be achieved in the four year period from 1986 to 1989.

A power station subsequent to the two now planned may be required in service by 1989 to meet the requirements of major projects which are now in the feasibility study stage. Investigations are being conducted to establish the feasibility and costs of siting this station at alternative locations throughout the State based on the coal supply offers recently received. In conjunction with this work, investigations will proceed to determine the practicability of calling open tenders for private enterprise to design, construct and operate new power generation facilities.

5.2 Bulk Transmission System

Figure 1 shows the planned development of the bulk transmission grid to meet the demand throughout the populous coastal region to 1986. This demand depends upon both the incidence and location of electrical loads and the siting of the new power station.

Capital investment in the bulk transmission grid at mid-1981 price levels amounts to some $40 per kilowatt of power transmitted over 100 kilometers. To put this figure into perspective, on the average a domestic customer in Brisbane requires about 2.5 kilowatts (after diversity) and the distance from Gladstone to Brisbane is 510 kilometers, requiring a capital investment for bulk transmission of only $510 for each domestic customer. The corresponding investment in generating plant is $2 100.

To ensure the most effective utilisation of capital funds, the installation of new generating plant and the development of the bulk transmission grid has been, and will continue to be, planned and constructed in stages to match as nearly as practicable the projected timing and location of new loads.

Because of the large distances and the relatively small electrical load densities in western Queensland, it has not yet proved economic to establish a transmission grid for electricity supply in this region. However, escalating diesel fuel prices and increasing consumption are factors favouring supply from a transmission grid tailored to the requirements of this region.

The impact of new industrial loads upon the electricity supply system depends essentially upon the magnitude and location of the load. In all areas except the far north and west of the State, new industrial loads will be supplied from the interconnected grid system and it is necessary to ensure that there is both sufficient generating plant and transmission capacity to meet the requirements of the new loads. A new mining load of typically 20 megawatts is unlikely to have a marked impact upon the installation programme for 350 megawatt generating units whereas a 400 megawatt aluminium smelter is a major consideration. While smaller loads may not have a discernible direct impact upon existing generation programmes, there is clearly a notional cost for the generating capacity pre-empted by all such smaller loads.

On the other hand, a 20 megawatt mining load typically located in a sparsely populated area can have a significant impact upon the development of the bulk transmission grid supplying the area with electricity. Examples include the centres of Moranbah, Dysart, Lilyvale and Blackwater where no 132 kilovolt bulk transmission grid would exist or be required apart from the coal operations in these areas.

To allow sufficient time for a review of long range plans, for the adjustment of construction schedules and the completion of major new projects, the electricity supply industry requires advance notice of new industrial loads ranging from three to seven years depending on the magnitude, location and build-up period of their electricity requirements. In special circumstances, shorter periods of notice may be arranged but this generally will depend upon prospective customers entering into financial guarantees to cover any early commitments that may be necessary on their account.

6. SUPPLY OF STEAMING COAL

A number of factors have lead the State Electricity Commission to adopt a new approach in securing coal supplies for future power stations. The Commission does not itself hold mining leases nor does the State operate any mines.

The establishment of a reasonably strong grid system combined with the increased number of coal fields now capable of supplying coal at competitive prices for major power station developments has greatly increased the number of projects to be considered in forward planning. More efficient methods of transporting coal by rail also increase the options for siting new power stations.

Reliable planning information is needed for each possible source of coal and certain contractual commitments need to be made by the prospective coal supplier prior to the electric authority itself being committed irreversibly to a site and a project. Calling tenders for coal for future power stations in these circumstances becomes a logical step. By the nature of the problem, the form of specification and tender adopted will be noticeably different from the more familiar documents used, for instance, for the purchase of plant.

Bids are invited for coal at alternative annual rates of supply corresponding to various planning options. Tenderers are required to submit escalation proposals since coal deliveries are made over a period from five to twenty years after acceptance of the original offer. Usually, escalation formulae apply to labour, material, electricity and other consumable supplies but less obviously, provision may be made for changes in the purchase price and performance of major plant items from the date of tender and the date of their initial purchase or replacement.

Tenderers are required to submit plans for the mining of the coal deposit offered and to submit evidence that adequate economic reserves of coal are set aside to supply the tendered quantities. A supplementary offer to dedicate additional reserves for long-term utilisation may also be required.

This arrangement proved successful in establishing a supply of coal for the Tarong Power Station and the mine operator and The Queensland Electricity Generating Board have entered into a long term contract for the supply of steaming coal based on tenders received.

It has become evident that some of the coking coal deposits in Queensland are associated with other coals classified as non-coking or steaming coals. These non-coking coals may be mined as a necessary part of the extraction of the coking coal or as an adjunct to the coking coal operation. Depending upon the disposition of coal seams and the characteristics of the coal, quantities of steaming coal produced in this way can be quite large and new markets for coking coal will present further opportunities for joint mining operations.A portion of the coal supplied to the 1 650 megawatt Gladstone Power Station includes steaming coal produced as a by-product from a coking coal export operation at Blackwater.

Whilst the incremental cost of such coal may be low, the as-burnt cost will rise substantially if it is held in stockpile for any period of years. This likelihood arises from the different rates of supply required for the export coking coal and local steaming coal markets. To conserve resources, arrangements must be made which will achieve the maximum justifiable co-ordination of production for the two markets. Such a joint arrangement has been achieved for the devlopment of the Curragh deposit, 13 kilometers north of Blackwater, which will supply steaming coal to the new 4 x 350 megawatt station commencing operation in 1987 as well as additional coal for the existing Gladstone Power Station.

A recent estimate of the reserves of coal available for electricity generation in Queensland (7) is shown in Table 5 and the known distribution of these coal resources is shown in Figure 2. These estimates of coal resources do not include the large quantities of coking quality coals presently estimated to exceed 15 000 million tonnes with measured or indicated status.

TABLE 5
QUEENSLAND COAL RESOURCES FOR ELECTRICITY GENERATION
(millions of tonnes)

Coal Basin	NON COKING COAL		
	Measured	Indicated	M & I
Laura	-	-	Unknown
Galilee	800	-	800
Bowen	2 196	6 116	8 312
Callide	140	65	205
Mulgildie	-	15	15
Tarong	260	20	280
Ipswich	390	100	490
Surat/ Moreton	878	1 485	2 363
Total	4 664	7 801	12 465

By comparison, a new power station comprising four 350 megawatt generating units is expected to use some 80 million tonnes of coal and produce 160 000 million kilowatt hours over its economic life. The annual production of electricity in Queensland in the financial year 1979/80 was 11 500 million kilowatt hours and this annual production is expected to increase by a factor of five by the year 2000.

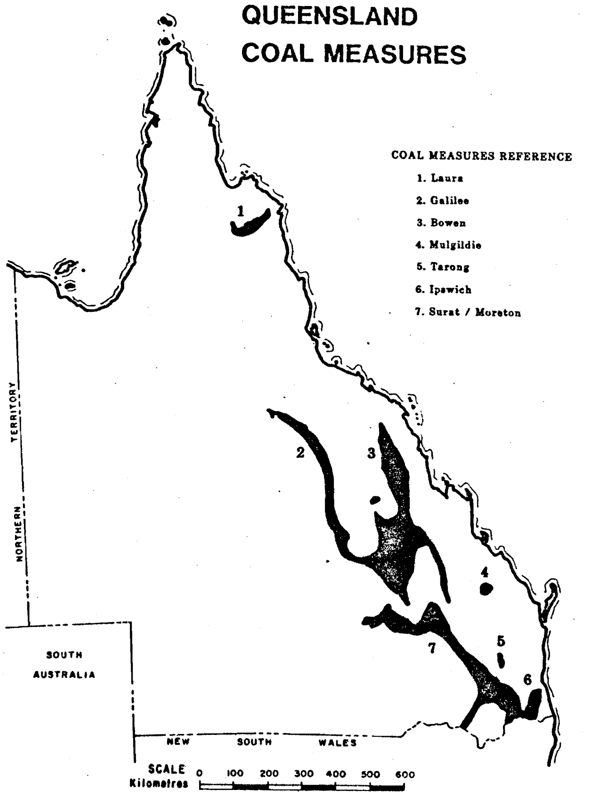

FIGURE 2.

Despite the substantial increase in electricity consumption forecast for Queensland it is apparent that the presently known reserves of non-coking coals are more than adequate as a basis for planning future electricity production. Much of this very large resource is high quality coal with a very low sulphur content by world standards and is minable by open pit mining methods.

7. HYDRO-ELECTRIC POTENTIAL

Hydro-electric generation can be considered under two categories- natural, and pumped storage. In the former, energy is derived from the natural flow of streams from their rain-fed sources to the sea. In the latter category, water is stored in an upper reservoir by pumping from a lower reservoir and this water is used later to generate hydro-electric power.

The potential for hydro-electric power in Queensland is limited by the topography and climatic conditions of the State. The relatively flat terrain of Queensland and the generally low rainfall over much of the area indicates that hydro-electric energy cannot be expected to meet a substantial part of the State's energy requirements. The natural hydro-electric potential of Queensland is almost entirely restricted to the north-eastern coastal area where geological changes have resulted in shortening and steeping of the coastal streams.

The region has the highest rainfall in Australia, with mean annual rainfall ranging from some 4 500 mm near Babinda to 1 100 mm at Townsville. The climate of the region is of monsoonal type, with predominating summer rainfall and dry winter and autumn. This results in uneven stream flows throughout the year and, as a consequence, reservoirs for hydro-electric developments in north Queensland must, for a given regulated outflow for power generation, have relatively greater storage capacities than would be required in southern Australia.

The potential for hydro-electric power generation exists at all major water supply or irrigation storage developments. However, the restricted heads available and the control of timing of releases from the storage by water supply demands, normally results in limited and uneconomic development at these sites.

In contrast, potential sites for pumped storage developments, as a consequence of their lesser dependence on natural stream-bed profiles and natural stream flows, have been identified at several locations on the eastern dividing ranges in both northern and south-eastern Queensland.

A reassessment of the hydro-electric development of the Burdekin Falls scheme was made in 1974-76 and considered both pumped storage and a conventional hydro development incorporating two 250 megawatt units, with provision for later construction of a 1 000 megawatt pumped storage station.It is estimated that the annual energy production of this scheme would be approximately 440 million kilowatt hours firm and 360 million kilowatt hours non-firm, with the reservoir operated as an irrigation and water supply storage. This is equivalent to a firm capacity factor of 10%.

A number of proposals for pumped storage schemes of about 500 megawatt capacity have been investigated, involving existing or proposed water supply dams. Engineering feasibility investigations have been conductd for several of these proposals, while one such scheme was selected for development at Wivenhoe. Two tandem pump-turbine sets of 250 megawatt rating will be installed in the power station, planned to be completed in 1984. The upper reservoir will store the equivalent of 2.5 million kilowatt hours of electrical energy but the scheme will be a nett consumer of electricity as some energy is lost in the pumping and generation cycles of the plant. The advantages of such a scheme lie in low capital cost relative to coal fired power stations and in the ability to use low cost energy at night to pump water into the upper reservoir and to use that water to generate electricity during heavy load periods when the value of electricity produced is high.

Although potential hydro-electric resources are small in terms of energy production, investigations will continue into the use of hydro-electric and pumped storage projects for supply of power over peak periods. It should be noted that the average annual output from the proposed Burdekin Falls power station with 500 megawatts of installed generating capacity would be less than one third of the output of a single 350 megawatt coal fired generating unit because of the variability of stream flows and the prolonged nature of droughts that can be experienced in the region.

There are no other feasible or economic alternatives to coal fired power stations for providing the generating capacity and energy requirements of the State during the next 10 years. In view of the short construction times required for gas turbine plant, the feasibility of installing this type of plant has been considered, but no satisfactory fuel other than high priced fuel oil can be found for gas turbine plant.

It is therefore concluded that the anticipated growth in electricty requirements must be met by construction of new coal fired power stations.

9. WATER RESOURCES

While the relative abundance of high grade, low cost coal in Queensland forms a sound base for electricity supply to power intensive industries, the scarcity of supplies of good quality water within the State could determine the direction electricity supply development should take.

For inland power stations sited adjacent to coal fields, fresh water is required to condense steam after it leaves the turbine generators. For a 1 400 megawatt power station such as Tarong, a supply of water of drinkable quality amounting to 87 million litres per day, an amount equal to one tenth of the peak daily consumption of the Moreton region, is required. By siting power stations near the sea-board or on river estuaries, much of this fresh water usage can be replaced by the use of salt water which is returned to the sea after use.

To develop power station sites on the coast will require the transport of coal by rail although alternative transport by slurry pipeline has been examined. The siting of power stations is therefore an economic balance between the transport of coal to a source of cooling water, the development of adequate water storages in the vicinity of the coal fields and the cost of transmission between the proposed site and the state grid.

Responsibility for the administration of the State's inland water resources rests with the Water Resources Commission of Queensland and the construction of new storages is planned by that Commission. Where possible, the needs of the electricity supply industry are integrated with other requirements and joint use projects involving irrigation and town water supplies have been implemented to achieve economies of scale.

While the State's fresh water resources are sufficient to meet all of the near term requirements, the more economically attractive storage sites are now being developed, and with increasing distances for delivery from suitable storages to power station sites, increasing costs of obtaining water for power station use can be predicted. Air cooling of the reject steam from turbine generators has been investigated, but this reduces the efficiency of electricity production.The scarcity of water in Queensland has not yet reached the stage to justify economically the introduction of this relatively new technology.

10. MANPOWER

The design and construction activities associated with the power station programme discussed will impose a heavy burden on the manpower resources of the electricity industry, which are already heavily committed to current projects. There are currently over 1 400 people employed in power station construction in Queensland. This will increase to some 2 700 with the two new power stations presently approved with an average requirement over the next 10 years of 2 000 people for construction on power stations. In addition, there will be an increase from the present 1 800 to some 3 000 in the number of people employed permanently for operation of power stations.

The open cut mines supplying coal to the power stations could be expected to require 1 000 people during their construction and at least 800 for their operation. The power station and mine projects will create the need for other service and commercial industries which will also provide a significant amount of new employment opportunities.

In essence more than 3 000 people will be required in the short term on construction and 2 000 new jobs will be created for permanent operation. If servicing the needs of these people and the projects is taken into consideration, employment opportunities will be created for an even greater number of people. Enlisting a workforce of this magnitude with qualifications and skills suitable for the specialised tasks to be carried out, is a cause for considerable concern within the electricity supply industry and other responsible authorities.

11. FINANCE

The estimated capital required to finance the planned development of the electricity supply industry for the next 10 years is $5 710 million at current price levels. This amount provides for the following:

$ 933 million	to complete 2450 megawatts of generating plant presently under construction.
$2 734 million	for new generating capacity of 2 100 megawatts approved and initial expenditure on a new station planned for the early 1990's.
$ 700 million	for augmentation of the State's bulk transmission grid, and
$1 343 million	for distribution and other capital works

The electricity industry already meets a significant amount of its capital works commitments from current tariffs. The present high relative level of internal funding could not realistically be increased. It is anticipated that some of the funds required to finance the rapid generation development required to supply special power intensive industries will have to be from loans beyond the usual resources of the electricity supply industry, found either domestically or off-shore.

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PORT FACILITIES

A.H. BRITTON, B.E.

Assistant Director, Works Division, Department of Harbours and Marine, Brisbane.

The Author, Alan Britton commenced work with the Stanley River Works Board in 1947 as a Cadet Engineer, and graduated B.E. (Civil) in 1953, the Board by this time having been incorporated into the Co-ordinator General's Department.

From 1955 to 1960 he was associated with the construction of the Tully Falls Hydro-electric Project by both day labour and contract, and from 1960 to the close of 1963 carried out similar duties on the Barron Falls Hydro-electric Project.

In 1964 he was appointed Senior Engineer Investigation, Department of Harbours and Marine, and has held the position of Chief Engineer now titled Assistant Director Works Division, since 1966.

1. SUMMARY

This paper outlines recent developments at Central Queensland Ports and the reasons therefore, and indicates briefly measures being taken to cater for the large vessels expected to enter the future coal trade.

2. INTRODUCTION

In 1980 the Gladstone Harbour Board commissioned the Clinton Coal Export facility at a cost of some $26M and since then has increased stockpile capacity at an additional cost of $15M. Currently the Board has two other wharves under construction, one to handle the export of cement clinker produced by Queensland Cement & Lime Pty. Ltd. and the other to cater for the export of aluminium produced by Gladstone Aluminium Pty. Ltd. at a combined cost of some $13M.

During the latter part of 1980 and early 1981, the Harbours Corporation of the Department of Harbours and Marine let contracts to the value of some $142M for the construction of a Common User Coal Export Facility at the port of Hay Point, and on March 16, 1981, the Gladstone Harbour Board let a contract for the deepening of the main shipping channels at Gladstone leading to the Clinton coal export facility in the sum of $57.5M.

In all cases the developments have been triggered by the upsurge in demand for minerals in either the raw or processed form.

3. THE PORT CONCEPT

Until recent years the export or import cargo from Queensland ports has been small in tonnage by world standards and with the exception of Townsville and Mackay ports were developed in sheltered estuaries or rivers and the city grew around the port.

The volume of general cargo, that is cargo to meet the general population needs of the people of Central Queensland is relatively small and will continue to be handled by the traditional ports and vessels engaged in that trade. However, to cater for special trades connected with the export of minerals or energy in its various forms I foresee the further development of ports either existing or entirely new, dependent upon such factors as the depth of water in the sea approaches, the proximity of centres of population though new cities cannot be ruled out, environmental considerations, the provision of land transport and perhaps of major importance, an adequate supply of fresh water.

In other words, the provision of ports is just another section of the overall infrastructure cost and in general as the volume of trade increases, port costs are of lesser significance in the overall economic viability of a project.

This is well illustrated by the development of the Common User Coal Export Facility under construction at Hay Point where none of the potential coal export companies could individually economically justify the provision of port facilities to cater for 150,000 D.W.T. vessels and were thus not in a position to actively seek export orders on the world market. However, with the input of some $83M by the State through the Harbours Corporation of Queensland for the provision of offshore port facilities, which acted as a catalyst to the further development of onshore facilities, the coal export companies collectively now have viable export contracts.

4. <u>PORT REQUIREMENTS OF THE VARIOUS TRADES</u>

BAUXITE

The bauxite trade from the Gulf of Carpentaria will be limited to vessels of a draft of some 40 feet (60-80,000 D.W.T.) due to depth constraints of the Torres Strait channel. Presently alumina is exported in 30-60,000 D.W.T. vessels and there is no indication of demand for larger shipments in the foreseeable future. Aluminium, a high price commodity, will probably be exported in smaller shipments to the requirements of the importer.

COAL

While the largest shipment of coal from Hay Point has been 151,271 tonnes, the average shipment has been about 78,000 tonnes, spread over vessels from 50,000 D.W.T. to some 180,000 D.W.T. At Gladstone the general size of coal ships has been 60,000 D.W.T. due to depth limitations. Channel dredging now under way by contract will allow vessels of 120,000 to 150,000 D.W.T. to use the port, depending on tide, which will equate Gladstone to Hay Point, except that Hay Point has the advantage of maximum tide range of 6.4 metres at spring tides compared to 4.5 metres at Gladstone and is thus capable of handling larger vessels though channel depths at datum are Gladstone 15.3 metres and Hay Point 13.5 metres.

However, the explosion in oil prices and the resulting demand for steaming coal as an alternative energy source has caused an upsurge in inquiries as to whether vessels of 220,000 D.W.T. can be handled at Hay Point.

Certainly the existing European ports of Rotterdam and Marseille-Fos can handle vessels in excess of 200,000 D.W.T. and as they will be the gateway to the European trade, the demand for larger size vessels is expected to increase dramatically.

With this in mind, the Queensland Government has authorised investigations of additional port sites in Central Queensland to cater for vessels of a draft of 23 metres i.e. 250,000 to 300,000 D.W.T. and it is only in Central Queensland that depths in the main sea of this order occur close to the mainland and viable ports could be constructed. Land features will also play an important part in the final selection.

5. MAIN FEATURES OF PRESENT DEVELOPMENTS AT GLADSTONE AND HAY POINT

GLADSTONE

The successful contractor was Gladstone Dredging Joint Venture, the joint venturors being Westham Dredging Pty. Ltd. of Sydney, and Australian Dredging and General Works Pty. Ltd. of Melbourne.

The channel width upstream from South Trees will be 160 metres and will be dredged to 15.0 metres, the existing navigation depth being 9.5 metres. The sea channels downstream from South Trees will be 183 metres wide and will be dredged to 15.3 metres the existing navigation depth being 10.3 metres.

The net quantity of material to be removed is some 18 million cubic metres of which approximately 6 million cubic metres will be pumped to reclamation at Auckland Point and Clinton Estate using the Cutter Suction Dredger A.D. Australia which will dredge the upper channels where still clay exists. The material will be pumped ashore through a 850 mm pipe line, the total installed power on the dredger being 5293 K.W.

The outer channels will be dredged by the Suction Trailer Dredgers W.D. Resolution and A.D. Geopotes I of hopper capacities of 4,000 and 3,000 cubic metres respectively and the material will be dumped at sea.

The time for completion of the whole works is 22 months.

HAY POINT

The Common User Coal Export Facility at Hay Point has been designed to allow for the installation of two export berths fed from a common approach trestle. Stage 1 allows for the construction of the first berth to cater for a throughput of approximately 15 million tonnes per annum, the committed users being:

Capricorn Coal Management Pty. Ltd.	3.25 M.T.P.H.
Oakey Creek Joint Venture	3.0 M.T.P.H.
Thiess Dampier Mitsui Coal Pty. Ltd.	3.3 M.T.P.H.
Blair Athol Coal Pty. Ltd.	5.0 M.T.P.H.

It is anticipated that further companies will commit to ship through the facility in the near future requiring the construction of the second wharf.

The main features of Stage 1 of the facility are as follows:

Private sidings and single balloon loop rail track to Queensland Railways' requirements including sufficient track length to hold, both before and after the train unloader, two full lengths of unit trains (a unit train consists of 110 wagons each 61 tonne payload, 5 locomotives and a locotrol unit).

Receival pit for unloading trains by bottom dumping at the rate of 3,600 tonnes per hour with provision to increase the rate to 7,200 tph by duplication as part of future expansion of CUCEF.

Inloading conveyor for 3,600 tph to carry coal from the receival pit to the stockpile area with transfer towers providing for coal to be passed on to selected yard conveyor. The towers and other support structures to provide for future duplication of the inloading conveyor and for future yard conveyors to an ultimate expanded capacity of CUCEF to 30 million tonnes per annum.

One way yard conveyors for carrying coal within and through the stockpile area at 3,600 tph.

Stackers to receive coal from a yard conveyor and deliver it to stockpiles at 3,600 tph.

Stacker/reclaimers to receive coal from a yard conveyor and deliver it to stockpiles at 3,600 tph when in stacking mode and to recover coal from stockpiles and deliver it to the yard conveyor at 3,300 tph when in reclaiming mode.

Reclaimers to recover coal from stockpiles and deliver it to a yard conveyor at 3,300 tph.

Earthworks including bunding, drainage works, excavations and filling to provide an area for on ground storage of coal in stockpile rows, each of approximately ½ million tonnes capacity. Ultimate stockpile capacity is to be approximately 3 million tonnes.

Outloading conveyors to collect coal from the yard conveyors via transfer towers and thence convey it through a surge bin along a trestle to the shiploader. The outloading conveyors to have a capacity of 6,600 tonnes per hour to match two yard conveyors.

A surge bin with a storage capacity of 1,000 tonnes to allow the yard conveyors to continue to supply coal for outloading while the shiploader has stopped loading for hatch changing. Facilities for coal sampling are to be provided on the surge bin. A second surge bin is to be provided when outloading conveyors are duplicated for the future second berth.

Connection to electric power supply and reticulated water supply.

An offshore trestle and wharf to support the outloading conveyor, transfer towers, shiploader and concrete roadways. Provision is to be made for future duplication of conveyors to provide for a future second berth.

A shiploader capable of loading ships of up to 200,000 dead weight tonnes with coal at the rate of 6,600 tonnes per hour.

Approaches to the berth dredged to 13.5 metres below Low Water Datum to permit the sailing of a 15.5 metres draft vessel on any day of the year. This complements the existing CQCA Hay Point berths.

Berth dredged to 20 metres below Low Water Datum so that ships of up to 200,000 D.W.T. may use the berth to capacity - at suitable spring tides.

6. CONCLUSIONS

Australia is a MARITIME NATION and is entirely dependent on world trade to develop its resources for the benefit of Australians. Central Queensland, with its hinterland rich in minerals and its natural deep water approaches from the sea, its above average fresh water resources, is in a unique position to play its part in the development of this State, for the benefit of Australia. I do not think I need to remind you that the export of coal from Hay Point accounts for 7% of Australia's export income.

I am also convinced that through conferences of this nature that we will perceive the challenge, and by virtue of the expertise that has been developed in all facets of human endeavour in recent decades sustain our place in the world scene.

7. ACKNOWLEDGEMENTS

The permission of the Director, Department of Harbours and Marine, Mr. John Leech, to present this paper is gratefully acknowledged.

RAIL TRANSPORT INNOVATIONS

P.J. Goldston, F.C.I.T., M.I.E. Aust.

Commissioner for Railways.

After serving apprenticeship in the Queensland Railways, Mr. Goldston qualified in Queensland University Diploma in Mechanical and Electrical Engineering in 1944, was appointed an Assistant Mechanical Engineer in 1946, and in 1952 qualified as an Associate Member of the Institution of Engineers Australia (now F.I.E. Aust.). He became Divisional Locomotive Engineer of the South Eastern Division, Brisbane, in 1953, and Divisional Locomotive Engineer of the Central Division at Rockhampton in 1954. In the Central Division, he was associated with the development of the coal export industry in that area. In 1963, he was appointed General Manager of the South Western Division at Toowoomba, returning to Rockhampton as General Manager of the Central Division in 1965. He returned to Brisbane as Commissioner for Railways in July, 1976.

Synopsis:

The paper sets out the progress made by Queensland Railways in meeting the needs of transport in this State. It identifies the achievements realised from the early post-war years, through dieselisation, multiple unit operation and tremendous improvements in signalling and communications facilities now in general use. It deals with the transformation of Queensland Railways, particularly in the fields of planning, training, bulk transport, contract carrying, and suburban passenger services, and of planning for the future.

RAIL TRANSPORT INNOVATIONS

With a war-worn fleet of steam locomotives, and wooden wagons and carriages in the late 1940's, Queensland Railways faced the aggressive challenges of road, sea and air transport of the 1950's with diminishing success.

By the 1960's Railways had struck back with Diesel Electric Locomotives, steel wagons and air-conditioned trains, and was tending to even the score.

With the enormous leap forward of coal and mineral export traffic in the 1970's, Queensland Railways climbed into world freight class with huge radio-controlled multiple unit coal trains of 10,000 tonnes, fast heavy general freight trains, centralised traffic control, etc.

They reached world passenger class with the 25,000 volt air-conditioned, electric suburban trains in Brisbane; this system is still expanding.

Railways face even more exciting growth and improvement in the decade of the 80's.

1. 1067 mm GAUGE

A basic factor of our System is the 1067 mm gauge of our track compared with the 1435 mm gauge considered to be the "standard" around the world.

One must not forget, however, that major world rail systems, such as South Africa, Japan, and many parts of South America, have operated 1067 mm sections to very high standards for many years, and that this gauge does, in fact, form the major part of the Australian and New Zealand (ANZR) rail system, being used in New Zealand, Tasmania, West Australia and parts of South Australia, as well as Queensland. New South Wales is the only full 1435 mm State.

2. USE OF TECHNOLOGY

This paper will describe how modern technology has been used to optimise our 1067 mm rail system and produce results which visitors from around the world come to study from time to time.

3. COAL TRAFFIC

Coal provides the greatest volume and highest revenue of any commodity on our System.

For the year ended 30th June, 1980, this single source aggregated 25.2 million tonnes of our total railings of 38.4 million tonnes.

Although this is big traffic, it is expected to rise to 60 million tonnes by 1985 and 90 million by 1990.

TO HAY POINT ONE AND HAY POINT TWO

	1985 M.T.p.a.	1990 M.T.p.a.
Riverside		3.0
Goonyella	4.917	4.917
Blair Athol	5.0	8.0
Isaacs River		3.4
Daunia		5.0
Poitrel		2.0
Winchester	5.0	5.0
Peak Downs	5.73	5.73
Saraji	4.572	4.572
Norwich Park	4.3	4.3
German Creek	3.25	3.25
Oaky Creek	3.0	3.0
Hail Creek	4.5	4.5
	40.269	56.669

TO GLADSTONE

	1985 M.T.p.a.	1990 M.T.p.a.
Gregory	3.0	6.0
Kinrola	4.0	5.0
Boorgoon	2.6	2.6
Laleham	3.0	4.0
Koorilgah	.8	.8
Curragh	2.9	5.9
Yarrabee	1.0	1.0
	17.3	25.3

TO ABBOT POINT

	1985 M.T.p.a.	1990 M.T.p.a.
Newlands	2.0	4.0
Collinsville	1.0	1.5
Suttor		2.0
Havilah		1.0
	3.0	8.5

In this context, remember that ten years ago, Queensland Railways carried a total tonnage of 13.5 million, of which 7 million was coal.

20 years ago in 1960, the total tonnage carried on the System was 7.7 million.

4. EFFICIENCY

In 1960, the staff of Queensland Railways was 28,566 as against 24,948 to-day. This makes the tonnes shifted per employee 1539.2 now as against 269.5 20 years ago. Perhaps you can realise the annoyance felt by Railway staff when various publications refer to the "Coal traffic supporting an inefficient Railway System".

The facts are that six times the tonnage of traffic is being moved per employee to-day as against 20 years ago.

This has been achieved only by application of the best railway technology the world has to offer, to our situation.

5. CORPORATE PLANNING

Certainly, the unremunerative segments of our traffic, such as suburban and long-distance passenger services, and freight services to many country areas, are cross-subsidised by earnings from the more profitable bulk traffic operations, including coal.

To study the effects of various options in emphasis, and to better inform all Railway staff of their expected roles and performance, considerable work has been done in recent years on "Corporate Planning" in the Railways.

One of the recommendations in the report following my study trip overseas last year with the Hon. K.B. Tomkins, then Minister for Transport, was that a corporate plan would be placed before the Government by the middle of this year, and this work is in hand.

This is expected to further highlight desirable lines of action and to tie together in the most effective way, the various progressive moves that have been made, and are continuing, in our System.

Action in other Australian Rail Systems, and in most major overseas systems, e.g. Britain, Japan, France, U.S., South Africa, is currently being taken also, on these lines.

6. OBJECTIVES

The corporate plan will elaborate on Departmental objectives but the basic objective, refined from various Government statements is "Efficient transport at balanced cost".

In other words, this means that "the revenues should balance with the operating costs of the System".

7. ENERGY EFFICIENCY

Considerable research has been done in recent years on means of energy-saving in transport in response to world awareness of coming availability and cost problems with liquid fuel.

There is unified acceptance of the fact that for long distance freight hauls, diesel electric drawn trains offer four times the energy-efficiency of road transport.

8. CONTRACT CARRIERS

There is therefore every justification for the door-to-door delivery policy adopted by the Queensland Government in 1970, and put into effect by the Railway Department since that date. The use of contract carriers, or forwarding agents, to implement this, recognises the effectiveness of having road carrying firms do the local collection and delivery of goods, and the railways doing the line haul.

Door-to-door services are providing a growing proportion of our general goods traffic and are a fine example of the efficient melding of road and rail modes to give the best result in both cost and energy efficiency.

9. SPECIFIC INNOVATIONS

General mention has been made above, of some of the results of applying modern technology and concepts to Railway operation.

It is interesting to look more closely at a few of the new techniques being used.

10. BIG HEAVY TRAINS

The basis of profitable railway freight operation is held by the world leaders in that field, the privately owned U.S. railways, to be "the biggest possible wagon in the biggest possible train".

Many variations of this concept may be argued, but this is the prime objective which has brought Queensland Railways to the vastly improved productivity levels mentioned above.

The "Unit train" concept, of maintaining complete trains, including locomotives, intact during loading, transit, and unloading, similarly patterned on U.S. practice, is also vital to our efficient operation.

The main design features used to bring about this position are described below.

11. TRACK

To carry the "biggest possible wagon" the track, of course, needed to be improved.

Heavier Rail

To achieve higher axle load it was necessary to have heavier rail, going from 30 kg per metre to 54 kg per metre.

Deeper Sleepers and Anchors

Also it was necessary to use deeper sleepers - 150 mm against 112 mm - steel plates under the rail on each sleeper, and anchors to prevent longitudinal movement of the rail over the sleepers.

Crushed Stone Ballast

The old river ballast often used under the sleepers was replaced with crushed stone ballast to a greater depth and width, (250 mm under the sleepers).

Continuous Welding

All of this strengthening gave the track sufficient strength to withstand the contraction and expansion stresses caused by temperature change, and permitted the abolition of that great destroyer of track and vehicle stability, the rail joint. With continuously welded rail so produced, of course the clickety-click also went out of rail travel.

Fully Decked Bridges

To carry this better ballast and track and permit mechanised maintenance, the old type transom bridges were abolished and new fully decked pre-stressed concrete bridges became the accepted standard.

Grade and Alignment

The tight curves and heavy grades formerly evident had to be respectively widened and eased to a new standard of 300 metres minimum radius of curvature and 1% grading against the loaded train. (150 metres radius and 2% grade was present in the original track).

New Track and Upgrading

All new lines for heavy mineral traffic have been built to these standards and old sections such as that from Blackwater to Gladstone have been similarly upgraded.

Track Maintenance

To maintain such track to the required standard, it was necessary to introduce modern machinery. This includes -

Electronic Tie Tampers
Re-sleepering Machines
Ballast Regulators

and numerous cranes, cutting wall graders, backhoes, multiple borers, and others to take the drudgery out of track maintenance and improve the efficiency and economy of track repair operations, and the quality of the finished job.

Extended Crossing Loops

To accommodate the "Big Heavy Train" it was necessary to build crossing loops up to 2 kilometres in length on new lines and to extend those needed on existing lines. For instance, 30 crossing loops on the Blackwater-Gladstone section were extended from the old single engine 300 metre length, to the 600 metre Double Header length, then to the 900 metre Triple Header length, to the 1200 metre Four Header capacity and finally now to 2000 metres for 5-engine trains with locotrol.

The total capital cost of these progressive extensions is about $10 million.

This took the gross train weight from 600 tons for 400 tons of coal in the days of steam, to 7,100 tonnes gross to-day for 5,500 tonnes of coal.

12. SIGNALLING

The "Big Heavy Train" also brought with it the need for operating methods different from the old "Staff and Ticket" or "Electric Staff" systems formerly used. These systems involved an officer at the station handing up a token, in the form of a staff, a ticket, or an electric staff, to the driver of the train as an authority for him to pass on to the next section.

When these very long (2 kilometre) trains have to cross at a station, the procedure of handling the staff, etc., becomes too difficult and time consuming when an Officer has to move from one end of the station yard to the other.

Centralised Traffic Control

This led to the introduction of Centralised Traffic Control (C.T.C.) into the "Big Train" areas, on the Moura to Gladstone line, the Goonyella-Hay Point System and the Blackwater to Gladstone area.

C.T.C. has been used for over thirty years in European and American Railway operations and was a tried and proven system when first introduced in Queensland on the Moura Line in 1971.

It provides for a central control point in a Main Centre operating signals and points in the field, perhaps 200 kilometres away.

By operating a push button in the control centre a signal can be changed in the field, or an electric motor energised to wind over a set of points to the required setting.

The system is fool-proof in that -

(a) It prevents an unsafe signalling or points movement being made (this depends on human memory factors in the old system).

(b) If there is a failure of the system it always fails to "red", i.e. "Stop".

C.T.C. is one of the biggest single factors which has been developed to improve efficiency, safety and economy of railway operations.

Train Describer

A further refinement of C.T.C. recently introduced on the Gympie-Bundaberg and Rockhampton-Blackwater sections, is the Train Describer. On the ordinary C.T.C. the panel in the Controller's Office shows that a particular section of track is occupied by a train. The Controller must deduce from his diagram which train it is.

With the train describer, once a train enters a C.T.C. territory the controller types its number into the computer and thereafter wherever it appears, it is designated by its number.

Also, the Controller can call for the position of that train and it will immediately come up on the wall diagram.

13. COMMUNICATIONS

The Railways have always had their own communication system, originally by morse telegraph, later replaced by teleprinter and much more sophisticated telephone systems.

Whilst we still lag far behind our communications brethren in Telecom in this field, we do have quite good multi-channel telephone systems compared to a few years ago.

In some of the lighter-trafficked areas in the North and West, improved communication is still a pressing need.

14. LOCOMOTIVES

Having looked at the steps which were needed to accommodate the "Big Heavy Train" on the track, let us look at the train itself, starting with the locomotive.

The steam engine was a most inefficient means of converting fuel into energy.

Comparative Thermal Efficiencies are -

Steam Locomotive	Diesel Engine	Electric Power Station
Under 10%	38%	40%

Apart from that, the disadvantages of Steam locos against Diesel Electric lie in -

Less availability for service
More expensive repair procedures
Need for frequent fuel and watering stations
Inferior tractive effort patterns at slow speeds.
Non-availability for multiple unit operation.

The first Diesel Electric locomotive was introduced into the Queensland Railways in January 1952 and the last commercial steam train ran on 21st December, 1969.

The effectiveness of Dieselisation is shown in the following figures. -

Year	No. of Locos.	Tonnes Carried	Tonnes per Loco.
1950	797 Steam	5.95 m.	7 465
1980	551	38.4 m.	69 691

Multiple Unit Operation

This increased efficiency is due in large part to extensive use of multiple unit operation, which was not possible with steam locos.

In Multiple Unit operation the locomotives (up to four in Queensland) are coupled together with electric and compressed air couplings so that the actions of the driver in the leading unit handling throttle or brake, are electro-pneumatically conveyed to the other locomotives in the group.

These bigger trains involve the use of radio communication between the locomotives and van and also between the train and certain wayside stations.

In the later innovation, "Locotrol" (a by-product of the space exploration program) one group of up to 3 M.U. locomotives (in Queensland) heads a train, and a second group of 3 M.U. locomotives in the centre of a 148-car train receives operation commands by radio impulse and so the one driver controls 6 locomotives.

Where, in the 1940's, our largest steam-hauled train was 650 tons, trains of up to 10,500 tonnes are now handled at the rate of 50 to 60 per week on the Goonyella-Hay Point system by these methods.

We will discuss later, the further step of main line electrification now under planning.

15. WAGONS

Having discussed the track, signalling and locomotives, we come to the units of the "Big Heavy Train" itself, that is the wagons.

The standard coal wagon 30 years ago was a 4-wheel steel hopper of 10-11 tons carrying capacity and a drawgear strength of about 30,000 lbs. Its tare-to-load ratio was about 5½ tons tare to 11 tons nett load, i.e. 1:2. The drawgear limited the load over the coal lines - Blackwater, Moura - to 45 wagons - 750 tons gross, with van - even when diesel electric locos. became available.

The modern wagon has a tare of 17 tonnes for a load of 54 tonnes, i.e. 1:3 and drawgear of about 1 400 kilonewtons (300,000 lbs.) strength, allowing "head end" power for trains up to 4 300 tonnes gross. (7 200 tonnes for a locotrol arrangement of 3 locos.in front and two in the middle).

Automatic Couplers

This has been made possible by use of U.S. technology again, with heavy automatic centre couplers, and the use of modern design techniques in aluminium giving the necessary body strength, with the much better tare to load ratios.

Roller bearings have replaced the old plain bearings to lower train resistance, and fast (2 500 tonnes per hour) loading at the Mines and 4 500 tonnes per hour unloading at the ports have played their part in speeding turn-rounds and so wagon fleet productivity.

All of these factors have combined together to make the "Big Wagon - Big Train" concept a successful and accepted operation in Queensland which should more than adequately answer those who have referred to "the inefficient operation of the Queensland Railways".

General Freight

Turning to the innovations used in general freight traffic, again the "Big Wagon - Big Train" has played a vital part.

It is a far cry from the wooden box wagon of 20 tons carrying capacity and low-grade drawgear of the 1950's to the big 'CLO' wagons of high volume (16.74m. long) and over 40 tonnes carrying capacity used on our freight trains to-day. It is worthy of mention that these latter wagons were developed in conjunction with one of our large contract carrying firms based on market needs.

General freight trains of 2 locomotives and 2 000 tonnes gross weight run up and down the 1 600 km route between Brisbane and Cairns. The maximum load in 1950 on this route was 650 tons.

16. PASSENGER SERVICES

For long distance passenger services the old wooden coaches have been almost entirely eliminated and modern dining car and club car facilities on our air-conditioned trains have drawn many favourable comments from travellers.

20 new air-conditioned cars, including 10 first class roomette cars, and 5 each first and economy sitters are now under construction in Brisbane, deliveries commencing from July, 1981.

Better reservation and ticketing arrangements have also been introduced.

Suburban electric services will be mentioned later.

17. CONTAINERISATION

It has become apparent in recent years that removable standard containers would supersede the box wagon for most general goods transport. So far as Queensland Railways are concerned, there are two main reasons for this.-

(1) On the Interstate traffic, the change of gauge at Brisbane ensures that containers vastly facilitate the transfer of goods between the wagons of the different systems.

(2) For Intrastate traffic large customers, particularly in the supermarket field of packaged goods, require minimum handlings between warehouse and customer,

Loading into containers at warehouse, then by road to rail, and from rail destination to customer by road gives this minimum handling of each package.

18. ORGANISATIONAL INNOVATIONS

Some positive steps have been taken to bring organisational arrangements into line with modern requirements in a corporation as large as ours.

Planning and development

Whilst there has naturally always been a large volume of planning work going on in the Railways, a Planning and Development Section was set up in 1976 and has been able to cope with the enormous volume of feasibility and other study work required of us in recent years.

Apart from studies required for development projects, such as mining, manufacturing, etc., the Planning and Development Section have carried out a great deal of "in-house" study and planning, including the ground work and development of the Corporate Plan.

A considerable body of expertise in planning has been built up in this section.

Over the past 4 years projects involving about $1,000 million of capital investment in Queensland Railways have been investigated and of these about $580 million have been built or are in final planning stages.

Training Section

A training section was also set up in 1976, its activities being monitored by a Personnel Development Committee, chaired by the Manager, Industrial and Personnel, and comprising the various Assistant Heads of Branches.

Training is given in the following main categories. -

Induction Training for new employees entering the service.

Operator Training for people such as drivers, firemen, guards, signalmen, station masters, control clerks and also people aspiring for improvement in the Mechanical, Electrical and Civil Engineering Branches.

Particular attention is paid to training in the Dining Car and Conducting Sections of Air-conditioned trains.

Supervisor Training for Foremen Inspectors, etc.

Management Training for Higher Management.

Whilst the benefits of such training are long-range in expectation, very positive results have been seen in many areas already, particularly in response from the public to extra little courtesies extended.

National Rail Electrification Study

A.R.R.D.O. last year, at the request of A.T.A.C., carried out a Study which ranked Railway Sections throughout Australia for their viability as candidates for electrification.

The results of their Study are being considered at State and Federal Government level.

State Studies

A.R.R.D.O. has carried out studies in each State in preparation for a general report on Railway needs and potential to go before the Federal Government this year.

19. SUBURBAN ELECTRIFICATION

The most progressive step in Queensland Railways in recent years has been the introduction of a 25,000 volt electrified rail system into the Brisbane suburban system.

This project is now well on the way to being half completed and with the letting of a contract for a further 108 electric cars recently, a positive and successful finish to the current approved scheme is assured.

So successful is the system proving, that with increased patronage it may be necessary to further extend the electric train fleet in the future.

Early Research

As might be expected, there were strong protagonists for the use of a D.C. System, just as there were supporters for a high voltage commercial frequency A.C. System.

Considerable research was carried out to determine which system was best for Queensland. Available data indicated that total operating and maintenance costs would favour the A.C. System.

Reasons for choice of 25 KV A.C.

The final decision to adopt the 25 KV A.C. was taken on the basis that:

(A) For the system planned for Brisbane, the total costs of A.C. do not exceed those for an equivalent D.C. alternative. You will readily appreciate that, for capital cost considerations, the introduction of the electrified suburban system must be carried out in stages. Our present programme envisages the electrification of 155 route kilometres as an eventual target figure. To date, some 55 route kilometres have been constructed over which regular passenger services have been operating since November 1979. Work on the remaining 100 route kilometres is under way with completion anticipated progressively from 1982 to early 1984. It is of interest to note that the current estimated total costs of the complete electrification programme, excluding rollingstock are about $100 million.

(B) The scope for further development of electrification in Queensland lies predominantly in the field of main line freight operations, for which high voltage A.C. has no rival. Adoption of A.C. in the first instance would avoid the future problems and costs of a dual current system.

(C) The "State of the Art" in relation to technological development is more advanced for A.C. traction than for D.C. It is of particular interest to note that only two sub-stations will be necessary for the Brisbane Suburban System, as compared with thirteen sub-stations previously planned for a proposed D.C. System. Each sub-station will be equipped with two 15 M VA transformers providing approximately twice the designed load capacity. If circumstances necessitate, operation of the system can be maintained using one sub-station, albeit with some loss of train performance at outer locations during peak demand periods.

Rollingstock

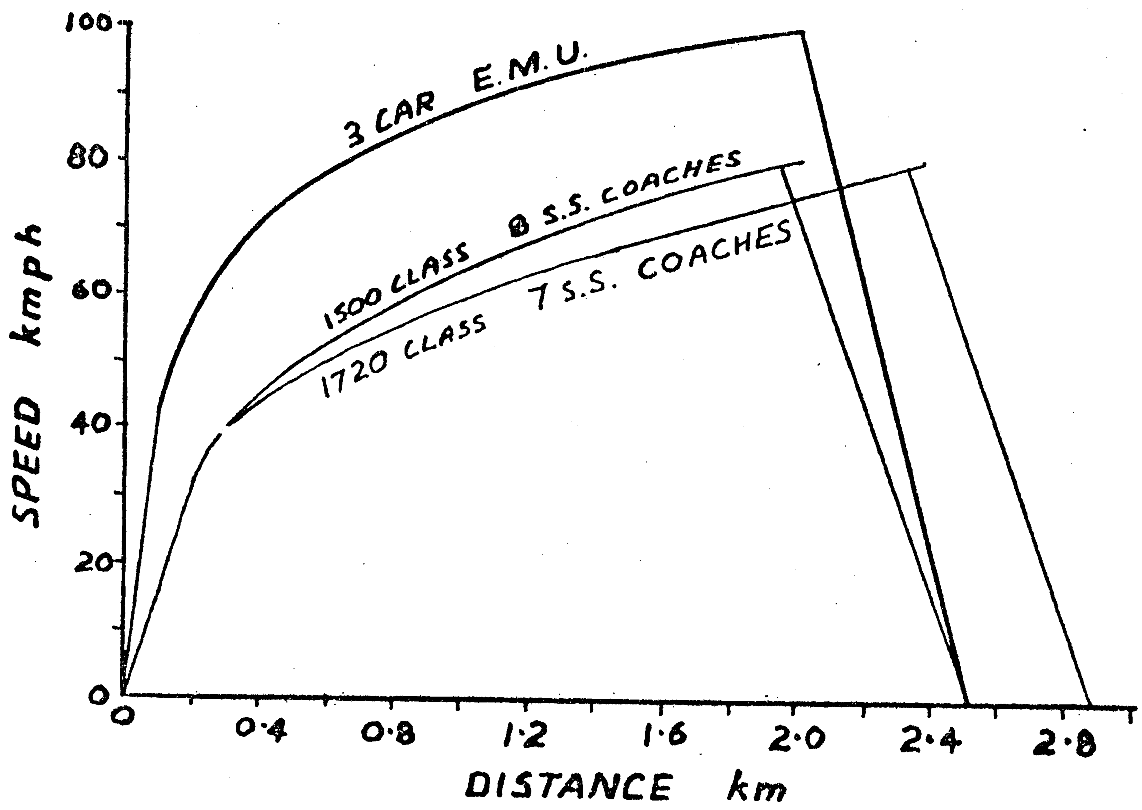
The electric stock is designed to operate to a top speed of 100 km/h compared with 80 km/h for existing diesel stock. The higher speed and more importantly high acceleration and braking rates in excess of 0.8 M/SEC^2 and 1.15 M/SEC^2 respectively (as against present 0.37 M/SEC^2 and 0.893 M/SEC^2 respectively) enables an overall reduction of 20 - 25% in previous journey times. A typical example of comparative times appears below:-

Ipswich -	Brisbane
63 mins.	Diesel Electric
48 mins.	Electric

Performance

The indicative performance characteristic curves for the electric stock are clearly shown on the following illustration. The superior acceleration of the 3 Car E.M.U. set, which is similar to that of the alternative 6 car configuration (as horse-power to weight ratios remain in the same) over the existing diesel electric locomotive hauled suburban train will be clearly evident by the relative steepness of the two curves showing the acceleration phase. Basically, we are comparing the performance of a diesel electric hauled train of 750 KW with the new electric stock which will have the potential to utilise 2080 KW fed directly from the sub-station. It will be further noted that there is a 40% improvement in retardation for the electric stock. This is obtained by using retardation control limiting features to enable optimum braking. You will readily appreciate that the retardation force cannot exceed that which is available from wheel to rail adhesion or we would be soon plagued with passenger complaints of noisy operation due to flats developing on the wheels.

A further significant point is that since each 3 car consist will cost us in the order of $2.1 million we will be looking to a high availability and utilisation factor and down time must necessarily be kept to a minimum figure.



Performance comparison - electric and diesel hauled suburban trains.

20. MAIN LINE ELECTRIFICATION

In August, 1978, the Government gave approval for the Commissioner for Railways to engage consultants to carry out a feasibility study of electrifying the main lines from Brisbane to Rockhampton and Blackwater, and Brisbane to Toowoomba.

The results of this study were positive in the Brisbane, Rockhampton, Blackwater case and on 12th November, 1979, the Commissioner was given Government approval to engage further consultants to carry out detailed design studies during 1980/81, with a view to construction commencing in 1982 and operation in 1984.

Considerable progress has been made with this study and availability of funds will determine future progress.

Meantime Federal and State Governments arranged for the Australian Railway Research and Development Organisation (A.R.R.D.O.) to carry out a National Rail Electrification Study (N.R.E.S.). This study found that three lines in Queensland, i.e.

Goonyella Railway

Newlands - Abbot Point

Blackwater Mine - Gladstone

were in the group highest Australian ranking, and the total picture of electrification is being considered at State and National level.

Advantages of Main Line electrification -

- Low fuel (elect.) cost
- Improved energy efficiency
- Use of plentiful local coal source
- Non-use of scarce and expensive liquid fuel
- Higher average speed (better adhesive) factors
- Lower maintenance cost
- Lower capital cost of locos. (due fewer locos.)
- Better loco. availability
- No pollution

21. CONCLUSION

The Railway Systems have the inherent advantage of the lowest resistance to movement of any land transport medium, with the steel wheel rolling on the steel rail. Added to this is the ability to put large numbers of loaded vehicles together in long trains, and move them at controlled speeds over unlimited distances.

The energy effectiveness of this mode of transport will keep Railways in the forefront of the land movement of materials into the foreseeable future.

In addition is the technical ease of converting this country's enormous stocks of steaming coal into transport energy by means of the generation of electrical power.

So far as the transport of passengers in urban areas is concerned, Railways again offer the capacity to shift people in large numbers at high speed through the urban areas. With electric trains, passengers are conveyed in comfort and without any impingement on road transport in the areas they serve. They minimise pollution of noise and fumes, and practically eliminate traffic accidents where complete security of an urban transport system is obtained.

With these advantages, nothing but a rapidly expanding growth of rail for urban passenger transport, and heavy long distance freight transport, can be foreseen. The linking of road transport with rail for door-to-door deliveries of long distance transport of general goods is considered to be a very important factor in land transport planning for the future.

WATER RESOURCES OF THE CENTRAL QUEENSLAND REGION

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1. SUMMARY

The Central Queensland Region occupies some 40% of the State and because of its land water and mineral resources is one of the most important regions in Australia. The gross useable water resources both surface and underground are estimated to be of the order of 7 million megalitres, but the practical limit development is much below that. Current use for all purposes is approximately assessed at 340 000 megalitres with the possibility that this could double in the next two decades. Substantial additional development could be serviced but this will be costly and in some cases will require lengthy distribution systems.

2. THE REGION

The Central Queensland Region for the purposes of my paper extends from the Coast to the Northern Territory Border, and from latitude 21°30 S to latitude 26°S with an area of 650 000 square kilometres or almost 40% of the State. The Region is shown on Figure 1.

In terms of water resources and agricultural, pastoral and mineral production, it is one of the most important regions in Australia.

The Region is bounded by the Denham, Connors and Broadsound Ranges in the north east, the coast in the east, the Carnarvon Range in the South, the Gowan and Cheviot Ranges in the south west, and the Selwyn Range and Barkly Tableland in the north west.

The Great Dividing Range runs more or less north-south through the Region separating the easterly flowing coastal rivers from those flowing to the south west.

Elevations range from as high as 1200 metres in the Carnarvon Ranges to less than 150 metres along the coast and in the south west of the Region.

The Region includes the very important Fitzroy River Basin, the southern part of the Burdekin Basin and large parts of the Cooper, Diamantina and Georgina Basins. Coastal streams including the Boyne and Calliope Rivers and Baffle Creek also discharge significant volumes of water.

Rainfall and Evaporation

Rainfall over the Region is highest along the coast where it often exceeds 1200 millimetres per year and decreases towards the south west corner where annual precipitation is less than 150 millimetres. As is so often the case with rainfall in Queensland, there are large variations from year to year and within each year. Table 2 provides maximum, minimum and mean rainfall registrations for 20 stations in the Region. At a quarter of the stations, the maximum annual rainfall is 10 or more times greater than the minimum. At Boulia the ratio is 33:1. Isohyets are shown on Figure 1.

Average annual evaporation in the Region is high, ranging from 1735 millimetres at Taroom to more than double this at Birdsville. Evaporation records from 16 stations are shown in Table 3.

3. SURFACE WATER

Drainage Systems

Drainage from the Region is discharged in the North-east Coast and the Lake Eyre Divisions, two of the 12 Australian Divisions. Principal drainage Basins and their tributaries are shown in Table 1.

DRAINAGE DIVISION	DRAINAGE BASIN		MAJOR STREAMS
	Name	Area '000 km^2	
North-east	Burdekin	48	Belyando River Suttor River
	Plane	2.7	Plane Creek
	Styx	3.1	Styx River
	Shoalwater	3.7	Shoalwater Creek
	Waterpark	1.8	Waterpark Creek
	Fitzroy	142.6	Fitzroy River Isaac River Nogoa River Mackenzie River Dawson River
	Calliope	2.3	Calliope River
	Boyne	2.5	Boyne River
	Baffle	3.9	Baffle Creek
Lake Eyre	Georgina	145	Georgina River Mulligan River Eyre Creek Burke River Hamilton River
	Diamantina	115	Diamantina River
	Cooper	180	Cooper Creek Thomson River Barcoo River Alice River

TABLE 1 - PRINCIPAL DRAINAGE BASINS AND TRIBUTARIES

BASIN	RAINFALL STATION	START OF PERIOD	ANNUAL RAINFALL (mm)				
			Maximum		Minimum		Mean
Georgina River	Boulia	1886	799	(1950)	24	(1905)	269
	Camooweal	1891	1003	(1974)	151	(1961)	397
Diamantina River	Winton	1884	1086	(1974)	88	(1905)	414
	Birdsville	1892	542	(1916)	33	(1913)	161
Cooper Creek	Longreach	1893	1076	(1894)	109	(1902)	441
	Barcaldine	1886	1191	(1950)	148	(1946)	507
	Windorah	1887	990	(1950)	76	(1938)	289
Burdekin River	Alpha	1886	1576	(1956)	225	(1946)	573
	Elgin Downs	1888	1400	(1950)	150	(1926)	574
Fitzroy River	Rockhampton	1871	2096	(1890)	398	(1957)	945
	Emerald	1883	1406	(1956)	205	(1919)	639
	Clermont	1870	1294	(1882)	123	(1885)	680
	Taroom	1870	1206	(1890)	242	(1902)	687
	Nebo	1870	1490	(1958)	289	(1915)	763
Plane Creek	Sarina	1910	3402	(1950)	850	(1923)	1831
Styx River	St. Lawrence	1870	1963	(1890)	317	(1885)	1058
Shoalwater Creek	Kumwarara	1918	1500	(1956)	348	(1919)	824
Waterpark Creek	Yeppoon	1891	3082	(1910)	301	(1902)	1358
Calliope River	Gladstone	1872	2213	(1956)	355	(1902)	1006
Baffle Creek	Miriam Vale	1885	2458	(1893)	553	(1932)	1196

TABLE 2 - RAINFALL RECORDS OF SELECTED STATIONS
CENTRAL QUEENSLAND

BASIN	PAN LOCATION	EVAPORATION (mm)
Georgina	Boulia	3302
	Urandangi	3464
	Camooweal	3364
	Birdsville	3571
Diamantina	Winton	2946
Cooper Creek	Longreach	3150
	Windorah	3276
	Blackall	2481
Burdekin	Twin Hills	2136
Fitzroy	Rockhampton	2293
	Biloela	1984
	Theodore	2198
	Taroom	1735
	Emerald	2111
Styx	St. Lawrence	1809
Calliope	Gladstone	1810

TABLE 3 - AVERAGE ANNUAL EVAPORATION (CLASS 'A' PAN)
CENTRAL QUEENSLAND

Measurement of Stream Flow

The Queensland Water Resources Commission operates 104 gauging stations in the Region. The first of these was established on the Dawson River in 1908.

Information from 14 selected gauging stations is shown in Table 4. Their locations are shown on Figure 2.

The Table underlines the great variation in yearly stream flow. Even the mighty Fitzroy River stopped flowing for 4 months in 1965. The minimum recorded annual flow was 1.3% of the mean annual flow and the maximum yearly flow was more than 8 times the average.

A comparison of rainfall and runoff for the 14 catchments shown in Table 4 shows high proportion of precipitation running off the smaller and steeper higher rainfall coastal catchments. This comparison is made in Table 5.

4. GROUNDWATER

Groundwater in the Region is found in three broad environments, viz. unconsolidated sediments, sedimentary rocks, and fractured rocks.

- Unconsolidated sediments -

Water is stored between the particles of silt, sand or gravel and flows through the interstices. The most important alluvial aquifers are in the valleys of the Don and Dee Rivers and Callide and Denison Creeks. Smaller supplies are available in the catchments of the Belyando, Boyne and Burke Rivers, but are not much used.

- Sedimentary Rocks -

Water is stored and flows through the spaces between grains of sand and other material which is cemented together to varying degrees. In the eastern part of the Region these aquifers are not widely distributed, but in the western two-thirds they are the major source of water for domestic purposes and livestock production.

The Great Artesian Basin is an example of sedimentary rocks. It extends west from the Great Dividing Range. This Section is known as the Eromanga Basin. The Surat Basin extends into the Region from the south. Recharge to the Basins is through sandstones exposed along the edges of the Basins which soak up surface water. The high level aquifers do not generally flow to the surface, but are equipped with pumps mostly driven by windmills.

Approximately 770 bores tap the deeper aquifers where water pressures are, or have been, sufficient to cause the bores to discharge at the surface.

- Fractured Rocks -

Fractures and decomposed zones in volcanic and harder sedimentary rocks are often useful aquifers but in the Central Queensland Region they do not usually provide large quantities of groundwater. Nonetheless they are an important source of stock water in the area bounded by Rolleston and Nebo and Anakie and Duaringa, and the coastal strip.

More details of the groundwater resources are given in Table 6.

<u>TABLE 4</u>

<u>DETAILS OF SELECTED GAUGING STATIONS</u>

STREAM	SITE NAME	PERIOD OF RECORD	AMTD[(1)] (km)	CATCHMENT AREA (km^2)	ANNUAL DISCHARGE ML x 10^3			MEAN ANNUAL RUNOFF (mm)	LONGEST PERIOD OF NO FLOW	
					MAXIMUM	MINIMUM	MEAN		(ceased to flow)	(months
Burke River	Boulia	1966 -	53.1	15 540	2 607.3 (1973/74)	38.6 (1968/69)	578.8	37	March 1970	10
Diamantina River	Birdsville	1949 -	11.6	115 205	10 674.7 (1973/74)	12.1 (1951/52)	1567.0	14	March 1961 and May 1970	9
Cooper Creek	Currareva	1939 -	508.6	150 220	13 211.8 (1954/55)	0.0 (1943/44 and 1951/52)	3341.7	22	March 1951	21
Belyando River	Mt. Douglas	1919 -	7.7	35 585	3 298.0 (1949/50)	10.0 (1968/69)	1051.3	30	May 1951, May 1953 and June 1968	7
Connors River	Gins Leap	1966 -	95.3	1 320	1 672.4 (1975/76)	0.02 (1968/69)	480.7	364	May 1966	9
Isaac River	Yatton	1961 -	43.0	21 200	2 992.7 (1967/68)	10.0 (1968/69)	1028.0	48	July 1965	5
Fitzroy River	Yaamba	1915 - 1973	108.8	136 650	50 120.7 (1917/18)	80.0 (1968/69)	5973.5	44	August 1965	4
Dawson River	Boolburra	1908 - 1978	16.1	49 290	5 533.9 (1955/56)	3.0 (1968/69)	1110.7	23	February 1969	10
Comet River	Comet Weir	1919 - 1973	10.8	16 395	3 703.4 (1955/56)	0.0 (1930/31)	468.2	29	September 1930	15
Nogoa River	Emerald	1919 - 1963	665.8	16 720	3 728.8 (1955/56)	10.8 (1919/20)	571.6	34	March 1944	9
Sandy Creek	Homebush	1966 -	32.5	335	329.9 (1973/74)	14.2 (1968/69)	126.8	379	March 1967	2
Waterpark Creek	Byfield	1952 -	25.1	240	515.5 (1962/63)	24.2 (1969/70)	202.2	843		0
Calliope River	Castlehope	1938 -	32.7	1 310	722.4 (1973/74)	2.2 (1968/69)	189.1	144	January 1969	2
Boyne River	Annondale	1938 -	20.8	2 240	2 102.4 (1970/71)	1.1 (1968/69)	373.2	167	January 1969	10

(1) Adopted Middle Thread Distance
Distance measured along an arbitary centreline of a stream upstream from its mouth or junction with a larger stream.

STREAM	SITE	MEAN ANNUAL CATCHMENT RAINFALL (mm) (1)	RECORDED MEAN ANNUAL RUNOFF (mm)	RUNOFF AS % OF RAINFALL
Burke River	Boulia	352	37	10.5
Diamantina River	Birdsville	175	14	8.0
Cooper Creek	Currareva	305	22	7.2
Belyando River	Mt. Douglas	607	30	4.9
Connors River	Gins Leap	802	364	45.0
Isaac River	Burton Gorge	598	15	2.5
Fitzroy River	Yaamba	691	44	6.5
Dawson River	Boolburra	677	23	3.5
Comet River	Comet Weir	640	29	4.5
Nogoa River	Emerald	647	34	5.5
Sandy Creek	Homebush	1743	379	21.7
Waterpark Creek	Byfield	1693	843	49.8
Calliope River	Castlehope	908	144	15.8
Boyne River	Annondale	1048	167	15.9

(1) Rainfall is estimated for the whole catchment and only for the period of available runoff record, which is much less than that of rainfall. Hence mean annual rainfall here may differ from that shown for particular streams in Table 1.

TABLE 5 – COMPARISON OF RAINFALL AND RUNOFF

TABLE 6 - GROUNDWATER SUPPLIES IN THE CENTRAL QUEENSLAND REGION

AQUIFER TYPES	AREAS OF OCCURRENCE	DEPTH TO AQUIFER (m)	AQUIFER THICKNESS (m)	BORE YIELDS L/Sec	WATER QUALITY T.D.S. Mg/L
Unconsolidated Sediments	Alluvium of Nebo, Bee and Denison Creeks	10 - 15	1 - 10	1 - 25	300 - 14 000
	Funnell Creek and Connors River	12 - 20	2 - 15	5 - 70	300 - 2 000
	Isaac River alluvium	10 - 15	1 - 6	1 - 20	500 - 7 000
	Comet River alluvium	10 - 18	2 - 8	2 - 30	2500 - 20 000
	Vandyke and Cona Creeks alluvium	5 - 10	1 - 5	1 - 5	500 - 2 500
	Sandy, Retreat and Theresa Creeks alluvium	5 - 10	1 - 5	0.5 - 20	500 - 3 000
	Belyando River catchment	4 - 30	1 - 15	1 - 12	500 - 1 000
	Burke River alluvium	6 - 20	1 - 10	1 - 10	200 - 600
	Lower Fitzroy River and tributaries' alluvia	6 - 30	1 - 10	1 - 75	300 - 85 000
	Don and Dee Rivers and Callide Creek alluvia	8 - 20	2 - 9	1 - 75	300 - 7 000
	Dawson River alluvium	12 - 18	2 - 10	2 - 60	600 - 10 000
	Boyne River alluvium	6 - 21	1 - 10	1 - 40	300 - 1 500
	Coastal Streams alluvia	6 - 25	1 - 15	0.2 - 25	200 - 30 000
Porous Rocks	Carborough sandstones (Nebo)	50 - 80	1 - 5	0.5 - 8	200 - 5 000
	Colinlea sandstones (Springsure)	20 - 40	5 - 30	1 - 15	500 - 2 000
	Stanwell area	25 - 40	2 - 50	1 - 15	100 - 7 000
	Callide Coal measures	15 - 60	10 - 30	1 - 8	500 - 2 000
	Clematis sandstones (Bauhinia Downs)	50 - 600	1 - 150	1 - 15	200 - 500
	Hutton and Precipice sandstones of Great Artesian Basin	50 - 2000	50 - 1000	up to 70	100 - 1 500
	Coastal Strip	40 - 50	10 - 15	not known	not known
Fractured Rocks	Bowen Basin, Rolleston to Nebo and from Anakie to Duaringa	15 - 60	1 - 30	0.1 - 25	300 - 20 000
	Coastal Strip, Sarina to Miriam Vale	6 - 50	1 - 50	0.2 - 3	300 - 4 000
	Georgina Basin	130 - 180	10 - 100	1.2 - 2.4	500 - 7 000
	Mount Isa Area	60 - 80	1 - 30	5 - 10	800 - 1 000

5. SURFACE WATER DEVELOPMENT

Considerable development of surface water has taken place during the last decade. Three dams and a large barrage have been constructed with a total capacity of 1 620 000 megalitres. Twenty-eight weirs with capacities ranging from a few megalitres to 17 700 megalitres and totalling 78 000 megalitres have been constructed in the Region. Table 7 provides details of existing and approved storages. Their locations are shown in Figure 3.

- Fitzroy River Barrage -

Of capacity of 66 400 megalitres this barrage some 60 km from the mouth of the Fitzroy River provides water for the City of Rockhampton and some adjacent towns, by arrangement with the owner, the Rockhampton City Council, some use of the water is made for irrigation purposes.

- Awoonga Dam -

This Dam on the Boyne River is owned by the Gladstone Area Water Board and supplies water for urban and industrial development in the City of Gladstone and the Shire of Calliope. The capacity of the dam is being increased from 44 000 megalitres to 255 000 megalitres.

Community irrigation development has taken place at Eton, Theodore and Emerald, and in the Callide Valley existing development has been stabilised by Callide Dam.

- Eton Irrigation Area -

Although not yet completed, this Irrigation Area began operating in 1979. When completed it is to serve 8 500 hectares of canelands. Water is pumped from the Pioneer River to supplement the catchment of Kinchant Dam. The Dam has a present capacity of 11 000 megalitres and is capable of enlargement to 62 800 megalitres. Releases of water from the dam will be pumped to serve seven (7) districts within the Area.

During 1979/80 seven (7) farms with assigned areas of 370 hectares were supplied with water.

- Dawson River Irrigation Area -

The source of water for this Irrigation Area is a series of weirs of total capacity of 30 370 megalitres on the Dawson River between Taroom and Theodore. In 1979/80, 2 031 hectares were irrigated in this Area.

Weirs on the Dawson River at Moura and Baralaba provide water for urban, irrigation and mining purposes.

- Emerald Irrigation Area -

This Irrigation Area and farms along the Nogoa and Mackenzie Rivers will ultimately include 20 000 hectares of irrigated lands. Water is drawn from Fairbairn Dam of 1 440 000 megalitres capacity.

In 1979/80 a total of 9 086 hectares was irrigated. Significant volumes of water were also used for urban purposes at Emerald and Blackwater and to service a number of coal mining ventures in the Region.

TABLE 7 - EXISTING AND APPROVED SURFACE WATER STORAGES CENTRAL QUEENSLAND

STREAM	STORAGE NAME	NEAREST TOWN	AMTD (km)	CATCHMENT (km^2)	HEIGHT (m)	CAPACITY (ML)	PURPOSE OF STORAGE
Alice River	Charles Lloyd Jones Weir	Barcaldine	69.2	7 565	3.0	419	Urban
Callide Creek	Callide Dam	Biloela	80.1	520	27.7		Power Station, groundwater recha Capacity to be increased to
Comet River	Comet Weir	Comet	10.8	16 395	-	50	Railway Weir.
Dawson River	Neville Hewitt Weir	Baralaba	82.7	40 225	8.5	12 600	)
	Moura Weir	Moura	150.2	29 010	5.9	6 300	)
	Theodore Weir	Theodore	228.5	27 350	5.7	4 760	)Irrigation, Urban and Industrial
	Binda Weir	Theodore	253.9	25 538	6.7	1 130	)
	Orange Creek Weir	Cracow	270.7	24 685	5.8	6 780	)
	Glebe Weir	Taroom	326.2	23 000	10.1		)
Eight Mile Creek	Bajool Weir	Bajool	36.9	-	2.4	123	Urban
Fitzroy River	Fitzroy River Barrage	Rockhampton	59.7	139 150	9.3		Urban, Irrigation
German Creek	Bundoora Dam	Middlemount	20.0	109	19.4	11 800	Mining
Grevillea Creek	Grevillea Weir	Thangool	18.0	-	4.7	-	Recharge Weir
Kariboe Creek	Thangool Weir	Thangool	12.5	600	4.6	-	Recharge Weir
	Kariboe Weir	Thangool	16.4	560	10.1	-	Recharge Weir
Mackenzie River	Bingegang Weir	Dingo	489.6	50 790	8.0	5 000	)Urban, Mining and Stock
	Bedford Weir	Blackwater	548.8	45 935	6.7	6 420	)

TABLE 7 Cont'd.

STREAM	STORAGE NAME	NEAREST TOWN	AMTD (km)	CATCHMENT (km^2)	HEIGHT (m)	CAPACITY (ML)	PURPOSE OF STORAGE
Nogoa River	McCoskèrs Weir	Emerald	652.2	-	-	142	
	Emerald Town Weir	Emerald	663.5	16 720	-	487	
	Selma Weir	Emerald	668.7	16 680	6.8	1 180	Irrigation, Mining and Stock
	Fairbairn Dam	Emerald	685.6	16 320	31.7		Irrigation, Urban and Mining
One Mile Creek	Saraji Mine Storage	Dysart	-	-	-	400	Mining
Ripstone Creek	Peak Downs Mine Storage	Moranbah	-	-	-	618	Mining
Sandy Creek	Clermont Weir	Clermont	63.3	505	-	360	Urban, recharge weir
Boyne River	Awoonga Dam	Gladstone	21.9	2 230	14.0		Urban, Capacity to be increased to 255 000 ML.
Sandy Creek (North Branch)	Kinchant Dam	North Eton	9.4	32	17.4	11 000	Irrigation, Capacity to be increased to 62 800 ML.
Middle Creek	Middle Creek Dam	Sarina	6.0	7	22.0	1 300	Urban and Industrial
Plane Creek	Weir	Sarina	12.7	96	-	73	Industrial
	Weir	Sarina	14.0	93	-	32	Industrial
	Weir	Sarina	15.4	91	-	50	Industrial
	Sarina Weir	Sarina	16.7	88	4.57	64	Urban
St. Lawrence Creek	Weir	St. Lawrence	-	-	-	152	Urban
Tondoon Creek	Tondoon Creek Weir	Gladstone	-	5	-	435	Urban

- Callide Dam -

This Dam of 57 600 megalitres capacity provides water for cooling purposes at the Calcap Power Station and water for the recharge of groundwater supplies in the aquifers of the alluvium of Callide Creek and two of its tributaries.

- Supply of water to Mining Areas -

Several small storages have been constructed to help serve mining development in the Region. Bundoora Dam of 11 800 megalitres on German Creek is one example.

Large mining operations in the Region have brought about lengthy pipelines to serve the mines and associated townships. Some of these have been constructed by the mining companies and others by the Queensland Water Resources Commission. Pipelines now existing are:-

Eungella Dam (outside the Region) to Peak Downs - 120 km;

Bingegang Weir to Saraji - 130 km - and Peak Downs - 18 km;

Bedford Weir to Blackwater - 25 km - and Leichhardt Mine - 14 km;

Bedford Weir to South Blackwater Mine - 65 km;

Bedford Weir to Blackwater Mine - 42 km;

Selma Weir to Gregory Mine - 64 km.

In addition to these public water supply schemes and the large private systems, there are a very large number of smaller private surface water storages ranging from excavated tanks for stock watering, weirs on watercourses, large offstream storages filled by pumping from surface flows in nearby watercourses to gully dams to trap local runoff. Furthermore, there are approximately 300 licenses to pump water from watercourses for irrigation or industry and a large number of permits to take water for domestic and stock purposes.

6. GROUNDWATER DEVELOPMENT

Groundwater has been used since the early days of European settlement for domestic, stock and irrigation purposes. This use has increased and today 43 towns in the Region have groundwater as a source of their water supply and more than 12 000 hectares of crops and pastures are irrigated with water drawn from local aquifers.

The principal groundwater irrigated areas are the Callide, Don and Dee Valleys. Here a strip of alluvium some 80 kilometres long and 5 to 10 kilometres wide provides water for irrigation on the rich soils which overlie the aquifer. The area irrigated is approximately 8 300 hectares.

Water is released from Callide Dam to help replenish its yield. Three small weirs have also been built to assist recharge.

Another significant irrigation area is on the alluvia of Sandy and Plane Creeks in the north-east of the Region. Here 4 000 hectares of crops, mainly sugar cane, are irrigated.

Smaller areas of groundwater irrigation are scattered through the Region, including the Isaac River, Gogango and Springsure areas and along coastal streams.

The largest single groundwater resource is the Great Artesian Basin underlying about 60 per cent of the Region. The main aquifers are found at depths of up to 2000 metres and except in elevated areas, water gushes to the surface. Overlying these deeper aquifers are less prolific, but nonetheless, valuable water supplies, most of which require pumping to bring them to the surface. These are described loosely as sub-artesian bores.

It is estimated that there are 3800 sub-artesian bores discharging 40 megalitres per day for domestic, urban and stock purposes.

Approximately 770 artesian bores tap the deeper aquifers. Of these, 290 have ceased to flow and are now pumped. The daily discharge of artesian bores in the Region is 220 megalitres. Much of the water is distributed through long narrow excavated drains - bore drains. While these are wasteful of water through seepage and evaporation, they have been valuable in developing pastoral lands which might not otherwise have been developed because of the high cost of alternative watering techniques.

Artesian water is not normally used for irrigation due to a policy of reserving it for domestic and pastoral purposes in areas without satisfactory alternative supplies and due in some cases to unsatisfactory water quality. This policy has been modified to allow limited use of the water for irrigation if the user undertakes to replace wasteful bore drains and leaking bores with more efficient distribution systems. The resulting increase in irrigated areas has not so far been significant.

Present Use of Water

The present level of use of water resources is difficult to assess, however, the following provides an approximate indication of use in the Region:-

Domestic and Urban	65 000
Livestock	80 000
Mining	25 000
Industry	20 000
Irrigation	140 000
TOTAL	330 000 megalitres per annum

7. POTENTIAL FOR FUTURE WATER RESOURCES DEVELOPMENT

Surface Water

The Region, and the Fitzroy Basin in particular, offer considerable potential for development of surface water resources. A large number of storage sites have been identified and no doubt others also exist. Table 8 shows details of 20 storage sites which have been investigated in varying detail. The size of structures at these sites range from relatively small weirs to a huge dam on the Fitzroy River at The Gap. The sites are shown on Figure 4.

In addition to those sites investigated, 28 potential sites have been noted. These are listed in Table 9.

Insufficient data are presently available to predict the upper level of development of the Region's surface water resources. However, based on information from the Review of Australia's Water Resources - 1975, it appears that the very approximate annual level of use could be 4.2 million megalitres made up as follows:-

TABLE 8 - STORAGE SITES INVESTIGATED - CENTRAL QUEENSLAND

STREAM	SITE NAME	AMTD (km)	CATCHMENT (km^2)	CAPACITY (ML)	YIELD (ML/Year)	HEIGHT TO F.S.L. (m)	REMARKS
Denison Creek	Spencer	33.5	726	127 000	23 300	23.4	
Funnel Creek		69.7	1 102	275 000	49 000	27.0	
Bee Creek		66.0	1 322	98 700	9 800	18.7	
Isaac River	Grovenor Downs	206.8	2 644	180 000	7 400	21.3	
	Burton Gorge	281.0	577	24 800	3 170	15.6	
Connors River	Mt. Bridget	95.7	1 220	740 000	96 000	26.6	
Mackenzie River		592.1	45 080	630 000	91 500	26.0	
Theresa Creek		49.9	4 390	200 000	2 410	17.6	
Comet River		14.5	16 320	400 000	33 400	18.0	
Fitzroy River	The Gap	143.6	135 895	10 000 000	1 975 000	53.4	
		141.2	135 895	56 000	48 000	7.0	
Raglan Creek		65.7	290	50 000	10 400	29.0	
Dawson River	Woolthorpe	236.1	26 575	600 000	99 000	27.3	
	Baroondah	472.5	5 750	800 000	90 000	35.3	
	Nathan	307	23 620	3 150 000	265 000	45.7	
Alligator Creek		26.2	15	30 000	6 700	41.3	
Flaggy Rock Creek		9.0	33	50 000	9 400	30.9	
Sandy Creek		13.3	433	8 970	8 080	9.6	
Belyando River	Mt. Douglas	9.7	35 530	5 000 000	147 000	32.0	
Calliope River	Castlehope	33.0	1 310	434 000	55 000	36.6	
Baffle Creek		56.6	1 420	120 000	45 000	20.3	

STREAM	SITE NAME/ LOCALITY	AMTD (km)	CATCHMENT (km^2)	CAPACITY (ML)
Nebo Creek	Nebo	40.2	192	-
Sandy Creek	Clermont	72.3	230	-
Wolfang Creek	Clermont	3.5	555	-
Lotus Creek	Markwell	20.1	192	-
Isaac River	Carfax	115.9	6 460	370 000
Retreat Creek	Sapphire	80.2	375	300 000
Fitzroy River	Rookwood Crossing	266.1	-	-
Dee River	Wura	45.9	585	2 000 000
Don River	Dululu	103.5	280	97 000
Comet River	Warrinilla	210.8	2 900	2 640 000
Mimose Creek	Mimose Gap	10.5	-	-
Kroombit Creek	Biloela	54.7	415	60 000
Dawson River	Nipan	191.8	28 440	320 000
	Binda	254.0	25 535	370 000
Palm Tree Creek	Taroom	11.4	5 220	1 230 000
Bell Creek	Jambin	27.8	300	120 000
Lonesome Creek	Gonyelinka	30.2	163	34 500
Castle Creek	Theodore	18.5	685	-
Suttor River	Eaglefield	245.0	1 918	-
Cerito Creek	Newlands	) Possible mine storage dams		
Eastern Creek	Newlands	)		
Kangaroo Creek	Newlands	)		
Barcoo River	Arno	133.6	-	-
	Tambo	502.1	-	-
Thompson River	Stonehenge	664.7	88 060	-
Burke River	Digby Peaks	153.0	5 930	-
Wills Creek	Buckingham Downs	68.0	4 780	-
	Dajarra	118.0	2 115	-

TABLE 9 - STORAGE SITES NOTED
CENTRAL QUEENSLAND

Fitzroy River Basin	2.6 million megalitres
Coastal Streams	1.4 million megalitres
Belyando River Basin	0.15 million megalitres
Georgina, Diamantina and Cooper Basins	0.05 million megalitres

It should be noted that those estimates do not consider economic, construction or environmental constraints and that the practical limit would indeed be lower.

Groundwater

Even less information is available on the groundwater resources of the Region. However, the Review of Australian Water Resources - 1975, suggests that the upper level could be 3.4 million megalitres per year, viz.

Fitzroy River Basin	1.72 million megalitres
Coastal Streams	0.56 million megalitres
Belyando River Basin	0.35 million megalitres
Georgina, Diamantina and Cooper Basins	0.76 million megalitres
	3.39 million megalitres

However, throughout much of the Region individual bore extraction rates are likely to be insufficient to provide more than stock water supplies. The possibility of large scale use for industry or irrigation is remote. Furthermore, current policies are likely to reserve most of such supplies for domestic and stock purposes.

Irregular Distribution

The foregoing information demonstrates that significant additional development of water resources is possible in some areas. However, it has to be realised that in some parts of the Region water resources are scarce and are fully committed. New large scale demands for water in these areas could only be met by transporting water over long distances.

8. LIKELY MEDIUM TERM DEVELOPMENTS

It is clear that in the next few decades, mineral exploitation and associated activities will be the major users of water. It is envisaged that not only will the mining industry itself and attendant urban needs use increasing volumes of water, but that power generation, coal to oil conversion plants and mineral-processing industries will demand very large quantities of water.

Estimates of increased water use by the year 2000 in the Region are not put at 200 000 to 300 000 megalitres per year.

Present policies require new mining and industrial users to meet the full costs of developing their own water supplies. The State, however, has ownership of the storages at all times. Provision is made wherever possible for pipelines to serve minor domestic and stock needs where the pipeline traverses agricultural and pastoral lands. Ownership of the pipelines reverts to the State when the mining or industrial operations cease.

8. CONCLUSIONS

The Central Queensland Region contains some of the State's most important water resources, and in its eastern part there are substantial opportunities for the development of these resources.

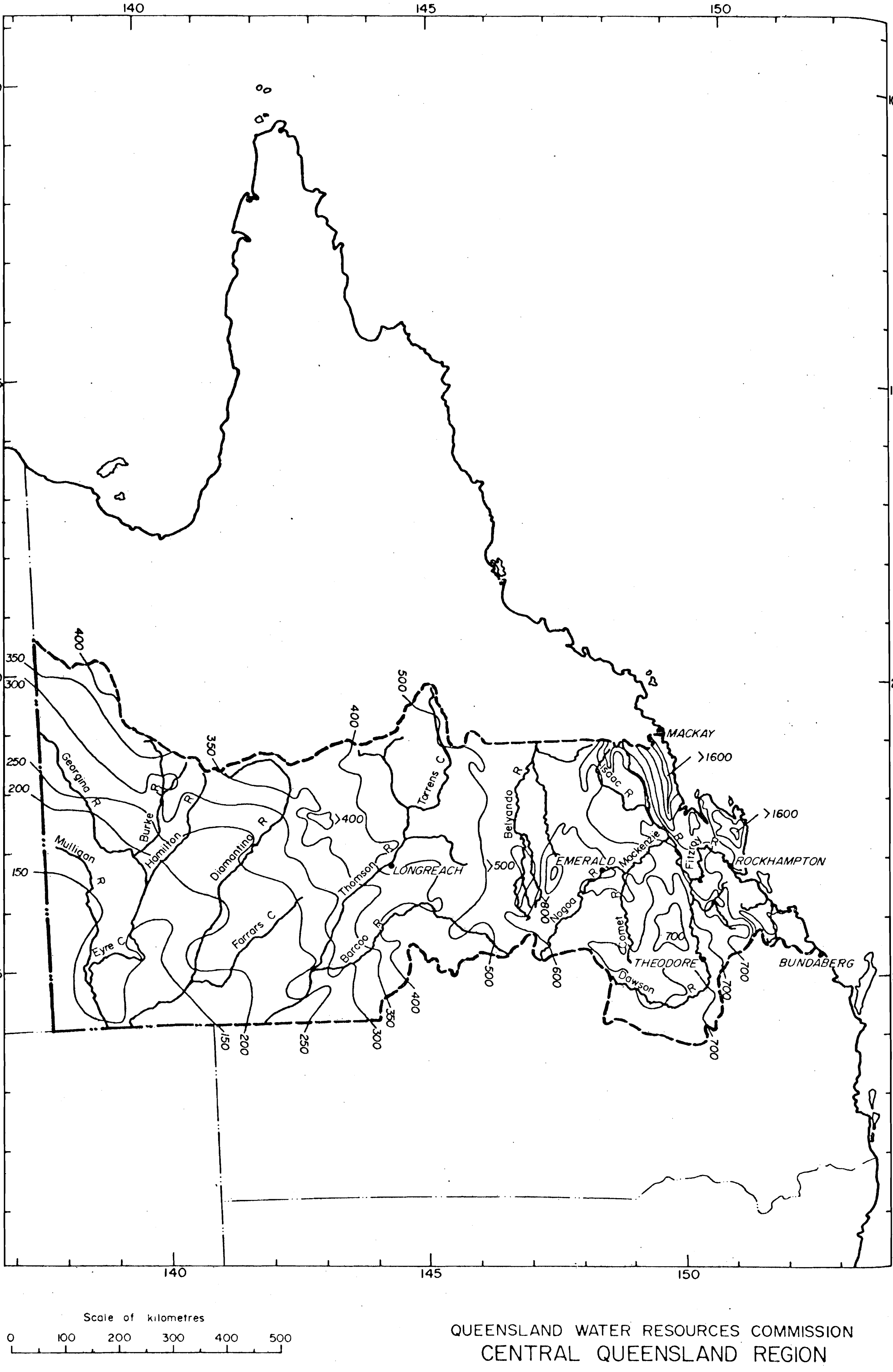
The Region is well endowed with minerals, particularly coal, as well as lands with good pastoral and agricultural potential.

A small proportion of the Region's water resources have so far been tapped, but there is little doubt that the utilization of the mineral opportunities of the Region which has now begun will require the extensive development of water storages and lengthy distribution system.

Surface storage possibilities to meet these demands have been identified. Some of these will be costly and only highly profitable enterprises will be able to afford the costs involved. Others, although, of significant cost could be used for irrigation purposes in association with mineral and industrial activities.

There is good potential for increased groundwater utilization, however, its use could well be largely restricted to domestic and stock watering purposes, particularly in areas where alternative water supplies would be excessively costly.

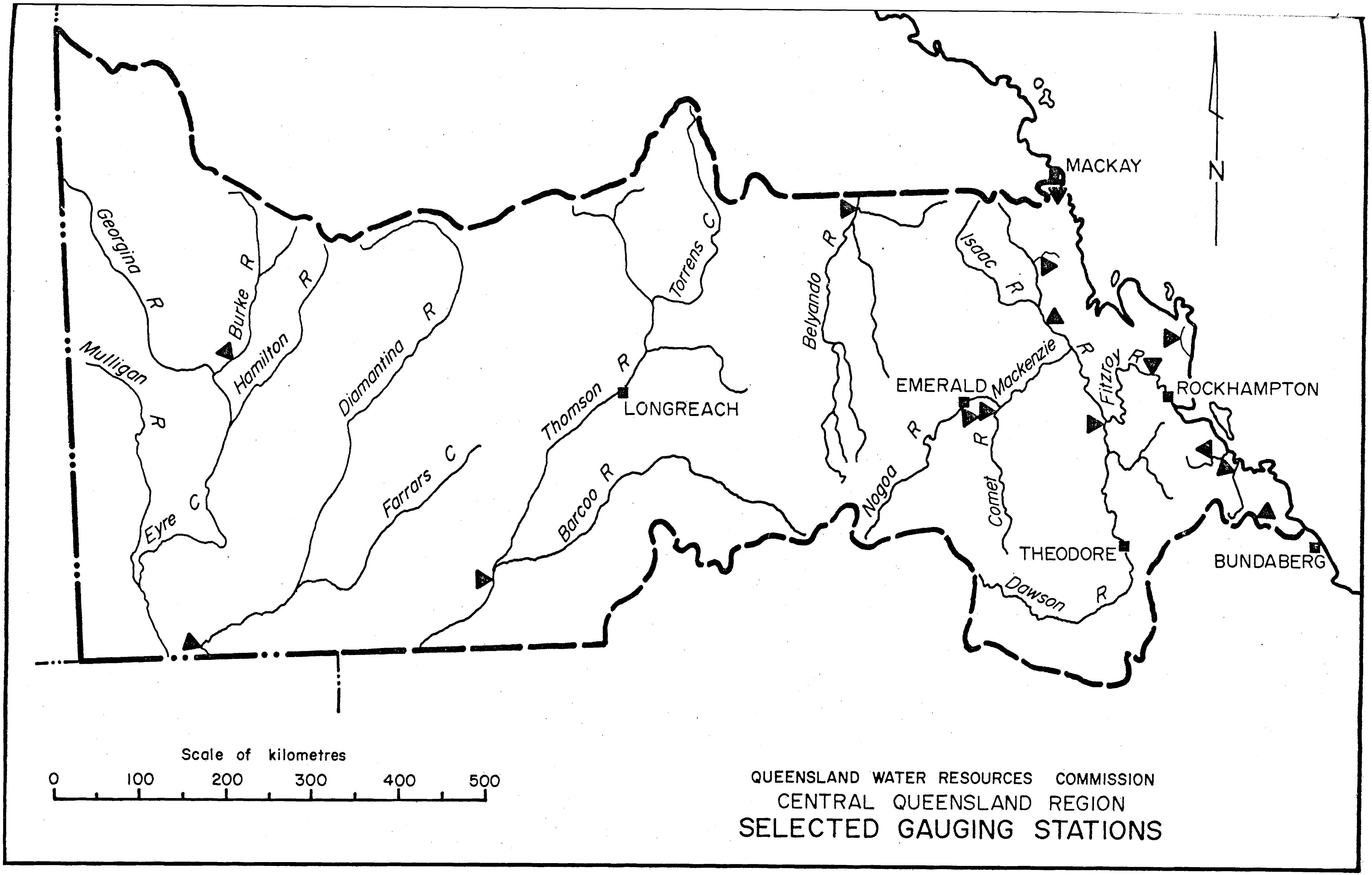
The Region can expect major increases in water storages and distribution over the next few decades.



QUEENSLAND WATER RESOURCES COMMISSION

CENTRAL QUEENSLAND REGION AND ISOHYETS

FIGURE 1

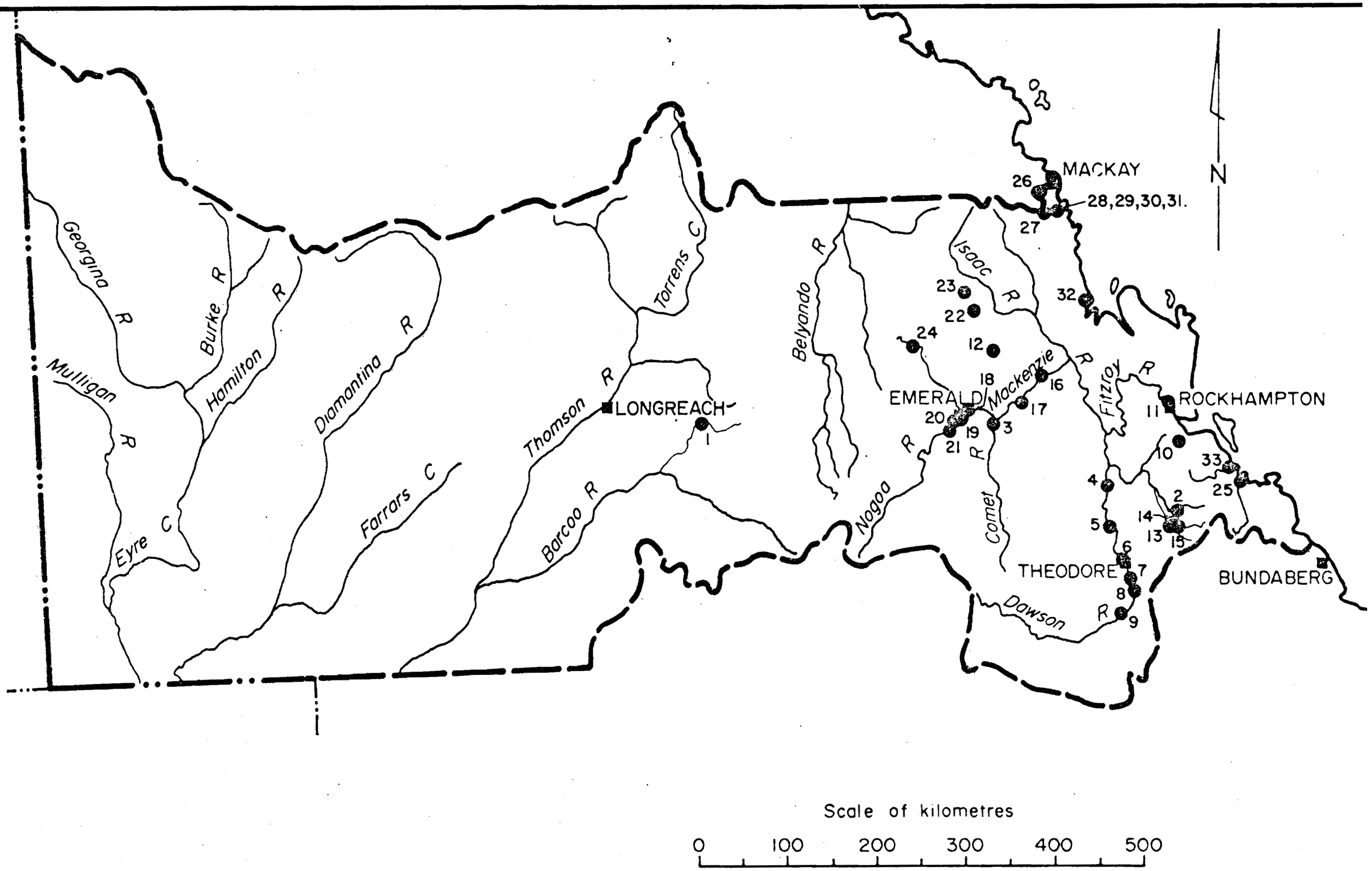


QUEENSLAND WATER RESOURCES COMMISSION
CENTRAL QUEENSLAND REGION
SELECTED GAUGING STATIONS

FIGURE 3

EXISTING AND APPROVED SURFACE WATER STORAGES

No.	Stream	Storage Name
1	Alice River	Charles Lloyd Jones Weir
2	Callide Creek	Callide Dam
3	Comet River	Comet Weir
4	Dawson River	Neville Hewitt Weir
5	Dawson River	Moura Weir
6	Dawson River	Theodore Weir
7	Dawson River	Binda Weir
8	Dawson River	Orange Creek Weir
9	Dawson River	Glebe Weir
10	Eight Mile Creek	Bajool Weir
11	Fitzroy River	Fitzroy River Barrage
12	German Creek	Bundoora Dam
13	Grevillea Creek	Grevillea Weir
14	Kariboe Creek	Thangool Weir
15	Kariboe Creek	Kariboe Weir
16	Mackenzie River	Bingegang Weir
17	Mackenzie River	Bedford Weir
18	Nogoa River	McCoskers Weir
19	Nogoa River	Emerald Town Weir
20	Nogoa River	Selma Weir
21	Nogoa River	Fairbairn Dam
22	One Mile Creek	Saraji Mine Storage
23	Pipstone Creek	Peak Downs Mine Storage
24	Sandy Creek	Clermont Weir
25	Boyne River	Awoonga Dam
26	Sandy Creek (N. Br.)	Kinchant Dam
27	Middle Creek	Middle Creek Dam
28	Plane Creek	Weir
29	Plane Creek	Weir
30	Plane Creek	Weir
31	Plane Creek	Sarina Weir
32	St. Lawrence Creek	Weir
33	Tondoon Creek	Tondoon Creek Weir



QUEENSLAND WATER RESOURCES COMMISSION

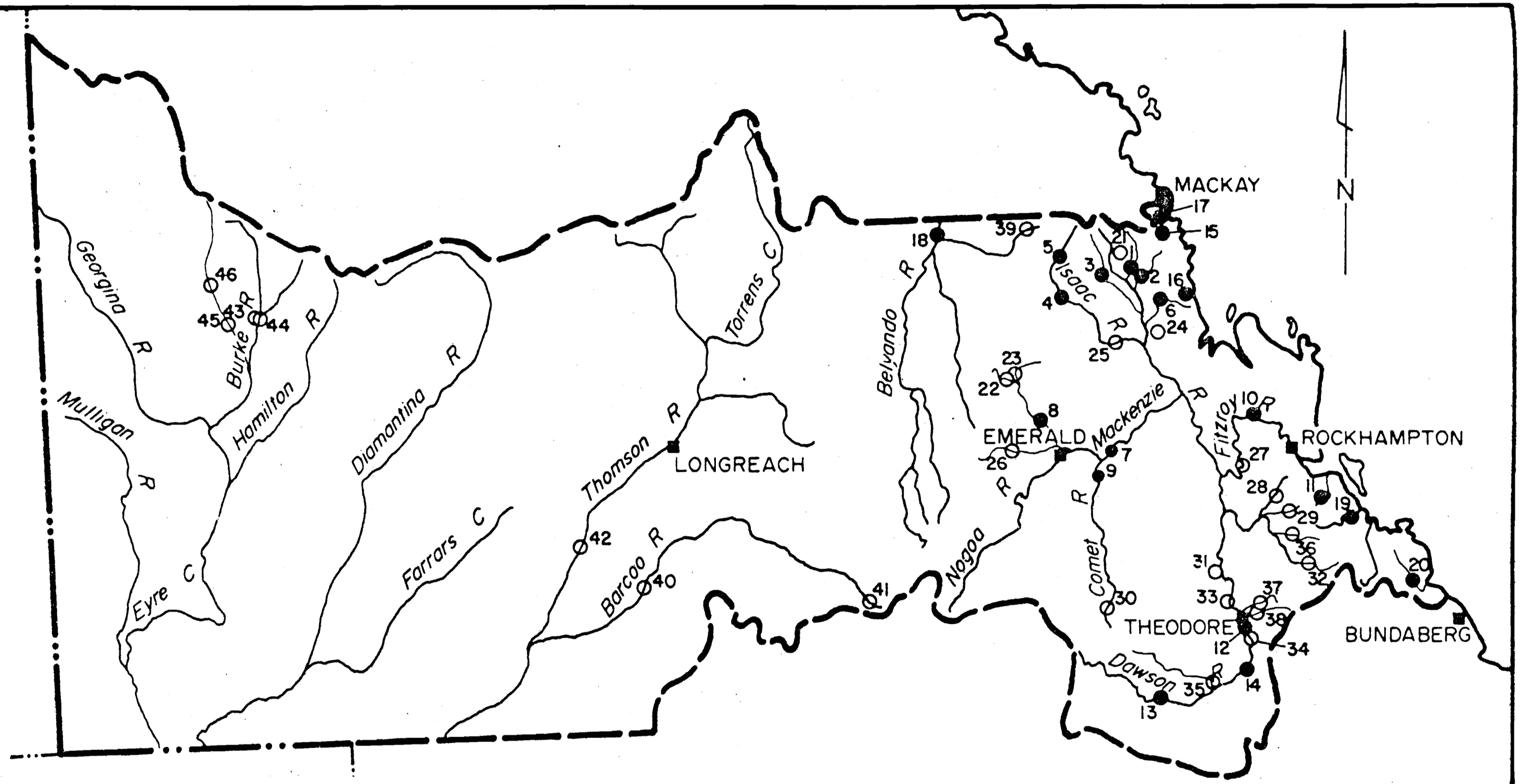
CENTRAL QUEENSLAND REGION

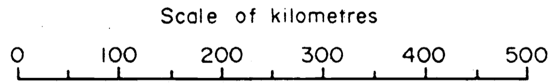
EXISTING & APPROVED SURFACE WATER STORAGES

FIGURE 4

STORAGE SITES INVESTIGATED

No	Stream	Site Name
1	Denison Ck	Spencer
2	Funnel Ck	
3	Bee Ck	
4	Isaac R.	Grosvenor Downs
5	Isaac R.	Burton Gorge
6	Connors R.	Mt. Bridget
7	Mackenzie R.	
8	Theresa Ck	
9	Comet R.	
10	Fitzroy R.	The Gap
11	Raglan Ck	
12	Dawson R.	Woolthorpe
13	Dawson R.	Baroondah
14	Dawson R.	Nathan
15	Alligator Ck.	
16	Flaggy Rock Ck	
17	Sandy Ck	
18	Belyando R.	Mt. Douglas
19	Calliope R.	Castle Hope
20	Baffle Ck	





STORAGE SITES NOTED

No	Stream	Site Name
21	Nebo Ck	Nebo
22	Sandy Ck	Clermont
23	Wolfgang Ck	Clermont
24	Lotus Ck	Markwell
25	Isaac R	Carfax
26	Retreat Ck	Sapphire
27	Fitzroy R	Rookwood Crossing
28	Dee R	Wura
29	Don R	Dululu
30	Comet R	Warrinilla
31	Mimosa Ck	Mimosa Gap
32	Kroombit Ck	Biloela
33	Dawson R.	Nipan

No	Stream	Site Name
34	Dawson R.	Binda
35	Palm Tree Ck	Taroom
36	Bell Ck	Jambin
37	Jonesome Ck	Gonyelinha
38	Castle Ck	Theodore
39	Suttor R.	Eaglefield
40	Barcoo R.	Arno
41	Barcoo R.	Tambo
42	Thomson R.	Stonehenge
43	Burke R.	Digby Peaks
44	Burke R.	Digby Peaks
45	Wills Ck	Buckingham Downs
46	Wills Ck	Dajarra

QUEENSLAND WATER RESOURCES COMMISSION

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STORAGE SITES INVESTIGATED AND NOTED

EDUCATION AND TRAINING RESOURCES IN CENTRAL QUEENSLAND

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1. SUMMARY

There is little or no prospect of additional regular post-secondary education institutions being established specifically to serve the needs of Central Queensland. The effective provision of the educational and training services to meet industrial and community needs in those areas and centres remote from existing institutions rests on the adoption of a coordinated range of policies and options by employers, individuals and family groups, communities, post-secondary education institutions and their State-wide authorities, and State and Commonwealth governments. The various options potentially available to these several interest groups are outlined. It is suggested that a broadly based regional education and training task force be convened to formulate a development program in this field, to identify the priorities and the timetable, to estimate the costs and to recommend how these should be distributed between public and private sources.

2. INTRODUCTION

This topic was seen by the organizers of this Conference to fall under the heading of Infrastructure related to the general theme, 'Energy and Industry in Central Queensland', thereby implying that education and training is exclusively an infrastructural question. This paper will, I hope, show that such an assumption is invalid.

A catalogue of the present institutional programs in the post-secondary sector in Queensland is readily available in such annual publications as the 'Handbook of Technical and Further Education Colleges and Courses', 'Queensland Tertiary Courses' and the 'Commonwealth Directory of Higher Education Courses'. The details are not, therefore, reproduced here and the paper is primarily directed to broader issues of policies and options.

I propose, first, to try to sketch my understanding of Central Queensland and its industrial development, present and future; second, to consider the structure and relative significance of institutional and non-institutional education and training; and finally, say something about my expectations concerning future policies and options.

In this paper I shall deal exclusively with post-secondary education, embracing essentially the three sectors, university, advanced education, and technical and further education.

3. SOME CHARACTERISTICS OF CENTRAL QUEENSLAND

Central Queensland is not a defined geographic region. While its boundary on the east is the coastline, those on the north, west and south are matters of political or administrative convenience. A recent Queensland Government publication, 'Queensland Resources Atlas', refers to Central Queensland not as a region, but as a segment of the State.

Central Queensland is officially defined as comprising the three statistical divisions of Mackay, Fitzroy and Central-West, extending essentially as an east/west band about 200 kilometres on either side of the Tropic of Capricorn. These divisions are shown in Figure 1. They incorporate thirty-one local authority areas and Councils and account for 32 per cent of the area and 10 per cent of the local Government expenditure of the State of Queensland.

The areas and populations embraced by these three statistical divisions are summarized in Table 1. The three main centres of population are the cities of Mackay, Rockhampton and Gladstone. Their estimated populations as at 30 June 1978 are shown in Table 2.

TABLE 1: AREAS AND ESTIMATED POPULATIONS IN CENTRAL QUEENSLAND STATISTICAL DIVISIONS

Division	Area km^2	Estimated Population (as at 30 June 1978) No.	Population Density No.per km^2
Mackay	68,440	85,120	1.24
Fitzroy	121,920	134,760	1.11
Central-West	370,470	14,100	0.04
Total Central Queensland	560,830	233,980	0.42
Total State	1,727,000	2,166,700	1.25

TABLE 2: AREAS AND ESTIMATED POPULATIONS OF MAIN CENTRES OF POPULATION IN CENTRAL QUEENSLAND

Centre	Area km^2	Estimated Population (as at 30 June 1978) No.	Population Density No. per km^2
Mackay	21	22,000	1,048
Rockhampton	161	53,900	328
Gladstone	128	20,360	159

Queensland as a whole has experienced the rates of population increase over the three quinquennia since 1961 shown in Table 3. Considerable interest turns on the next entry in this Table for the quinquennium, 1976-81, the geographic distribution of the growth and the long term relative importance of natural increase and net migration.

TABLE 3: POPULATION INCREASE IN QUEENSLAND

(Annual average per 1000 of population)

	July 61- June 66	July 66- June 71	July 71- June 76	July 76- June 81
Natural increase	13.48	11.70	10.52	?
Net migration	4.94	5.94	12.66	?
Total	18.42	17.64	23.18	?

The economy of Central Queensland rests on a wide diversity of industrial activities. Cattle and sheep grazing are still major industries; salt harvesting and limestone extraction continue; the economy of the coastal lowlands of the Mackay Division depends primarily on the production of sugar; tourism, particularly in the Central Coastal district, long established at a modest level, has begun to develop in recent years.

Over the last decade, Gladstone has flourished as a major port and industrial development centre based on the processing of Weipa bauxite and large scale power generation from coal. Coal mining for export through Gladstone and Hay Point have been major elements in the industrial development in Central Queensland.

There is considerable scope for increased rural production. Irrigation schemes are expected to lead to further developments in the beef cattle industry and in the production of grain and cotton. The establishment of at least one aluminium smelter, cement clinker works, oil shale developments and further coal mining projects are planned. Coastal tourist developments include the Iwasaki Sangyo Company (Aust.) Pty Ltd resort proposal at Yeppoon and others which might be expected to develop following the declaration of the Capricorn Section of the Great Barrier Reef Marine Park.

With 11 per cent of the population of the State, the gross value of production in Central Queensland by sector is summarized in Table 4.

TABLE 4: DISTRIBUTION OF GROSS VALUE OF PRODUCTION IN CENTRAL QUEENSLAND BY SECTOR

Sector	Central Queensland as percentage of State
Agriculture	21
Mining	53
Manufacturing	13

The distribution of employment by industry group in Queensland as a whole in 1976 is set out in Table 5. It is unlikely that the distribution in Central Queensland will differ sufficiently from the State overall to discount the dominance of the tertiary group.

TABLE 5: DISTRIBUTION OF EMPLOYMENT IN QUEENSLAND

(Census 1976)

Industry Group	Number	Percentage
Primary production	81,348	9.7
Mining and quarrying	15,943	1.9
Manufacturing	116,259	13.9
Tertiary	624,015	74.5
TOTAL	837,565	100.0

The immediate future is likely to be dominated by developments involving major capital investment. A perspective of these investments is given in Table 6.

TABLE 6: DEVELOPMENTS IN QUEENSLAND AND CENTRAL QUEENSLAND, 1979
(Projects announced or under development)

	Queensland	Central Queensland	Central Queensland as percentage of Queensland
Number of Projects			
Private Sector	1,188	98	8.2
Public Sector	712	138	19.4
Total	1,900	236	12.4
Gross Value of Projects ($ million)			
Private Sector	10,376	6,915	66.6
Public Sector	5,954	1,372	23.0
Total	16,330	8,287	50.7
Average Value of Projects ($ million)			
Private Sector	8.7	70.6	811
Public Sector	8.4	9.9	118
Total	8.6	35.1	414

The geographic location of much of this development in Central Queensland both present and future may be readily identified in Figure 2 in an arc commencing at Hay Point in the north, encompassing Blair Athol, Emerald and South Blackwater in the west and Moura and Callide in the south, terminating on the coast at Gladstone.

This brief outline is not intended as a comprehensive account of developments in Central Queensland to date or projected, but rather to give some general indication of the nature, distribution and magnitude of this development to date, and by implication to point to future growth in these directions in the immediate future.

In the context of education and training resources, attention is drawn to the following salient points:

- the overriding importance of the Mackay and Fitzroy statistical divisions;
- the dispersed population distribution, with only three centres with populations in excess of 20,000 and none approaching 80,000-100,000;
- the contributions to the gross value of production by the agricultural and manufacturing sectors as well as mining;
- the overriding significance of the tertiary sector in employment;
- the dominant position of Central Queensland as a location for major developments in Queensland;
- the capital intensive nature of development projects in Central Queensland, especially in the private sector;
- the geographic distribution of centres of major development.

4. SOME STRUCTURAL ASPECTS OF POST-SECONDARY EDUCATION AND TRAINING

Post-secondary education and training may have a multiplicity of purposes ranging from highly specific vocational objectives to the broad aim of personal development and cultural enrichment as a general contribution to the quality of life.

New towns, especially company towns directed to a particular industrial activity, do not have, and are unlikely to acquire rapidly, developed cultural patterns of life characteristic of larger, long established more diverse centres.

Two cities I know reasonably well serve to illustrate some of the relevant issues. Newcastle (population in 1976, 251,132) is one example of a city largely industrially oriented to coal mining and heavy industry and a port serving the coalfields and a rich and diverse agricultural hinterland. Here it took about one hundred and fifty years to develop a range of social and cultural activities before these began to have any widespread impact on the populace as a whole and to make a significant impact on the quality of life. There is little doubt that the establishment of a university college there in the 1950s contributed to this development, but it is debatable whether this was an essential component.

Canberra (population in 1976, 196,538) is by any definition the company town par excellence on which very large sums of public money were lavished to provide quality homes, schools, post-secondary institutions, social and cultural centres of considerable diversity for a population of well above average education and income largely committed to long term residence there. Even so, my perception is that a self-sustaining range of supportive quality of life activities only began to have a widespread and significant impact in the 1960s some forty years after Canberra's establishment.

My personal experience suggests that post-secondary education institutions generally do contribute to developments of this kind. They act as a possible focus and make a stabilizing contribution to communities in which they are centred, both culturally and economically. However, the circumstances of their establishment and the community pressures which lead to such developments are themselves symbols of already well established and articulated community aspirations.

A detailed study of Queensland provincial towns might reveal important clues to the essential criteria for the development of a diverse and satisfying range of activities which contribute in a non-material way to the quality of life. My general impression is that a substantial period of time, possibly spanning at least two generations, a reasonably stable population of the order of 50,000 and a varied employment base may be overriding preconditions. Gladstone will provide a useful test case over the next decade or so.

Vocationally oriented education and training are a somewhat more concrete issue. Table 7 attempts to outline the overall pattern covering both institutional and non-institutional activities. While not necessarily fully comprehensive, and despite some evident nomenclature problems, this Table underlines the fact that post-secondary education institutions contribute only a part of the total pattern.

TABLE 7: AN OUTLINE OF VOCATIONALLY ORIENTED EDUCATION AND TRAINING

Post-secondary Institutions

Award courses

TAFE colleges	Pre employment and pre vocational Trades and related skills Sub-professional technician
Colleges of advanced education	Sub-professional technician Professional (a) undergraduate (b) postgraduate
Universities	Professional (a) undergraduate (b) postgraduate

Non-award programs and courses

TAFE colleges	Continuing education and training Trades and related skills Sub-professional technician Specific skills General adult education Leisure, hobbies
Colleges of advanced education	Continuing education and training (a) general community (b) sub-professional (c) professional
Universities	Continuing education and training (a) general community (b) professional

Professional Institutions and Trade Associations

	Continuing education and training (a) specific vocational (b) personal development

<u>Employers</u>		
	<u>Formal</u>	Apprenticeship Training programs (a) specific vocational (b) personal development Professional development programs Skills development programs Personnel policies and general staff development
	<u>Informal</u>	On-job experience by, for example, (a) individual learning (b) team working (c) rotational employment
<u>Employees</u>		Extra-mural pursuits and activities (a) intellectual and cultural (b) sporting, social, community (c) skill related (d) personal development

Typically, in a working life of, say, forty years, it would be relatively unusual, even including the participation in institution-based continuing education programs, for post-secondary institutional education and training to exceed in time ten per cent of this total period. Even allowing generously for different learning intensities, it is difficult to escape the conclusion that on-the-job experience, training and retraining will contribute more to the overall performance and achievement of an employee than his or her institutional education experience. In recent times, however, there is a trend for more training of a practical nature, which at one time was regarded as the responsibility of the employer, to be undertaken in TAFE colleges.

There are, in addition, inherent limitations on the ability of post-secondary education institutions to place the application of principles, however well taught, within the full range of realities and constraints which are ever-present in practical industrial situations. These limitations are likely to be further intensified in specialized capital intensive industries subject to rapid technological change, especially where much of the new technology may be imported as an intrinsic part of equipment of overseas origin.

In recent years, the range of modes of study offered by post-secondary educational institutions has increased substantially for formal award and some continuing education programs. The diversity currently available in Queensland is evident from Table 8.

TABLE 8: MODES OF STUDY AVAILABLE IN QUEENSLAND POST-SECONDARY EDUCATION INSTITUTIONS

Award courses

TAFE	Full-time for few selected courses only Part-time for most courses (a) continuous with and without some day release (b) block release especially for trade courses External mainly by correspondence through Technical Correspondence School
Advanced education	
	Full-time for most courses Part-time for most courses (a) continuous with and without some day release (b) sandwich, some courses only (c) off-campus in selected centres with or without attendance on-campus for short periods External for many courses in State-wide coordinated program employing wide range of teaching strategies and techniques usually requiring attendance at vacation schools
Universities	Full-time for all courses Part-time for some courses External mainly in Arts, Education, Economics and Commerce, University of Queensland only

Continuing education programs

Range of methods, full-time and part-time, with some offered externally by correspondence, radio, TV, etc.

Educational opinion is somewhat polarized on the relative merits and disadvantages of these several modes. Though my personal preference is for continuous full-time or part-time attendance in a group situation, Queensland post-secondary institutions have sought to increase access in a variety of ways to meet the demographic needs of the State. Considerable efforts have also been made to improve the quality of delivery of external programs in those areas not served by appropriate local institutions. The total program of accredited courses offered externally by the colleges of advanced education in Queensland in 1981 is summarized in Table 9.

TABLE 9: ACCREDITED AWARD COURSES OFFERED EXTERNALLY BY COLLEGES OF ADVANCED EDUCATION IN QUEENSLAND, 1981

Capricornia Institute of Advanced Education

Graduate Diploma in Management
Bachelor of Applied Science (Biology)
Bachelor of Applied Science (Chemistry)
Bachelor of Applied Science (Mathematics and its Applications)
Bachelor of Applied Science (Physics)
Associate Diploma in Applied Chemistry
Associate Diploma in Biological Laboratory Techniques
Associate Diploma in Business

Darling Downs Institute of Advanced Education

Graduate Diploma in Education (tertiary)
Graduate Diploma in Educational Administration
Graduate Diploma in Teaching Exceptional Children
Bachelor of Business
Bachelor of Education (primary)
Diploma of Teaching (upgrading)
Associate Diploma in Civil Engineering
Associate Diploma in Electrical Engineering
Associate Diploma in Mechanical Engineering
Associate Diploma in Surveying
Associate Diploma in Mathematics and Computing

Kelvin Grove College of Advanced Education

Graduate Diploma in Resource Teaching
Graduate Diploma in Teacher Librarianship
Bachelor of Education (primary/secondary)
Diploma of Teaching (upgrading)

Mount Gravatt College of Advanced Education

Graduate Diploma in Reading
Graduate Diploma in Religious Education
Graduate Diploma in Educational Administration
Bachelor of Education (secondary)
Diploma of Teaching (primary/secondary - upgrading)
Diploma of Teaching (TAFE)
Diploma of Teaching (TAFE - upgrading)

Queensland Institute of Technology

Bachelor of Laws
Bachelor of Business (Health Administration)

Townsville College of Advanced Education

Graduate Diploma in Aboriginal Education
Bachelor of Education (primary)
Diploma of Teaching (upgrading)

5. SOME CRITERIA FOR THE ESTABLISHMENT OF POST-SECONDARY EDUCATION INSTITUTIONS

Several points of view need to be considered. Employers generally will wish to have readily available on a continuing basis an adequate supply of labour possessing the necessary range of skills and the convenient availability of facilities to permit desired concurrent or further vocational education and training to be pursued with a minimum of disruption. They may also have an interest in stablizing their local communities and in the provision of educational facilities that will encourage this development.

Individual employees may share the expectations of employers, but those with families and a commitment to long term residence and employment are likely to place increased emphasis on the local availability of an adequate range of educational opportunities for their children. These are likely to extend well beyond vocational programs specific to local employment needs.

Community groups and their leaders may share many of the expectations of employers and individual employees, but might be expected also to endorse the role which post-secondary educational institutions may play in enhancing the intellectual and cultural life of the region and its inhabitants. Elected local government and parliamentary representatives have a particular role in articulating these community aspirations to governments.

In the ultimate analysis, the response by governments will be related to the optimum deployment of resources based on a comparative assessment of needs, having regard to both the short and long term and, no doubt, taking political considerations into account. One approach to examining the non-political criteria employed is to look at the circumstances in which past developments have taken place.

For TAFE colleges, the non-metropolitan centres (excluding Ipswich and the Gold Coast) at which these institutions have been established are listed in Table 10 together with their estimated local populations as at June 1978.

TABLE 10: NON-METROPOLITAN TAFE COLLEGES RELATIVE TO LOCAL POPULATIONS

Location	Local population (June 1978)
Bundaberg	32,500
Cairns	36,200
Mackay	22,000
Maryborough	22,050
Mount Isa	27,200
Rockhampton	53,900
Toowoomba	71,900
Townsville	85,300

While these figures may need to be qualified because they do not take account of the immediately adjacent feeder areas, it is apparent that a local population centre of some 20,000 is a prerequisite. This seems to be confirmed by the establishment of a TAFE college currently under construction at Gladstone. Its estimated population in June 1978 was 20,360.

All three major population centres in Central Queensland are at present, or will shortly, be served by TAFE colleges. Given the relatively dispersed nature of coal fields development in Central Queensland, it seems doubtful whether the population of any of the larger centres would reach this historical criterion of 20,000 in the foreseeable future.

In respect of colleges of advanced education, these can broadly be classified into three main groups:

(a) Specialized colleges intended to serve the whole of Queensland, e.g., Queensland Agricultural College, Queensland Conservatorium of Music.

(b) Colleges largely involved in teacher education, e.g. Kelvin Grove College of Advanced Education, Mount Gravatt College of Advanced Education, Townsville College of Advanced Education.

(c) Multipurpose colleges offering courses in a substantial number of fields, e.g. Queensland Institute of Technology, Darling Downs Institute of Advanced Education, Capricornia Institute of Advanced Education.

The two multipurpose colleges of advanced education in the non-metropolitan area are at Toowoomba (population 71,900) and Rockhampton (population 53,900). Both offer courses in five major fields of study. Both depend for their educational and economic viability on non-local students from the surrounding regions and from further afield and through their involvement in the external studies program for the State as a whole. (See Table 9)

Quite apart from clearly defined Commonwealth Government policies against the establishment of further colleges of advanced education, there is no prospect, either in terms of population or need, of a further college of advanced education being established to serve the needs of Central Queensland. Optimally, a centre of population of at least 80,000 and preferably 100,000 is required if a new multipurpose college of advanced education were to be established anywhere in Queensland. The only possible location for such a development would be the Gold Coast.

In respect of universities, there is only one outside the metropolitan area in Queensland, namely, James Cook University of North Queensland. Even allowing for a major political component in its establishment, and its statutory responsibilities in relation to North Queensland and tropical Australia, it remains too small for reasonably economic operation.

Its per capita student cost is nearly twice that of many other universities in this country. It would need to increase in size about three times if it were to justify economically its present program range and take up some additional fields of study.

The conclusion which emerges from this brief review is that there are few if any prospects of any additional regular post-secondary educational institutions being established in Central Queensland. Consideration is, however, being given to the concept of 'mini-TAFE' colleges to serve smaller centres. What then should be the policies and options pursued by industry, the existing educational institutions and their authorities, and the community?

6. POLICIES AND OPTIONS

In order to focus the discussion of policies and options, it is convenient to identify the following main education and training components:

(a) Vocational, specific to major local industrial needs.

(b) Vocational, not specific to major local industrial needs.

(c) Non-vocational, leading to recognized awards.

(d) Continuing education and training related to (a) and (b).

(e) Non-vocational continuing education and training related to general community aims and aspirations.

In (a), (b) and (d), three main categories, professional, sub-professional technician, and trades and related skills can be identified; (c) and (e) are not discriminated in this way.

The policies and options adopted by employers generally in those parts of Central Queensland being considered might preferentially include the following:

(a) preferential recruitment of persons who have already obtained qualifications at basic level elsewhere;

(b) for the cadre not so qualified, optimization of the use of -

   (i) formal internal training programs;

   (ii) block release and sandwich programs;

   (iii) off-campus presentation of selected courses in locally provided facilities with visiting teachers;

   (iv) external studies preferably with some on-campus attendance;

   (v) cooperative arrangements between companies for the above;

(c) recruitment in (b) where these arrangements are most readily achieved;

(d) promotion of appropriate continuing education through arrangements similar to those in (b);

(e) provision of cadetships, scholarships, grants, etc for post-secondary education candidates of both young and mature age.

For young people and their families, appropriate policies and options might preferentially include:

(a) choice of school programs to maintain a wide range of possible employment and further education options;

(b) for the academically competent, pursuit of school programs to year 12 in keeping with (a) and the promotion of high attainment as a worthwhile goal;

(c) insistence on the provision of extensive, thoroughly competent and up-to-date career counselling at several appropriate stages;

(d) optimal use of employment opportunities associated with block release and sandwich programs, internal training arrangements, cadetships, scholarships, government allowances, etc;

(e) where educational and training aspirations require movement to a centre having the necessary facilities, continued maintenance of family and local contact and careful attention to the provision of stable supportive living and social conditions;

(f) recognition that relatively high family income affords an opportunity for a profitable investment in the future careers of children.

For the community generally, appropriate aims could include:

(a) continuing support for those options and policies noted above for both employers and for individual family groups which would facilitate their fruitful implementation and propagation;

(b) identification and articulation of needs and aspirations of the community generally and provision of facilities and public resources for continuing education and training to meet these needs, especially in those areas likely to contribute most to personal satisfaction and quality of life;

(c) establishment of an appropriate local organization or adaptation of an existing body to promote (a) and (b) above.

For post-secondary education institutions in or near Central Queensland and their corresponding State-wide authorities, the complementary policies and options include:

(a) Contact with and appreciation of the special needs and problems of a group of isolated communities characteristic of mining and related developments;

(b) Adoption of academic policies, programs and arrangements designed to accommodate these needs consistent with policies and options being pursued in these areas;

(c) Recognition that there is likely to be a cost penalty in the provision of appropriate services to such areas, requiring careful selection of programs and strategies, and the identification of these cost penalties in resource submissions to government authorities and in seeking local industrial or community support to help ameliorate them.

(d) Appreciation that the provision of educational services to such relatively isolated areas involves the whole State and not solely the local institutions, and that there are intrinsic limits to what it may be appropriate for local institutions to try to provide.

7. CONCLUSIONS

There is, in my judgment, little or no prospect that additional regular post-secondary education institutions will be established specifically to serve the needs of Central Queensland.

The provision of such education and training services to areas not adequately served in keeping with expected future developments rests on the adoption of a range of policies and carefully selected options pursued in a cooperative and coordinated manner by employers, individuals and family groups, the communities generally, post-secondary institutions and their State-wide authorities and governments, State and Commonwealth, which ultimately have to provide the public resources for this purpose.

Isolated ad hoc responses to short term stimuli are, in my view, unlikely to be cost effective or to lead to the necessary range of opportunities or services of the requisite continuity or quality.

There would seem to be a role for a broadly based regional education and training task force to formulate a considered development program in this field, to identify the priorities and the timetable, to suggest how it might best be implemented and to estimate the costs including cost penalties,and to recommend how these should be distributed between public and private sources.

Such a well developed plan for an area and an industrial activity of national economic significance would seem to be a prerequisite if the present restrictive policies on public expenditure being pursued by the Commonwealth Government were to be modified at least to the extent necessary to meet such an identified requirement.

This issue has already been placed prominently before the Commonwealth tertiary funding authorities by the Queensland Board of Advanced Education and the Department of Education on behalf of TAFE in respect of Gladstone and some distinctive developments in that centre have occurred. Further efforts in relation to other areas in Central Queensland would now seem to be appropriate.

FIGURE 1

STATISTICAL DIVISIONS IN QUEENSLAND

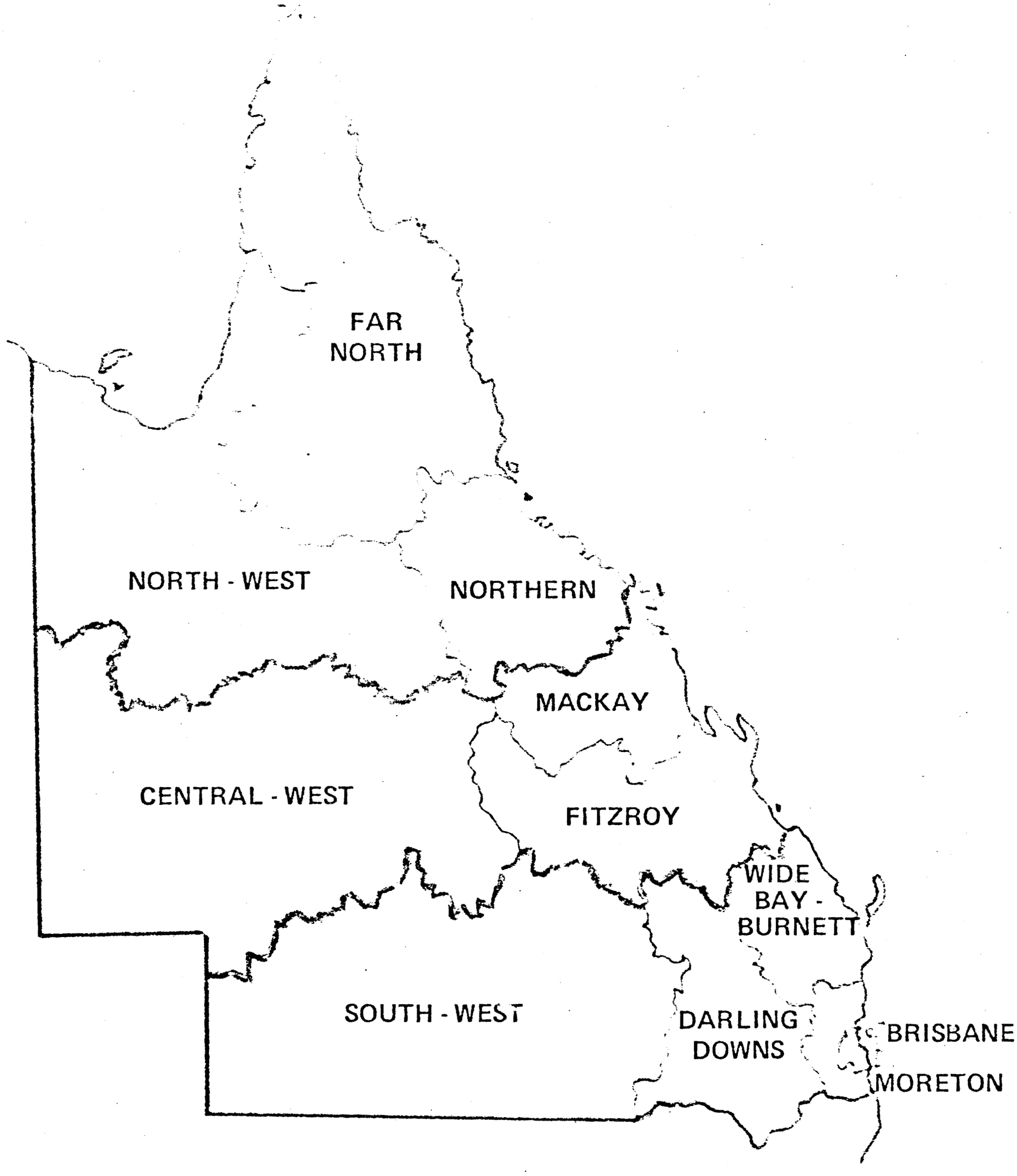
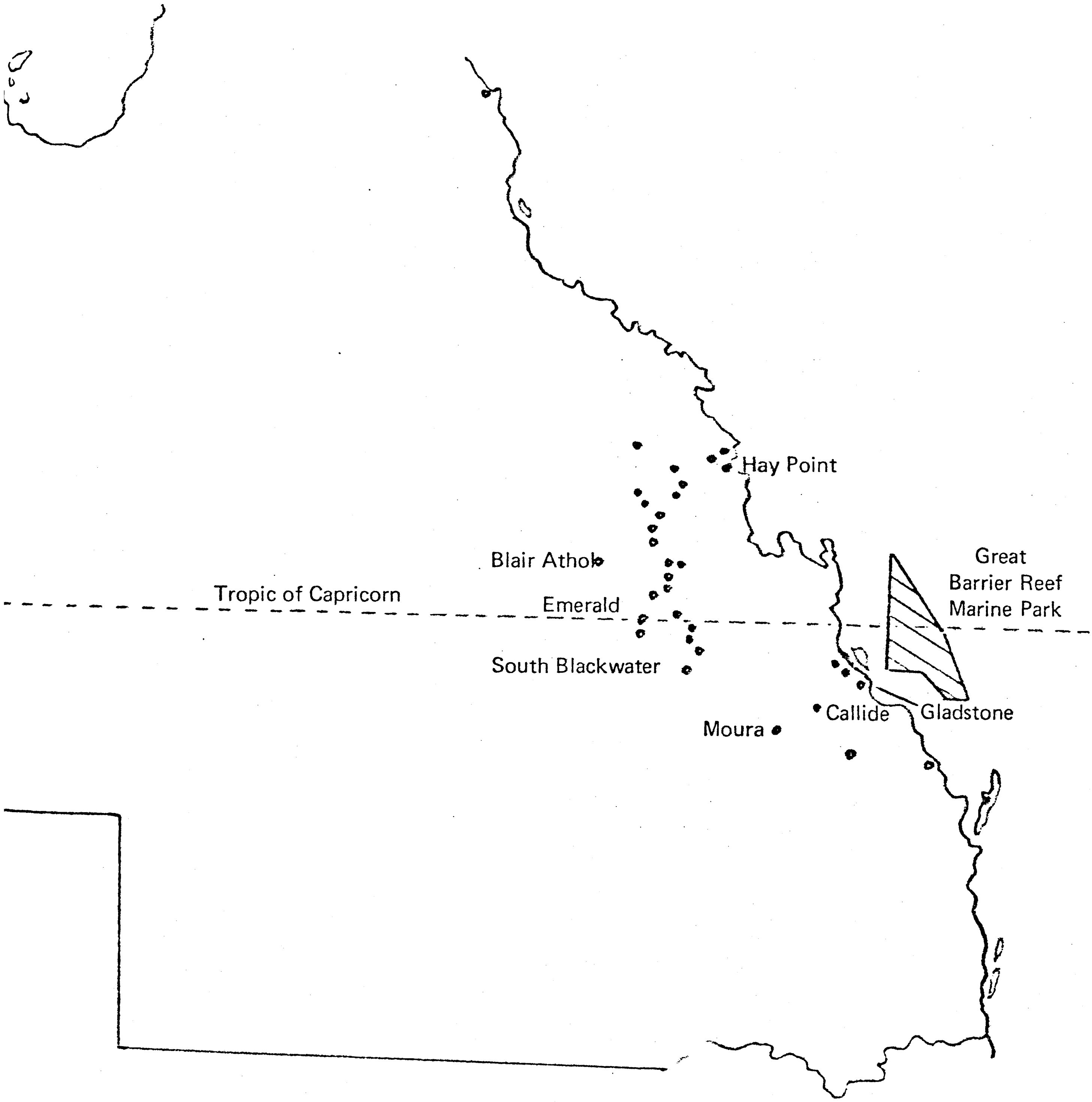


FIGURE 2

GEOGRAPHICAL LOCATION OF MAJOR CENTRAL QUEENSLAND DEVELOPMENTS



CHEMICAL AND PROCESS INDUSTRIES

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Grahame Baker graduated as a Chemical Engineer from the University of Queensland in 1959. After some years in the Royal Australian Air Force, he joined Ampol Refineries Limited in 1965 as a process engineer at their Lytton Refinery. In 1968 he joined the Department of Industrial Development. He is currently the Department's Deputy and Technical Director.

1. SUMMARY

There are large reserves of raw materials in Central Queensland such as coal, oil shale, salt and limestone. These with others such as agricultural land and the existence of infrastructure will inevitably lead to the establishment of more chemical and process industries in the region.

The paper discusses some of the existing industries and possible developments having regard to the availability of raw materials, energy, infrastructure and human resources.

2. INTRODUCTION

The energy and mineral resources of Central Queensland have resulted in the establishment of world scale process industries. The reserves of coal, salt, limestone and oil shales together with existing aluminium based industries and Australia's investment climate are providing the linkages for the establishment of a further range of process industries.

Without doubt, the key factor in the development of the chemical and process industries in Central Queensland will be the energy resources of coal and in the longer term, oil shale and petroleum.

3. RESOURCES

Central Queensland has a substantial resource base including base metal, industrial and energy minerals, pastoral and agricultural land, water, ports and other forms of infrastructure and a workforce with a diversity of skills and experience.

The most valuable of the mineral resources in Central Queensland are the coal measures in the Bowen and Galilee Basins. These range from hard coking coals through steaming coals to semi anthracties while the location of some of the high volatile sub bitumenous coals of the Walloon coal measures in the Wandoan-Taroom areas will probably result in their exploitation being economically linked to Central Queensland.

Major deposits of oil shales occur at Rundle and Stuart just to the north of Gladstone where combined insitu reserves are of the order of 4000 million barrels of shale oil. Other major deposits recently delineated in Central Queensland include those at Yaamba and Nagoorin while the presence of oil shale mineralization occurs at Lowmead, Byfield and Duaringa. A small but relatively rich deposit of high grade oil shale (torbanite) occurs some 47 kilometres south-east of Alpha.

Natural gas has been discovered in the Rolleston-Springsure region in the northern part of the Surat Basin. Further exploratory work is being undertaken while the Galilee Basin to the north-west is also attracting the attention of petroleum exploration companies. A significant source of methane, which has recently attracted considerable interest, is that associated with the coal measures of the Bowen Basin.

Copper mineralization occurs at Mount Morgan, Mount Chalmers and Mount Canindah while a large pyrite and gold reserves occur in the tailings at the Mount Morgan mine. Nickeliferous ores occur in the Marlborough district while heavy mineral sands occur on a number of coastal beaches.

Limestone, clays and salt are the most important industrial minerals in Central Queensland and already provide a significant input to the local economy.

The Central Queensland region was developed through the opening up of the land to pastoral and agricultural persuits. Today beef, wool, grain and horticultural industries besides earning export income provide the raw materials to a number of food processing industries. In addition to the current rural industries, the region has the soil, climatic and water resources to see further growth in the agricultural industries particularly for crops such as cassava and sugar cane.

Supporting these resources is a reasonably well developed infrastructure of cities and towns, ports, transportation systems, electrical, water and sewerage systems, etc.

The resources of Central Queensland, particularly the energy resources, have been the lynch pin for the development of the process industries of the region. This trend is expected to continue.

4. EXISTING PROCESS INDUSTRIES

The initial process industries in Central Queensland were based on the further processing of local resources such as abattoirs, brickworks, lime and cement works and flour mills. However it was the establishment of the alumina refinery of Queensland Alumina Limited (QAL) at Gladstone which has heralded the era of large scale, export based projects.

The availability of coal, limestone and a port were key factors in the establishment of the Gladstone alumina project. The subsequent availability of alumina from this plant and the establishment of an integrated power grid based to a large degree on the coal resources of the Bowen and Callide Basins was paramount to the decision by Gladstone Aluminium Limited (GAL) to proceed with the construction of a 206 000 tonne per year aluminium smelter at Boyne Island, to the south of Gladstone. This 2 pot line smelter, which has been designed to expand to a 4 pot line unit, will produce its first metal early in 1982.

The copper smelting operations at Mount Morgan are of great historical besides economic significance. In addition to the smelting of copper concentrates derived from Mount Chalmers, the pyritic tailings contain a substantial gold resource part of which is soon to be recovered.

There is a well established cement and lime burning industry based on limestone resources in the area between Gladstone and Rockhampton. This industry will expand substantially on the commissioning later in the year of a 500 000 tonne per year clinker plant at Fisherman's Landing.

However it is the mineral and energy resources of Central Queensland coupled with the availability of ports, water resources and the linkages between a number of process industries that are attracting the considerable interest of a number of project developers.

5. PROSPECTIVE PROCESS INDUSTRIES

The most significant resource in Central Queensland is coal. As a source of energy for power generation, as a fuel, reductant and feedstock it will be the most important item influencing the development of new process industries in the region.

5.1 Coal

The principal coal resources of Central Queensland are in the Bowen, Galilee and Callide Basins. The non-coking deposits, many of which have substantial reserves recoverable by open cut mining methods will provide for continuing substantial growth in the State's electricity supply system to cater not only for normal load growth but for the needs of a range of power intensive process industries. Within this decade 2100MW of additional capacity based on Callide (700MW) and Curragh (1400MW) will be installed in Central Queensland.

While the non-coking coals will provide for the energy needs of many new industries, the coking coals will probably support the establishment of a merchant coke plant. The availability of coke will provide linkages to potential new industries such as a steel industry.

5.2 Coke

The production of metallurgical grade coke for domestic and export markets is looking more attractive as a general world shortage of market metallurgical coke has developed. This has been due to a variety of factors including the use of additional coke in blast furnaces in the steel industry to replace injection of fuel oils in furnace hearths and the environmental pressures in some countries forcing the closure of old coke oven batteries.

A major cokeworks would not only give a substantial increase in value added to local coking coals but it would provide a wide range of by-products such as pitches used by the aluminium smelting industry, hydrocarbons and offgas which can be utilized to produce synthesis gas or used as a fuel in industry.

The coke itself would make the production of steel, ferro-alloys and other products reduced in arc furnaces far more attractive.

5.3 Coal Processing

Coal can be processed to produce gaseous, liquid and char type products. While the production of liquid transport fuels from coal may be a long term prospect, the production of gas from coal as a replacement for fuel oil is already looking attractive and further increases in the real price of fuel oil could see a major saving by the process industries to gasify coal for use in those areas where an ash free fuel is required. In this regard, QAL have been investigating the installation of a gasifier at the alumina refinery to enable the plant to become independent from imported fuel oils.

Another area of promise for the latter part of the decade is the production from coal of a petroleum coke substitute for anode production in the aluminium smelting industry. At present aluminium smelters are dependent on imported sources of petroleum derived coke for anode production. As some 0.4 tonnes of anodes are used for each tonne of metal produced, the growth of the aluminium smelting industry in Queensland alone will provide a substantial market for coal based anode grade coke.

5.4 Oil Shales

There are a number of relatively large deposits of sedimentary rocks containing kerogens which on heating yield shale oil. The major deposits are those at Rundle, Stuart and Nagoorin near Gladstone, at Yaamba to the north of Rockhampton and to the west near Duaringa. A smaller deposit of high grade oil shale occurs near Alpha.

The Rundle, Stuart and Yaamba deposits are all amenable to mining by open cut methods and each deposit contains approximately 2000 million barrels of recoverable shale oil and gas equivalent while the Nagoorin deposit appears to be considerably larger. Thus the deposits contain collectively several times the recoverable petroleum reserves of Bass Strait.

The development of a commercial oil shale industry which is a strong possibility within the next 10 years, will provide not only synthetic crude oils for our petroleum refining industry but a source of feedstocks for the establishment of petrochemical type industries.

5.5 Natural Gas

Further discoveries of natural gas in the northern part of the Surat Basin and the tapping of gas from the Bowen Basin coal measures could justify the construction of a pipeline to the Rockhampton/Gladstone area.

The availability of gas would not only assist industries currently dependent on fuel oil but would make the establishment of process plants utilizing synthesis gas much more attractive. The production of methanol as a chemical, fuel and gasoline feedstock and of ammonia/urea/ammonium nitrate for use as fertilizers and explosives would be the principal products.

5.6 Energy Based Industries

The mineral processing industries have been major areas of investment in Queensland in recent years. Significant projects in this field include base metal smelting, electrolytic refining, alumina and nickel refining and cement manufacture. However it has been the availability of the State's energy resources that has played a critical part in their establishment. In Central Queensland it has been the Gladstone power station which has been central to the development of large scale power generation in Queensland that has provided the catalyst for the growth not only of the region but for the State as a whole. The subsequent decisions to proceed with construction of the 1400MW Tarong power station and 2100MW of new generating capacity in Central Queensland has provided a continuing stimulus for growth.

5.7 Caustic Soda - Chlorine

Both U.S. and Japanese groups are investigating the production of caustic soda at Gladstone. This involves the electrolysis of salt solutions to produce the sodium hydroxide for use in the alumina refinery industry while the co-product chlorine is to be used to produce chlorinated hydrocarbons such as vinyl chloride monomer from which PVC is made. The investigations into a 1000 tonne per day caustic soda project are considering the use of both ethylene and acetylene as the hydrocarbon feedstocks.

5.8 Calcium Carbide

The increasing cost of petroleum has resulted in a corresponding increase in the price of ethylene, the principal feedstock in the manufacture of petrochemicals. This has increased the interest in the use of acetylene as an alternative to ethylene.

Acetylene is manufactured from calcium carbide which is produced by reducing lime with carbon in an electric arc furnace. The normal source of carbon is a mixture of metallurgical coke and anthracitic coal. Two major companies are known to be investigating the feasibility of establishing a 100 000 tonne per year calcium carbide plant in the Gladstone area to utilize local limestone, semi anthracite coals from the Bowen Basin and coke from the proposed Lend Lease project. A 100 000 tonne per year calcium carbide plant has a power demand of 45MW.

5.9 Abrasives

Australia does not produce basic fuzed abrasive grains. The major two materials of this type are silicon carbide and fuzed alumina, both of which are produced in arc furnaces. As the cost of electrical energy is a significant part of the cost of abrasives, their production in Central Queensland is attracting international interest.

5.10 Titanium

While Australia is the dominant world supplier of titaniferous ores, very little processing of rutile and ilmenite is carried out in the country. The potential availability of chlorine in Central Queensland makes the long term prospects encouraging for the production of titanium tetrachloride, titanium metal and titanium dioxide pigment.

5.11 Magnesium

Magnesium metal is not produced in Australia but involves a power intensive process having a similar energy consumption as for the production of aluminium metal. Magnesium is produced by the electrolysis of fuzed magnesium chloride. Electrical energy consumption is 16 000 kWh per tonne.

With increasing demands for magnesium in Australia and by the aluminium industry as an alloying agent, together with the international significance of the State's ability to generate relatively low cost electricity, the conditions that have attracted large scale aluminium smelting to Central Queensland are applicable to magnesium production.

5.12 Phosphorus

Duchess phosphate rock from North-West Queensland has proved to be eminently suitable for elemental phosphorus production due to its self fluxing properties. The production of elemental phosphorus is power intensive, a 30 000 tonne per year plant having an electrical power demand of 60MW.

The Central Queensland region has been considered as a potential site for the installation of electro-phosphorus furnaces though the prospects for the establishment of such a project depend not only on power costs but finding markets for electrothermal phosphorus and its derivatives.

In the longer term the real price of sulphur is expected to increase thereby enhancing the prospects for the establishment of a large scale sulphuric acid plant based on the pyritic tailings at Mount Morgan. Such a plant would most likely be integrated with a phosphoric acid plant based on processing Duchess phosphorites utilizing the wet acid process in contrast to producing phosphoric acid from electrothermal phosphorus.

A probable by-product of phosphoric acid by the wet process would be yellowcake wherein the uranium oxides which are present in Duchess phosphate rocks in small quantities would be recovered by a solvent extraction process from the acid liquors in the phosphoric acid plant.

5.13 Steel Industry

While major new world capacity in iron and steelmaking may not be installed for some years, there is expected to be a re-emerging of interest in the potential of establishing "off-shore" steelmaking plants in Australia due to both energy and planning problems in most developed countries.

Both Western Australia and Queensland are being considered for a jumbo type steelworks due to the availability of raw materials. A steelworks of this nature in Queensland would be dependent on Western Australian iron ore whereas a west coast based conventional blast furnace/basic oxygen plant would probably draw its coking coal requirements from Queensland. A project of this nature which would cost billions of dollars is the type that could provide the basis for the establishment of a new port and supporting infrastructure in the Port Clinton/Shoalwater Bay area of Central Queensalnd.

Of increasing international importance is the production of steel by smelting direct reduced iron ore in electric arc furnaces. The direct reduced material is expected to be produced in the Pilbara once North-West Shelf gas is available in the area. The energy reserves of Central Queensland make it a logical centre to smelt this material to raw and alloy steels.

However the prospects for the establishment of offshore steel plants in Australia are very dependent on a major increase in the world demand for steel and the economies of its production in Australia vis a vis the rest of the world. In this regard the cost of energy will be of paramount importance. Decisions in this area could be expected by the mid-1980's particularly if there is a resurgence in world trade over the next 2 to 3 years.

5.14 Ferro alloys

The energy cost factors which have attracted aluminium smelters to Queensland are of the same economic significance to producers of ferro alloys such as ferro-manganese, silico-manganese and ferro-silicon. These steel alloying agents are produced in electric arc furnaces by the smelting of the appropriate ores, iron and coke.

A typical ferro alloy plant would produce 150 000 to 200 000 tonnes per year of product, involve an investment of $200 million and need some 60 - 70MW of electric power. Permanent employment would be provided for some 250 to 300 persons with a significant part of the output being exported.

Ferro alloys, like the production of coke, are closely linked to the needs of the steel industry and their establishment in Central Queensland provides linkages which would enhance the eventual establishment of a steelworks. In this, the situation is not dissimilar to the linkages provided by QAL and the Gladstone Power Station in the establishment of the GAL aluminium smelter at Boyne Island.

6. ECONOMIC IMPACT OF DEVELOPMENTS

Resource development and associated processing operations not only result in initial capital investment through the development of the resource, eg. mining, processing plants and associated infrastructure, but provide a significant ongoing economic contribution due to multiplier effects not only to the region in which they are established but to the State and Australia. The major economic benefits occur through increases in the number of permanent jobs created (employment), the extra money in the form of wages and salaries generated by the project (income) and the gross value of goods and services produced (industry output).

There have been few economic studies of this nature due to the difficulties in developing a satisfactory economic model and in obtaining the necessary input data. The Department of Economics at the University of Queensland over the past few years developed a new method of studying regional economies and in forecasting economic impacts of specific developments. The project, which was funded by the Co-ordinator-General's Department and the Department of Commercial and Industrial Development, led to the development of a methodology based on the use of input-output tables. This enables the make-up of a particular economy to be quantified and to show the inter-relationships that exist between various sectors within that economy. From the tables, the impact of a chnage in one sector on another sector and the total economy can be predicted.

The first study using these techniques to determine the economic impact of major resource and energy gased projects on a community has recently been completed. The Report (1) which was prepared for the Department of Commercial and Industrial Development and Comalco Limited by the Department of Economics study team, provides a measure of the impact of the aluminium smelter of Comalco Limited, the cement clinker plant of The Queensland Cement & Lime Company Limited and the Gladstone power station on the economies of the Gladstone area, Fitzroy region, Queensland and Australia.

A further report (2) based on the use of input-output techniques has been prepared to measure the economic impact of additional industries on Gladstone, etc. not considered in the earlier study (1).

The studies considered not only the direct impact of these developments, but also the impacts in other sectors as a result of these primary growths.

The total impact of all of the developments on the Gladstone economy, eg. GAL smelter, QCL clinker plant , Gladstone power station and Rundle oil shale project, results in an increase in employment between 7 024 and 10 883 jobs, an increase of 76 to 117 percent, a corresponding increase in income of between \$93.7 to \$117.7 million (113 to 142 percent) and a growth in output of between \$2,095 and \$2,288 million (609 to 662 percent).

The impact of the developments on the Queensland and Australian economies is largely due to the multiplier effects diffusing their way through the increasingly larger economies. The impact on the Queensland economy is:-

	Employment	Income (\$M)	Output (\$M)
Total increase	8 898 - 18 426	100.8 - 149.1	2 229 - 2 714
Percentage	1.3 - 2.7	2.7 - 4.1	14 - 17

These figures indicate the significant economic impact the energy and other resources of Central Queensland will have on the future growth not only of the Gladstone/Central Queensland area, but of the State as a whole.

7. CONSTRAINTS TO DEVELOPMENT

A pre-condition for the major growth of the process industries in Queensland, and in Australia as well, will be that Australian industry remains internationally cost competitive. A holding of the level of inflation and greatly increased productivity through the restructuring and more specialization in industry will enable local processors to be competitive on world markets. The rate of growth of these international markets will also be a significant factor.

With an improved economic outlook in Australia, the development of many large scale resource based and numerous smaller process projects, will require the need for substantial sums of capital, of management and labour and of plant and equipment. If a number of such projects get going at the same time, it is possible that the demands for capital, management, labour and equipment may exceed the ability of the country to supply them.

Many of the projects mentioned will require large amounts of capital. Much of this will have to come from overseas with those projects being internationally cost competitive having few problems in raising the necessary funds though large increases in capital inflow will put pressure on the Australian dollar.

While unemployment levels currently are unduly high, the country does not possess any significant quantity of unutilized human resource capital in the management and skilled labour fields. The development of many of the projects mentioned together with those likely to proceed in Western Australia, will place high demands on those with the appropriate skills. Likewise, there is a certain thinness in the productive capacity of the manufacturing sector to handle very large increases in demand for the wide range of plant and equipment required for major growth in the economy. This is a legacy of a number of years of relatively low demand.

The cost of providing infrastructure and services is often a significant factor that influences the viability of a project. However the State Government and Local Authorities are not in a position to provide the basic infrastructure needs of major projects and thus the developers are required to meet the costs associated with their provision.

These are some of the factors which are most likely to provide the constraints to the rate at which the development of industries in Queensland, and elsewhere in Australia, will occur.

The development outlined will greatly increase export income and this with increased net capital inflows will, without taking other action, put pressure on the Australian dollar to be revalued. However with the higher level of economic activity that would result, it gives the nation a chance to restructure its highly protected industries without the severe social consequences which occur when such an action is undertaken in periods of stagnant economic growth. Such restructuring will give Australia a more competitive manufacturing sector, enabling a lowering of tariffs and resulting in higher imports to offset the effects of a growth in export income.

8. CONCLUSIONS

Central Queensland's wide range of resources, particularly energy resources will, with improving domestic economic conditions, provide the basis and conditions for a widespread growth of the process industries. The resultant investment will have a large multiplier effect on the local economy leading to increased economic activity throughout all sectors of the State economy and a chance to restructure the manufacturing sector further. However, given the appropriate economic climate for continuing growth, the factors that will control the extent of new investment probably will be the availability of capital, management and skilled labour.

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ALUMINA PRODUCTION AT QUEENSLAND ALUMINA

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1. SUMMARY

The plant operated by Queensland Alumina Limited at Gladstone underwent rapid expansion in the period 1967 - 1973. This paper outlines the Bayer process as operated at QAL and reviews both definite and possible expansions in alumina capacity in Australia.

2. INTRODUCTION

Queensland Alumina Limited (QAL) operates the world's largest alumina plant at Gladstone, Queensland, producing more than 2 450 000 tonnes of alumina in 1980 accounting for approximately 8% of western world capacity.

The plant was commissioned in 1967 with an annual capacity of 610 000 tonnes and has undergone three expansions to the present capacity.

Alumina is produced on behalf of four shareholder companies, and is shipped to their smelters in Australia and overseas. Companies participating in the consortium are Alcan Aluminium Limited, Comalco Limited, Kaiser Aluminum and Chemical Corporation, and Pechiney Ugine Kuhlmann. QAL functions as a tolling operation, supplying alumina to the owners in proportion to their equity in the company for a charge per tonne which covers the cost of processing. The plant was designed to process bauxite from the extensive deposits at Weipa using Bayer technology.

3. BAYER TECHNOLOGY

From the beginning of the industry two technologies were developed. These were the American Bayer or low temperature digest which was designed to extract alumina from low-iron gibbsitic bauxite deposits of Arkansas and later Guyana and Suriname; and the European Bayer, or high temperature digest for extraction of alumina from Mediterranean boehmitic type bauxites. Gibbsite (aluminium oxide trihydrate, $Al_2O_3.3H_2O$) is dissolved readily by 10 percent sodium hydroxide solution at temperatures under 150^{o}C. However, boehmite (aluminium oxide monohydrate, $Al_2O_3.H_2O$) will not dissolve readily below 200^{o}C. More recently, hybrid plants designed to extract mixed gibbsitic-boehmitic bauxites have been developed. QAL is of this type.

Bayer alumina plants consist of two facilities operating in series. The first is a hydrate plant and the second a calcination plant. The hydrate plant is essentially a devise to heat and cool a continuously circulating stream of sodium aluminate solution through a temperature range which currently does not exceed 250°C per cycle. Bauxite is added on the heating cycle and the slurry taken to the maximum temperature where alumina is dissolved from the bauxite. Residual solids, red mud, are separated at an intermediate temperature of the cooling cycle, and alumina trihydrate precipitated by seeding supersaturated sodium aluminate solution at the low temperature point in the cycle. Capital and operating costs of the plant are a function of the volume of caustic soda liquor circulated, quality of bauxite used and quantity and properties of alumina produced. The size and number of pieces of processing equipment, such as grinding mills, holding tanks, digestors, pipelines, valves, pumps and filters are basically functions of the flow rate of the process liquor stream. The types, requirements of mud separation, washing and disposal equipment are additional and also reflect the type and characteristics of the bauxite feed and process technology used. The same is true of the overall heat requirement of the plant, and the electrical energy load. The design engineer's primary objective is to maximise the production of alumina per unit volume of caustic liquor circulated and bauxite input, and to minimize the energy requirement and other inputs such as lime and flocculant.

4. WEIPA BAUXITE

Weipa bauxite is a mixture of both gibbsite and boehmite. A typical analysis is shown in Table I. The QAL plant is designed to extract both in a continuous process and is operated at temperatures around 240°C utilizing a 10 percent sodium hydroxide solution to dissolve alumina from the bauxite. The usage rate is about 2.2 tonne of bauxite per tonne of alumina.

CONSTITUENT	%
Al_2O_3	55
Alumina Available in Process	50
$Al_2O_3.3H_2O$, Gibbsite	37
$Al_2O_3.H_2O$, Boehmite	13
Fe_2O_3	13
Total SiO_2	5-6
TiO_2	3
Moisture	13
Other	11

TABLE I. TYPICAL ANALYSIS OF WEIPA BAUXITE

Bauxite received from Weipa is pisolitic and sized to a maximum of 20 mm. It is stockpiled in the open, reclaimed as required and ground wet in two compartment rod-ball mills to reduce particle size and provide greater surface area for extraction of alumina content during subsequent digestion. Recycled spent liquor is added to produce a pumpable slurry. Slaked lime is added for mud conditioning and phosphate control.

5. DIGESTION

Three parallel digestion units are installed at QAL, operating at a design flowrate of 1 450 l/sec. The process is a high temperature and high pressure leaching of ground bauxite slurry in two agitated, vertical digestion vessels in series on each unit. Sodium hydroxide is used to dissolve alumina, forming soluble sodium aluminate and leaving most of the impurities in the insoluble red mud and sand.

Reaction conditions are set to extract both the trihydrate and monohydrate fractions, typically 240°C and pressure of about 3 500 KPa. Attack on trihydrate alumina is rapid while reaction of monohydrate is relatively slow. By sizing digester vessels for optimum holding time, 97% of the total available alumina is extracted.

Principal reactions which occur during digestion are -

For Gibbsite

$$Al_2O_3.3H_2O + 2NaOH \rightarrow 2NaAlO_2 + 4H_2O$$

For Boehmite

$$Al_2O_3.H_2O + 2NaOH \rightarrow 2NaAlO_2 + 2H_2O$$

The silica component of the bauxite, is chemically attacked by sodium hydroxide in the digesters. Attack on reactive silica and quartz is rapid and causes about 85% of the caustic soda loss and some alumina loss by precipitating in a secondary reaction to form desilication product, $2Na_2O.2Al_2O_3.3SiO_2.6H_2O$. This passes out with the mud waste as a solid.

During the digestion process, the mass ratio of alumina to soda in liquor increases from about 0.350 to 0.670 as alumina dissolves. After leaving the digester vessels, slurry is flash cooled to atmospheric temperature by flowing in series through ten flash vessels operating at successively lower pressures. Flash steam is used to heat incoming spent liquor in tubular heat exchangers located parallel to the flash tanks.

Flash tank effluent is diluted with mud washer overflow liquor to control caustic concentration to a level required for the subsequent precipitation step.

6. CLARIFICATION

Slurry from the digestion area contains 3-4% residual solids which is removed by settling in raked 40 m diameter single deck thickeners. Flocculants are added to improve settling rate and overflow clarity. Overflow liquor containing 100 mg/l of fine mud is filtered in Kelly-type constant pressure filters fitted with polypropylene filter cloth. Slaked lime slurry is used as a filter aid to promote formation of a porous, rigid filter cake.

The settler underflow, containing mud and sand at around 35 wt % solids is pumped through sand traps which remove the +100 mesh fraction (sand) for deliquoring and washing to recover residual caustic prior to disposal to sand ponds.

Caustic soda associated with red mud in the settler underflow is recovered by counter current washing with make-up water which enters the plant through the washing circuit. Mud leaves the last washer with a liquor soda concentration of less than 3 gpl and is pumped to the mud lake, using sea water for pacification.

7. PRECIPITATION

In the continuous precipitation process, alumina trihydrate ($Al_2O_3.3H_2O$) is precipitated from pregnant sodium aluminate liquor, precipitation being initiated by seeding of cooled supersaturated liquor with fine hydrate particles.

Precipitation is carried out in 9 precipitator rows, each row consisting of 12 agitated tanks, arranged in series to provide 30-35 hours holding time. Entry temperature and temperature gradient across the rows, seed rate and caustic concentration are manipulated to achieve the required particle size distribution in product and to maximise production of alumina.

8. CLASSIFICATION

Hydrate of various crystal sizes is produced during the pass through precipitation. The finished mix of crystal sizes, ranging from 2-160 micron, is settled from the liquor stream and separated into three size ranges in three-stage classification tanks. Primary classifiers collect coarse fractions which becomes product hydrate. Intermediate and fine crystals from secondary and tertiary classifiers are returned to the first precipitation tanks as seed.

9. SPENT LIQUOR

Spent caustic liquor, essentially free from solids, overflows from the tertiary classifiers and is returned through an evaporation stage where it is reconcentrated and recycled to dissolve more alumina in the digesters. Fresh sodium hydroxide is added to make up for process losses.

10. CALCINATION

Coarse hydrate ($Al_2O_3.3H_2O$) from the primary thickeners is pumped to hydrate storage tanks, is filtered and washed on horizontal-table vacuum filters to remove soda. Soda recovered is returned to the process in the precipitation area.

The resulting filter cake is fed to oil-fired rotary kilns, 100 m long and 4 m in diameter, and calcined to remove both free moisture and chemically-combined water. Product sandy alumina particles are 90 percent +325 mesh in size. Firing-zone temperatures above 800°C are used.

Rotary or satellite coolers are used to cool the calcined alumina, and to pre-heat secondary combustion air for the kilns. Fluidised-bed coolers then reduce the alumina temperature to less than 90°C before it is discharged onto conveyor belts which carry it to storage buildings where it is stockpiled for shipment.

11. FUTURE GROWTH OF ALUMINA PRODUCTION IN AUSTRALIA

The current decade will see a movement of investment away from the major aluminium consuming countries, in particular North America and Japan, to bauxite and energy rich countries such as Australia. Table II shows committed and possible expansions in capacity in Australia.

DEFINITE EXPANSION 1980-1985 (Million Tonne/Year)		POSSIBLE EXPANSION (Million Tonne/Year)	
Wagerup (Alcoa)	0.5	Admiralty Gulf (CRA)	0.5
Worsley (Alwest)	1.0	Bowen/Weipa (Comalco)	1.0
Pinjarra (Alcoa)	0.3	Wagerup (Alcoa)	1.5
QAL	0.3	Worsley (Alwest)	1.0
		QAL	1.0
	2.1		5.0

TABLE II. SUMMARY OF EXPANSION IN ALUMINA CAPACITY IN AUSTRALIA

Australian expansion at 2.1 million tonnes per year represent 25% of western world expansion for the period 1980-1985. Major expansion is also planned in Venezuela and Brazil which both have abundant energy supplies.

Availability of energy, particularly coal, large high-grade bauxite reserves, and an expanding local need for alumina due to growth in smelter capacity make Australia an attractive proposition for investment from a purely economic viewpoint. Further incentives are offered by a very low risk of expropriation of the projects and the relative political and social stability.

Increasing transport costs will make it economically attractive to further upgrade alumina to metal with smelters projected for Australia requiring an additional 3.6 million tonnes of alumina if they all eventuate.

12. FUTURE DEVELOPMENTS AT QAL

In the past, QAL has undergone three expansions which increased annual production from an initial 610 000 to the existing rated capacity of 2 032 000 tonnes. The plant is currently operating at 120% of rated capacity. The current expansion, to be commissioned early 1982, will increase capacity by 300 000 tonnes per year and will be achieved through process improvements rather than addition of major equipment. Further productivity expansions through the 1980's are projected, depending on alumina demand, with ultimate capacity in excess of 3.7 million tonnes being feasbile.

Alternate fuels aimed at replacing oil used in lime and calcination kilns, and bauxite shipping are under study. To date the studies have shown -

(1) Replacement of oil by direct coal firing of lime kilns is feasible and economically attractive. Detailed engineering design is proceeding.

(2) Coal gasification to produce a gas suitable for firing alumina calcination kilns is technically feasible. A gasification plant sized to replace 250 000 tonnes per year fuel oil would require a total investment in excess of 150 million dollars. The project is unattractive at current oil prices and only marginal at projected prices. The possibility of gas supplies developing in the Gladstone area from exploration or other process industries further clouds the economics.

(3) Four coal fired ships, each 70 000 DWT capacity are under construction for transport of bauxite from Weipa to Gladstone. Two will be operated by the Australian National Line and two by Port Curtis Bulk Carriers and will require bunkering at the rate of 150 000 tonnes per year from facilities yet to be installed. The first is expected on the run in 1982.

13. CONCLUSION

The 1980's will see further growth of alumina capacity in Australia, as evidenced by committed and projected developments. At QAL, expansion will be achieved through introduction of improved technology, and debottlenecking where appropriate.

14. ACKNOWLEDGEMENTS

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ALTERNATIVE ENERGY RESOURCES

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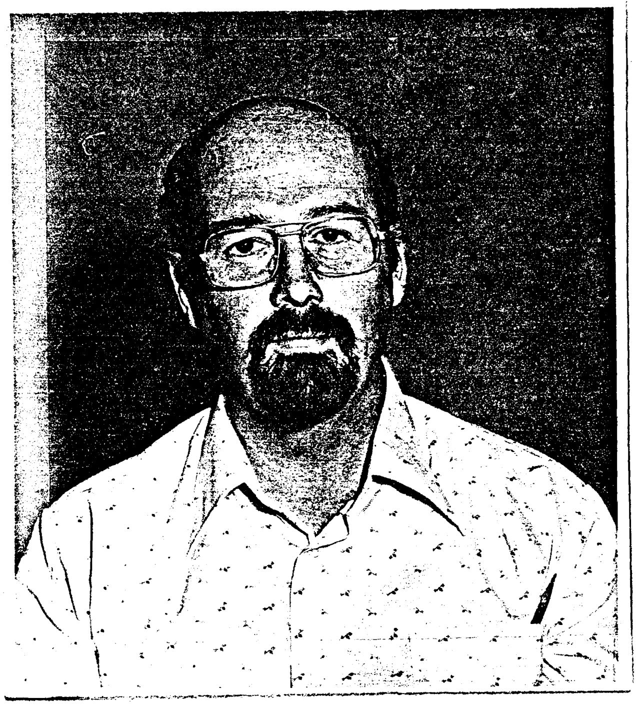


After serving in the British Army with the Royal Electrical and Mechanical Engineers, the Author, Rockley Boothroyd read the Mechanical Sciences Tripos at the University of Cambridge, U.K., graduating with honours in 1959. He spent ten years at the University of Birmingham, U.K., as a lecturer in Mechanical Engineering where he specialised in teaching nuclear power technology to masters degree level. After 3 years as Senior Research Scientist at CSIRO Division of Environmental Mechanics, Canberra he was appointed to his present position which he has held for 7 years. He is the Author of 'Flowing Gas-Solids Suspensions', (Chapman and Hall) and more than 40 technical papers.

1. SUMMARY

No particular feature suggests that Central Queensland is an especially suitable area for exploiting non-fossil energy resources. It is believed, therefore, that developments along these lines will probably parallel those experienced in other parts of the world. However there may be a more significant contribution of alternative energy use in remote areas of Queensland stimulated by increasing liquid fuel costs in agriculture.

Following the forthcoming coal/oil-shale based industrial boom, the role of increasingly competitive nuclear energy is examined as a possible future source of base-load electrical power supplies in Queensland. The very uncertain issue of a possible uranium enrichment plant for Queensland is also reviewed. Despite recent reports to the contrary, it appears that this is a relatively unattractive development for our area. Nuclear waste disposal in Queensland is also examined as another possible future industry.

The paper concludes with brief consideration of environmental and balance of payments considerations relevant to Central Queensland's new industries.

2. INTRODUCTION

2.1 Why Central Queensland and What is its Future?

We must recognise that the present investment interest in Central Queensland is simply in cheap and abundant energy and not much else. In many ways Central Queensland is intrinsically unattractive for industrial development at the present time. Because of these cheap conventional energy resources therefore, it seems reasonable to doubt that alternative energy will ever acquire much relevance here.

However history has shown that large areas of human settlement often tend to persist long after the forces which inspired human migration have disappeared. It is reasonable to suppose, therefore, that the boost in population in Central Queensland, which we can expect from the present industrial boom, will become a permanent feature in the longer term.

There are other factors which can also be expected to stimulate a permanent settlement in our area from migration. For example, on a worldwide basis, we can anticipate more migration, and particularly retirement, to the tropics as home heating in the temperate areas becomes more costly.

Thus, in the longer term, we might expect a greater use of alternative energy if only for demographic reasons. This will probably be in line with the same trend in other parts of the world. For these reasons the Author has thought it necessary to speculate a little further into the future than is likely to be the case in most other papers at this conference.

2.2 Alternative Energy Resources of Negligible Significance in Central Queensland

As a prelude to this paper it is necessary to mention briefly the many sources of alternative energy which are of little local interest.

Tidal power does not appear to be relevant: we lack suitable estuaries, the tides are moderate and the Barrier Reef itself precludes extraction of energy directly from waves. Also, environmental concern for the Barrier Reef eliminates any possible interest in such projects as exploiting sea water temperature differentials.

Likewise, geothermal energy[(1)] can be dismissed almost totally and hydroelectricity has little potential once the Burdekin River is developed. Even with regard to wind energy we are not particularly well blessed. Apart from its unreliability the wind power available increases as the cube of wind speed. This has always been found very inconvenient fundamentally for most users. Also in our cyclone-prone area, wind generators are not particularly attractive from the maintenance point of view.

Even our abundant and fairly reliable solar energy might be expected to have to compete with some fairly cheap electricity in the future. However improvements in the design of solar hot water heaters are likely to make them as ubiquitous, as T.V. serials used to be.

Central Queensland is still predominantly an agricultural society and is likely to remain so, despite the development of large scale energy-dependent industry. It is probably in the rural sector that we will find the most striking commercial application of alternative energy. Liquid fuel costs are a considerable burden on Australian agriculture.

In this paper the Author will try first to isolate the potential of the so called main alternative sources of energy: wind; solar; biomass etc. The paper will then conclude with a review of the potential for nuclear energy developments in Queensland.

3. SOLAR AND WIND ENERGY

3.1 High Capital Cost: the Main Disadvantage of Alternative Energy.

Despite recent advances such as Westinghouse's new process for growing single-crystal silicon-ribbon, the cost per installed kW of solar photovoltaic plant is still much more expensive than conventional generators. Solar cells are, therefore, still limited to low power applications such as electric fences and telecommunications in remote areas.

Even with an old technology such as wind energy, Cubitt[2] has pointed out that from 1951, over a period of 25 years, the sale of windmills in Australia has fallen by a factor of ten. The answer is not hard to find: capital costs of producing electricity from wind have risen by a factor of four in real terms. On the other hand rural subsidies of electricity connection in rural areas (recently also in the form of full tax deductability of capital costs) have artificially improved the competitiveness of grid electricity. Much the same can be said of the history of liquid fuel distribution in Australia.

For alternative energy to win customers in the rural sector we need to reverse this subsidy policy. Obviously this is completely untenable politically in the forseeable future.

The policy issue on rural energy is also part and parcel of other factors such as export subsidies for rural production (including the artificial low parity of the Australian dollar); problems of dumping of EEC surpluses on world markets, for example, and the not inconsiderable superior lobbying ability of electricity generating boards compared with the negligible influence of small manufacturers of alternative energy appliances. The issues are clearly far too involved for analysis in this paper.

Apart from salt-extraction near Port Alma - apparently our only solar-powered local industry - the industrial potential of solar/wind energy looks poor. We are therefore left largely with the domestic and rural market.

3.2 Recycling rubbish

One way round the high capital cost problem is to develop systems based on salvaging rubbish. Most developments stem from the 'do-it-yourself' alternative energy user who can also discount his labour costs to virtually nothing. Unfortunately alternative energy systems tend to be costly in labour as regards both assembly and maintenance. Thus, what makes no sense at all in economic terms to today's technology-oriented farmer-businessman can still become an attractive proposition to someone in the bush living the 'alternative life'.

"Junk windmill technology" has been developed in the Author's department by Sayers[3].

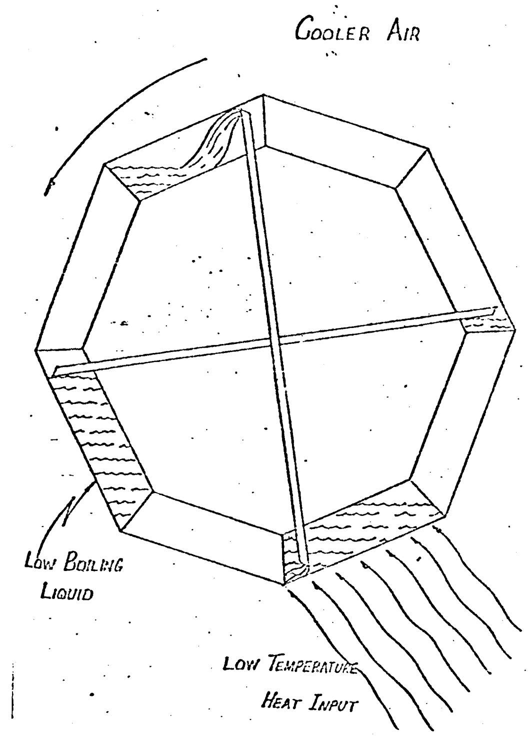


Figure 1 THE MINTO WHEEL

(Details are available in a small booklet (The Minto Wheel) from Wallace Minto, Sun Solar Laboratory, Sarasota, Florida, U.S.A.)

The Minto wheel, shown in figure 1, is another machine which can be made entirely from scrap materials. This device is a low speed heat engine using low grade heat from almost any environmental temperature imbalance. The increased saturation pressure in the (hotter) lower chamber forces the liquid to the upper (colder) chamber. Several pairs of chambers enable the wheel to revolve smoothly to drive a generator through step-up gearing. The device is virtually maintenance-free but it is expensive to make unless scrap materials are used.

It seems that all these home-designed systems, including, for example, farm power alcohol distilleries, farm hydrogen generating systems etc. are unlikely to make much impact on the overall energy scene.

3.3 The Need for Efficient Industrial Design and Marketing

It is only in the last few years, and mostly in America, that we have seen really efficiently designed and low cost alternative energy devices coming onto the market. These include, for example:

1) push-button operated swimming pool covers which act as solar 'heaters' cum child-safety anti-drowning cover cum pool cleaner. There is certainly an unexploited market for this type of product in Queensland.

2) UV-resistant, extruded-elastomer integrated solar energy heating panels, mass-produced at minimum manufacturing cost and weighing less than 5 kg/m^2. The panels are a simple 'push-on' fit for easy installation to standardised header tanks. Installation costs of such designs are minimal.

The fact that Australia, once a world leader in solar energy technology, has now lost so much ground to the USA can be explained mostly by two factors:-

a) the recognition by American industry that an alternative energy device is the same as any other product in that it needs the same ruthless, competitive approach in engineering design.

b) mass markets for alternative energy products are substantial in America and have been positively identified and researched.

There is one important selling factor in favour of the manufacturer of small-scale alternative energy devices. Even moderately skillful sales promotion can often persuade the average householder, or even a farmer, to invest in a device which is not necessarily competitive with traditional technology. By contrast, rarely does this situation arise in the sale of industrial plant, however small. The psychology behind this is fundamental to us all. We simply like to be independent. Moreover in an affluent consumer-oriented society such as ours, individuals will agree more readily to spending money speculatively and on gimmickry.

We can conclude therefore on an optimistic note. The manufacturer of alternative energy systems has much in his favour. Moreover hitherto unexploited markets can be quite massive. Just one such example, relevant to Central Queensland, is a commercially-competitive solar energy-operated air conditioning system. There is a growing 'peak' electricity demand in this area.

A joint NERDDC/Indian computer-optimisation design study of a solar air conditioner is scheduled to be reported in 1982 at James Cook University. This type of project illustrates how we must recognise that Central Queensland is just a small part of the world market for alternative energy devices. As the Author sees it, the immediate problem is to identify and classify these world markets so that they become large enough to attract private enterprise. Only private business enterprise has the necessary design skills and other infrastructure to develop and sell really attractive products.

4. BIOMASS SYSTEMS

A whole multitude of systems[4] can be used for obtaining energy from biological materials.[5,6] Plants only 'fix' 0.1-2% of solar energy. Nevertheless it is a popular misconception that biomass has enormous development potential.[7] McCann and Saddler[8] have estimated the 'maximum theoretical' production of biomass energy at only about 20% of petroleum consumption in Australia. Space precludes detailed discussion of the economic factors which limit biomass systems. These details are usually well covered in the original reference (e.g. ref. 9). Discussion here is limited to some basic principles.

4.1 Sugar-cane Bagasse

Many biomass systems have been in use for many years. In Queensland the use of bagasse (residue of crushed cane stalks) as a sugarmill fuel constitutes nearly 2% of our domestic fuel consumption.

The arguments for supplying a somewhat inconveniently-seasonal 600MWe from surplus bagasse to supplement Queensland electricity supplies has also been discussed, on and off, for many years. The details are reviewed by Nix [10].

Research on bagasse fuel is still very active at our Sugar Research Institute in Mackay. Together with other projects there is a programme to improve the calorific value and storage quality of bagasse by reducing the moisture content to 15%.

'Pelletised' bagasse is also under development as a fuel. This material may even have a potential market as 'roughage' feed for cattle when mixed with molasses. Also, despite damage during the milling process, bagasse has potential as a raw material for making paper. This latter situation is typical of many biomass energy systems: the 'product' is usually not a cheap fuel but often a very useful process material with a market price which is higher than the price of fuel. Essentially this illustrates the real nature of our 'energy crisis' as a crisis not of energy but of 'cheap' energy.

There is one other lesson to be learnt about biomass energy which is discussed in the next section. Whether the biomass is sawdust, pig excrement or waste liquor from a pineapple cannery, it is usually necessary to exploit the biomass in situ.

4.2 The Problem of Bulk Materials Handling in Biomass Systems

The slogan 'small is efficient' is often tagged[12] to alternative energy systems. The reason is not that small units are more efficient than larger ones (this is very rarely the case) but that alternative energy is, by definition, diffuse and hard to collect efficiently for utilisation in a central plant. This is certainly true of many grandiose past designs for biomass energy systems. Detailed economic analysis has often shown up the impracticalities of high transport costs of bulk biological material to and from a large central processing plant. For example, a proposal a few years ago to generate methane gas from dung in cattle feed lots in the United States failed miserably on this score. To exploit biomass effectively, the real challenge is for the process design engineer to develop reasonably efficient small scale plant at low capital cost. The emphasis on high plant efficiency tends to be much less important. It is almost axiomatic that processing plant needs to be installed near the biomass.

4.2.1 Controlling water hyacinth

In our own local Rockhampton area we might, perhaps, consider the possibility of cropping our own water hyacinth and other noxious water weeds for producing methane gas (actually a mixture of roughly 2 parts CH_4 to one part CO_2). Our attempts at controlling the weed by spraying chemicals have met with little success. The technology of producing methane gas from waste by anaerobic bacteria is well established and has been practised for years on a small scale in many villages in such countries as India and Papua New Guinea.

A floating water hyacinth cropping-unit feeding a digestor on the shore of the lagoon might be used to feed gas directly to a local energy-based industry. The possibilities certainly merit more detailed consideration than they have received. To the best of the writer's knowledge, the only local use of these weeds has been to produce a soft mulch. Obviously this has limited market potential.

In a study in Singapore[13], water hyacinth with plant doubling time of 8 days was estimated to yield 1.1 kg/m^2 of wet hyacinth/day. This is a very compact source of biomass. Water hyacinth is one of the few biomass systems we could use in Queensland which has a low transport penalty cost. Due to its sparsely vegetated vast areas, Australia is not fundamentally well-suited to the intensive agriculture systems needed for successful biomass systems with low transport overheads.

4.3 Ethanol

One alternative to digestion by anaerobic bacteria to produce methane is to employ fermentation to produce ethyl alcohol (ethanol). It is generally agreed, despite the recent enthusiasm of many local farmers, that only large scale systems have any chance of being economically attractive. Energy consumption in distilling alcohol is considerable and effluent disposal is also a problem. Sugar cane, giving ex-distillery alcohol at about 45¢/litre, has been considered more suitable than other crops. Sugar cane has one of the highest solar energy fixation rates and the agriculture used is intensive and is already adapted to cope with transport problems of biomass.

For poorer soils, cassava has been shown to be promising by McCann and Saddler[14]. A cassava-ethanol project has been considered for Maryborough. Other possible areas for large integrated cassava-ethanol systems are in the Burdekin and Cape York peninsular areas.

The cost of harvesting deeply buried tubers together with the speedy deterioration of harvested tubers are limiting factors in the process.[14] However the tubers can be cropped over a lengthy season, thus making reasonably efficient use of the ethanol processing plant.

However in much the same way as with other biomass systems, an alcohol product may be less profitable than, say, a cassava-pellet manufacturing plant, selling its product to the EEC animal feedstock market.

Unlike other countries Australia is sufficiently wealthy to avoid having the economic pressures of an alcohol programme forced upon it. Since 1975 Brazil has had an extended campaign to develop ethanol as a motor fuel. The economics are not relatable to Australian conditions however.

4.3.1 Ethanol or methanol?

In some ways methanol is more attractive than ethanol as a petrol extender as was discussed at a conference on 'Alcohol Fuels' in Sydney in 1978. At most, it costs 1/3 of the price of ethanol from sugar cane. Obviously, in this light, the Sugar Industry is not particularly interested in the considerable investment needed for a power alcohol programme. However, the apparent lack of commercial interest in making methanol from natural gas in Australia is much more suprising. It must be admitted, however, that the market and political incentive in New Zealand to develop the Taranaki natural gas field for methanol (and thence to petrol conversion via the Mobil process) is stronger than any incentive to do likewise with our own North West Shelf gas field.

4.3.2 Diesel fuels from plants

Oil can be obtained from the pyrolysis of municipal and other waste. Sundried plant residues can also be used to produce quite high yields of heavy oil by flash pyrolysis, but the economics[9] are unattractive for the reasons given in section 4.2

A number of studies are presently underway in Queensland and elsewhere in which vegetable oils such as peanut oil are undergoing tests in conventional diesel engines. This is an efficient way of exploiting biomass fuel. However many of these crops have a higher intrinsic value for their normal use. It is often hard to consider them as a source of cheap fuel. Also a further word of caution seems appropriate for the self-reliant farmer who tries to 'grow and use his own'. Diesel engines use clean refined fuel. 'Do it yourselfers' may be deterred very quickly from this practice after the first repair bill for the injection pump on a tractor!

Of more general interest is the possible cropping of certain hardy oil-producing plants in semi-arid areas of Queensland. For example, at the 1980 ANZAAS Conference in Adelaide, Professor Calvin and his wife drew attention to the wide range of latex-producing plants of the Euphorbia genus. He outlined the concept of machine harvesting such hardy crops to yield perhaps 25-30 barrels of oil/hectare. Also this plant genus appears to have possibilities for revegetating strip-mined land which is semi-arid thus offering the opportunity of well-contoured plantations. The Jojoba plant and 'rubber vine' (cryptostegia grandiflora) are other examples which have received a lot of publicity recently.

Some of the recent claims for 'oil-plants' appear to be rather optimistic nevertheless. For example, in a recent press statement, it was claimed that in dry-farming conditions, 6 tonnes of oil can be obtained per hectare-year to yield $1200/hectare per year. It remains to be seen how good these returns become in the light of processing costs in this fairly new form of agriculture.

As with all biomass systems, the problem is one of processing the biomass in a remote area with equipment with reasonably low capital cost. Lower speed agricultural diesel engines, using lower quality fuels, may be one useful approach to this end in the longer term[16].

* methane gas from water hyacinth in lagoons
* solar drying of grain sorghum
* wind energy (or Minto wheel) for electrolysis-hydrogen systems with iron-titanium hydride-hydrogen gas storage for rural properties.
* flash pyrolysis oil extraction from solar-dried cereal wastes
* advanced technology ethyl alcohol fermentation from crops
* oil from hydrocarbon producing plants

TABLE 1: SOME IDENTIFIABLE ALTERNATIVE ENERGY POSSIBILITIES FOR CENTRAL QUEENSLAND WHICH HAVE RECEIVED INADEQUATE STUDY

5. A POLICY TO PROMOTE THE DEVELOPMENT OF RENEWABLE ENERGY SYSTEMS

It is often misleading to make comparative costs in a changing market/technology situation but typically, and with few exceptions, at best, sources of alternative energy are still about twice as expensive as conventional fuels[9]. To make alternative energy systems competitive, our policy should be to:

1) develop, and encourage by fiscal means, local small-scale energy generation systems only where the alternative energy approach is really promising and transport/delivery costs are minimised.

2) identify similar mass markets worldwide so that economics of manufacturing scale can be achieved.

3) get away from the present amateur/academic status of alternative energy research and stimulate the development of the techonology within private industry which has the expertise to minimise the present burden of high capital investment.

Lastly, it is relevant to repeat, as has often been pointed out, that our large scale industrial facilities are totally unprotectable in modern war conditions. By contrast, alternative energy systems are so well distributed as to present prohibitively costly targets to an enemy. If Armegeddon comes, alternative energy is all we will have left.

6. NUCLEAR POWER

Even in this paper it is still premature to consider nuclear fusion, despite the significant advances in the last few years[17-20].

Also, despite the economic attractiveness of nuclear fission worldwide, the general consensus of informed opinion considers that Australia is unlikely to have nuclear power this century. Only recently this view was also expressed by Exxon. Moreoever Queensland, with its abundant low-sulphur steaming coal, is also considered the least likely of Australian States to go nuclear. Nevertheless, for some years there has been much pressure in West Australia for nuclear plant. More recently, even in the Northern Territory, high electricity costs and the possible loss of Federal Government subsidy have made the acquisition of a nuclear power station a potential election issue. Certain commonality of interests between our three northern states suggests that nuclear power will at least become a discussion point in planning Queensland's future within the next 5 years.

Although the anti-nuclear protest movement is strong and well-supported by public opinion in Queensland at the present time, this could have been said in Europe 5 years ago. Recent public opinion polls in UK and Germany now show 2 people out of 3 to favour a substantial nuclear power programme. It is suggested that this is not just a matter of economic pressure on European attitudes but a more balanced and better-educated public view. Now that the Three Mile Island nuclear disaster in 1978 has become part of history, informed people, at least, are realising that the real problem with nuclear power is not that it is likely to be hazardous to people but rather that system failure can produce a $1000,000,000 repair bill, as will indeed be the case at Three Mile Island, when the plant finally gets back into operation.

15 years ago nuclear power was hopelessly uncompetitive everywhere in the world when compared with coal fired power stations. Today, Queensland is one of the few places in the world where this is still true! The data in table 2 indicate how fossil fuelled stations are now unable to compete with nuclear plant in the U.K. These costs are made artificially high by using a simple official exchange rate of \$A 2= £1 Sterling. Nevertheless comparison with plant costs in Queensland indicates the present lack of competitiveness of nuclear power. The costs in table 2 are based on standard discounted (at 5% in real terms) cash flow. Capital costs included decommissioning costs and interest during construction. Nuclear fuel costs include fuel reprocessing and waste disposal but do not include an allowance for plutonium fuel by-product. Also the overall cost of nuclear plant has been overestimated by about \$A6/kW per year by neglecting on-load refuelling which will, in fact, be used.

	NUCLEAR		COAL-FIRED	
	\$A/kW per annum	¢/kW	\$A/kW per annum	¢/kW
Capital costs	154	2.78	72	1.52
Fuel costs	68	1.22	226	4.76
Other costs	24	0.44	20	0.42
TOTAL	246	4.44	318	6.7
Load Factor		63%		54%

TABLE 2: COMPARISON OF COSTS OF FUTURE BRITISH NUCLEAR AND COAL FIRED PLANT AT 1980 PRICE LEVELS

(data of ref. 21)

However despite this present evidence to the contrary, in no way can we guarantee that nuclear power will be unable to compete with coal in Queensland in the future.

Whereas the designer of nuclear stations can now call on a fair amount of operating experience to reduce plant capital costs, there is very little technical development potential left in coal-fired plant.

Indeed, environmentalist lobby groups are likely to cause costs of coal-fired plants to increase due to the demand for reduced ash (and in other countries SO_2) emmision.

It is still premature to speculate on a nuclear power future in Australia. The world's first commercial-sized fast reactor (the 1200 MWe French Superphenix) will not be operating until 1984 at the earliest. Its costs will exceed those of today's thermal reactors significantly but the economics of later versions of this type of plant cannot be ascertained accurately enough at this time for us to dismiss it as a possibility for Australia's first nuclear power station.

Power generation will remain a matter of comparative economics as it always has been. The costs of nuclear power have yielded many surprises in the past and the economic arguments still rage even at the most fundamental level.[22]

7. URANIUM ENRICHMENT PLANT

A matter of more immediate concern to Australia is the suggestion that we should soon acquire our first uranium enrichment plant. West Australia, South Australia and Queensland have all expressed strong interest in this proposal. Because of the need for economy of scale, only one plant in the price range $1-5 billion is likely to be built in Australia in the forseeable future. The case for establishing it in Queensland, together with its attendant uranium hexafluoride conversion facility, is at least as strong as any other. A number of sites, including one near Rockhampton, are suitable.

Federal Government is scheduled to receive a report this year from UEGA, the Uranium Enrichment Group of Australia (BHP, CSR, Peko-Wallsend and Western Mining Corporation). It is particularly unfortunate that this report is not to hand at the time of writing the present review because optimistic and encouraging details 'leaked' to the press (see, for example, the headline in the Australian of 9/1/81) and also from other 'informed' sources, seem to be contrary to reports in the technical press.[23]

On this basis we must ask ourselves the question whether the establishment of an Australian enrichment plant is attractive commercially at the present time. For example, we need to make a fair comparison with other heavy power-consuming industries such as aluminium smelting. Both uranium enrichment and aluminium smelting can be considered to come in the same category of "frozen electricity". The difference is that the latter appears to have sound market prospects, whereas the future of the former is very questionable.

7.1 The Technology Available.

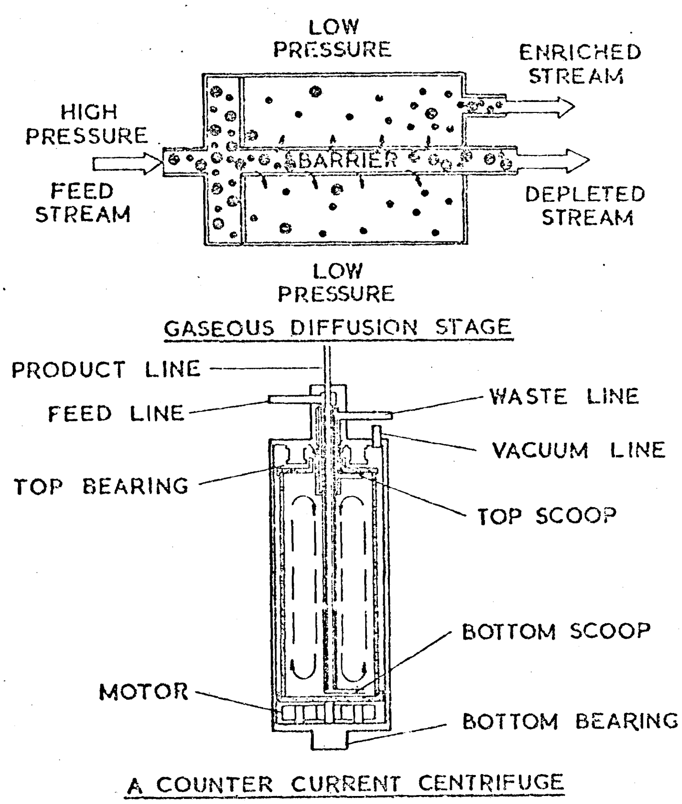
In considering the case for an enrichment plant in Queensland, it is necessary to evaluate the three main[24] alternative technologies available. These are summarised as follows.

7.1.1 Gas Diffusion

This is the original commercial method of separating ^{235}U (the fissile isotope) from the non-fissile ^{238}U component. Natural uranium containing only 0.7% of ^{235}U is first converted to gas (uranium hexafluoride). This UF_6 is pumped through a 'cascade' of many porous barriers (see figure 2). The lighter ^{235}U isotope diffuses through the barrier slightly faster than the ^{238}U isotope resulting in an enriched output of UF_6 containing about 3% of ^{235}U. Nearly all modern reactors need this slightly enriched fuel. The technology[25] is expensive in electricity consumption (see table 3) but is highly developed, with present capital costs which are now more favourable compared with the cost of centrifuge plant (see table 3).

FIGURE 2

URANIUM ENRICHMENT BY DIFFUSION AND CENTRIFUGE



Much has been said in the press lately about a French-designed plant for Queensland based on Tricastin[24]. The interest is in our cheap power supplies. However, the size of the project and its enormous power consumption, matters raised in section 7.2, and the nature of the technology do not, in the Author's view, add up to a reasonable proposition for Queensland.

7.1.2 Gas Centrifuge

Improvements in mechanical technology have resulted in commercial sized plant using the superior gas centrifuge (see fig. 2). Although plant capital costs[26] are still high, the electrical consumption is now even lower than the old data in table 3. It is reported in the press that this type of plant is favoured by South Australia. Whereas gas diffusion plants need to be large to be viable, a centrifuge plant can be built progressively in stages to match its output with market demand.

7.1.3 Laser Separation

There are three main approaches to laser separation[27] and all are in the early stages of commercial development in the United States which leads the field. Most technical data in this area is classified information. It is expected, but it is by no means certain, that this approach to separation will outperform both the diffusion and centrifuge processes when plant is scaled up to commercial size.

	LASER	CENTRIFUGE	DIFFUSION
Separation factor	10		1.0043
Energy requirement (kilowatt-hour/SWU)	170	210	2100
Capital costs ($/SWU)	195	233	388
Economic size (metric tons)	3000	3000	9000
Process area (acres)	8	20	60

TABLE 3: COSTS AND PERFORMANCE FACTORS FOR THE THREE MOST INTERESTING TYPES OF URANIUM ENRICHMENT. THE BASIC MEASURE OF URANIUM ENRICHMENT IS THE SEPARATIVE WORK UNIT (SWU); 1000 SWU IS EQUIVALENT TO A TONNE. THE LASER ESTIMATES REFER TO METHODS FOR SEPARATING URANIUM ATOMS, BUT NOT URANIUM MOLECULES. (Source: Richard H. Levy, Exxon Nuclear Corporation)

7.2 The World Market for Enriched Uranium

The fast changing technology in uranium enrichment complicates any investment decision considerably.

Another obvious argument against establishing an Australian enrichment plant is that at present there is a predicted world excess of enrichment capacity (see figure 3). Nevertheless it seems likely that this depressed situation will reverse in the near future due to a likely sudden accelerated development in thermal nuclear power programmes worldwide. A demand for new enrichment plant is also likely because of the increasingly unacceptable power costs (see table 3) of gas diffusion technology. In America, in particular, much diffusion plant still in good condition is to be replaced by centrifuge equipment.

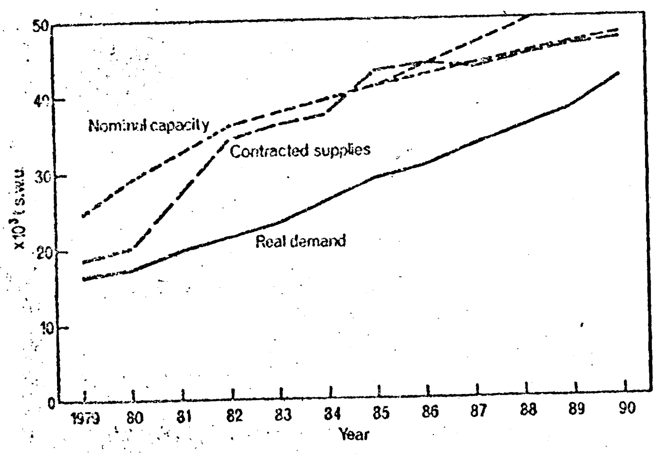


Figure 3 WORLD ENRICHMENT OF URANIUM IN TONNES OF SEPARATIVE WORK (ref. 23)

7.2.1 The Contract Problem

The main objection to building an enrichment plant in Australia is that, without a nuclear power industry of our own, we would be entirely dependent on world export markets which are potentially very volatile.[23, 26] This is not the case with other enrichment plants in the USA and Europe which enjoy captive markets and firm contracts[23, 25]. It is essential for Australia to secure similar terms but our ability to achieve this is questionable. Realistically enforceable agreements with Japan are one possibility and a high proportion of overseas capital investment is another possible approach to achieve this end.

Nevertheless, despite the obvious and jingoistic enthusiasm of the public at large for Australian resource processing i.e. an enrichment plant, the reality is that, in building an enrichment plant, we could risk acquiring one of the biggest white elephants of all time. In addition, we must consider a lesser, but important, factor namely the risk of upsetting our long term plans for electricity generating capacity.

7.3 A suggested policy

It seems to be wise to delay a firm commitment to an enrichment plant in Australia. The present Author believes that commercial details will become much clearer in the near future (say 1984). The commercial aspect of uranium enrichment should not be allowed to become confused by considerations of 'national prestige' or interstate rivalries, both of which could act against our national interests. If, however, Australia is to move into the enrichment field at an early date, then a centrifuge plant would be the logical choice.

8. NUCLEAR REACTOR WASTE DISPOSAL

Speculating a little further still into Queensland's possible future role in the nuclear age we might consider the 'attractions' of a future nuclear waste disposal industry along the lines suggested by Professor Ringwood at the Australian National University(28, 29). Such a concept is, of course, sheer anathema to politician and layman alike. Nevertheless, the Author is duty bound to raise the matter at this technical conference.

The reality of underground nuclear waste disposal is that it can even be undertaken in the middle of a European city! Shielding of the waste and its handling are not difficult problems. The real issue is in selecting a repository which is geologically suitable (i.e. stable and dry). Waste disposal itself will be a low technology industry well within the capacity of most countries. The same cannot be said of reprocessing of fuel elements which might also be considered as a possible future industry in Queensland at a later stage.

Other suggested methods of nuclear waste disposal such as sea-bed or ice-cap disposal are considered by the Author as unacceptable on environmental hazard grounds(30). However the general consensus of expert opinion(28) is that underground disposal, preferably in a few large repositories, is acceptable. Testson long term radiation stability and resistance to leaching of processed nuclear waste are reported to be satisfactory(31). However there is still argument about the best material (e.g. glass, supercalcine ceramic or Synroc) to be used for fixing the waste.

8.1 A Technical Decision Based on Public Prejudice?

The safest place to dispose of nuclear waste is about 1 km beneath one's feet. This is because contaminated water travels laterally and incorrect disposal will only be apparent some distance away. However, we live in a complicated era when technical decisions are often not taken for technical reasons. The public perception of safety is that nuclear waste disposal should be as far away as possible from human habitation. Inevitably our far western desert regions have been viewed as possible world nuclear waste repositories despite their obvious inconvenience. Such locations present a transport and infrastructure cost penalty but this is unlikely to be prohibitive.

It is not commonly realised that nuclear waste must spend the first 10 years or so above ground before ultimate underground disposal is acceptable. The present practice is as follows. The intensely radioactive spent fuel elements are taken from the reactor and are stored under water in 'cooling ponds' for about 1 year. During this period most of the short-lived fission products will have decayed away. The fuel elements, although still dangerously radioactive, are then chopped up and chemically reprocessed to extract the valuable uranium and plutonium which is recycled. The fission products are then stored in special cooled tanks for about 10 years. After this time the radioactivity and consequent internal heating have decayed away sufficiently for the waste to be made into a solid disposable form.

Because of this delay the nuclear waste disposal industry is only just starting to be developed. However the financial size and importance of this new industry will be considerable and it promises to become one of the most lucrative of new commercial ventures. By 2000 A.D. 45% of world electricity generation is estimated to be nuclear and new fossil-fired plant will probably be a rarity. The expenditure on nuclear waste disposal has been estimated to be between 0.5 and 2% of total generation costs and perhaps even as much as 5%.

If social pressures persist in forcing nuclear waste disposal to the world's few remote regions, the industry may well become a very profitable one indeed, and one which Australia may find irresistable.

Lang Hancock wants to see a railway from here to West Australia with steel-works at either end and well serviced mining ventures in between. Will all this come together one day in a grand design with one of the world's biggest nuclear waste disposal industries finally opening up our outback?

9. LIKELY FUTURE PROBLEMS AREAS FOR CENTRAL QUEENSLAND INDUSTRIES

In a paper where we have tried to anticipate the future, it seems appropriate to conclude by returning a little closer to our own time to try to isolate areas of adversity which may have an increasingly detrimental influence on our new industrialisation of Central Queensland.

9.1 Tougher Criticism of Central Queensland Chemical/Process Industries by Environmental Lobby Groups

We might expect an increased consciousness of the lay public at large in chemical pollution hazards. So far the world chemical industry has escaped rather lightly from the attention of environmental lobby groups. Conversely the nuclear industry (which, in the past, has been less well organised in its public relations) has come in for some severe - and often very unjust - criticism. The truth is that the technical criticisms against the nuclear industry are a good deal less convincing than much of the technical arguments alleging pollution which can be levelled at the chemical/process industries. Already this trend seems well set in the United States. As environmentalist lobby groups become better informed, it seems likely that we will find increased public reaction to chemical/process industries. This is a disturbing implication because Central Queensland will become strongly chemical, and not nuclear, based.

It would seem to be a wise policy for industries new to this area to go to some considerable trouble and expense to maintain good public relations on all matters relating to the environment. Compared with Europeans, it seems to the Writer that Australians are oversensitive in matters relating to the environment. One might explain this by the fact that, in the declining economies of Europe, many people now recognise that to maintain the living standards of a consumer society, implies coming to terms with 'acceptable' levels of industrial pollution. Central Queenslanders are more fortunate in that the affluent society is perceived by many as the natural order of things. It seems we believe, perhaps erroneously, that we can indulge our conscience without having to pay for it.

9.2 CO_2 build-up in the atmosphere

One truly 'international' environmental issue which may raise its head and become important to us in Queensland is the question of increasing CO_2 in the atmosphere[32, 33]. This has already risen 12% since the Industrial Revolution.

It is estimated that if the CO_2 content of the atmosphere doubles, then the temperature will rise by 2-3° C in the tropics and as much as 10 degrees at the poles with much influence on our climate. The melting of the ice-caps and the resulting inundation of coastal cities has been the subject of much speculation over the years. It has been predicted that the CO_2 content of the atmosphere may double as early as 2010 AD and the renewed interest in coal combustion will play a great part in this.

The influence of increasing atmospheric CO_2 on world climate still appears to be uncertain, particularly if an increase in coal burning technology also results in increased aerosol contamination of the atmosphere (this aerosol contamination offsets 'greenhouse' overheating of the environment due to CO_2 build up). As a major coal exporter and consumer we may well become involved in this international issue if it becomes demonstrable that CO_2 is changing the world climate measurably and adversely[33].

9.3 Australian Balance of Payments Surplus

High exports of energy stocks and other minerals, together with a high influx of capital investment from abroad, are likely to place Australia as a whole in an embarassing balance of payments surplus situation. The problem will, as in the past, become more severe due to the need to protect the manufacturing sector of our Southern States in what seems likely to become an era of chronic unemployment.

It is hard to see how the situation can be prevented from rectifying except by a rising parity of the Australian dollar. This will result in increasing difficulty in maintaining profit margins in exporting Queensland industries. Clearly the old conflict of interest is still with us: what is good for Queensland (and W.A.) is not necessarily good for Australia as a whole.

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